INTERNATIONAL

NATURE & ENVIRONMENT CONSERVATION AND PROTECTED AREAS CONGRESS

OCTOBER 29-30-31, 2025 / DEMRE, ANTALYA, TÜRKİYE

PROCEEDINGS BOOK



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I[st] International Nature & Environment Conservation and Protected Areas Congress

"(INECPAC 2025)"

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(Abstracts & Full Texts)

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İLGİLİ MAKAMA

10 Eylül 2024 tarihinde saat 13.30'da "Bilimsel Etkinlik Düzenlenmesi ve Görevlendirmeler" gündemi ile toplanan Yönetim Kurulumuz'un 2024/E2 sayılı kararı ile 29-31 Ekim 2025 tarihleri arasında Antalya'da

"ULUSLARARASI DOĞA & ÇEVRE KORUMA VE KORUNAN ALANLAR KONGRESİ" düzenlenmesine karar verilmiştir

İlgili kararın ifası için görevlendirilen düzenleme kurulu üyeleri unvan ve isimleri aşağıda belirtilmiş olup bilim ve danışma kurulunun düzenleme kurulu tarafından teşekkül ettirilmesi ile kongreye bizzat iştirak edecek düzenleme kurulu üyelerinin yolluk ve gündeliklerinin saymanlığımız tarafından ilgili harcama kaleminden ödenmesi

Arz rica olunur

Sefa Salih BİLDİRİCİ
Başkan Yardımcısı

Düzenleme Kurulu Üyeleri
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Iˢᵗ. International Nature & Environment Conservation and Protected Areas Congress

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CONGRESS ID

Congress Title

1st International Nature & Environment Conservation and Protected Areas Congress

Date and Place

October 29-30-31, 2025, Demre, Antalya, Türkiye

Organizing

Demre Deputy Demre-Antalya, Türkiye

https://demre.bel.tr/

The Editorial Board of the Journal of Architectural Sciences and Applications, Isparta, Türkiye. (https://dergipark.org.tr/en/pub/mbud)

Black Sea Nature and Environment Association (KADOÇED)

https://kadoced.org/associations/kadoced/

Institute of Economic Development and Social Research (IKSAD) Ankara, Türkiye. (https://www.iksadinstitute.org/)

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Architectural Sciences Platform

Evaluation Process and Policies

All applications have undergone double blind peer review process. In addition, each paper was accepted and the process of publishing in the book was carried out through editorial oversight.

The published papers were presented and discussed at the meeting.

Full texts and abstracts published in accordance with the Congress Policy have been prepared in accordance with ethical rules and APA standards.

All authors are responsible for the content and format of their articles, both ethically and legally. The Editors and Publisher are not responsible in any way for articles published in the Congress Proceedings.

Presentation

Oral and Online Presentations

Aim of The Congress

This Congress aims to bring together all disciplines related to Nature and Environmental Protection and Natural and Cultural Conservation Areas to establish a common language and vision, engage in scientific and technical discussions, and facilitate multidimensional knowledge sharing through interdisciplinary and multidisciplinary studies.

Topics of The Congress

- History and Philosophy of Nature Conservation
- Natural Protected Areas, Planning and Design
- Cultural Protected Areas, Legal and Administrative Dimensions of Nature And Environmental Protection
- Ecology, Ecosystem & Biodiversity
- Cultural Heritage
- Tourism, Recreation, Visitor Management
- Sustainable Conservation and Nature-Based Solutions
- Wildlife, Wild animals & Wild plants
- Global Warming and Climate Change
- Landscape Repair (Restoration, Rehabilitation, Reclamation)
- Urban/Rural Conservation, Restoration, Rehabilitation and Revitalisation
- Nature conservation, Human Health and Welfare,
- Historical Conservation and Archaeology
- Legal and Administrative Aspects of Nature and Environmental Protection
- Sociology geography, history, ethnology, anthropology, scientific terminology studies

Participants Countries

Afghanistan, Albania, Algeria, Azerbaijan, Bangladesh, Iran, India, Indonesia, Kosovo, Morocco, Nigeria, Pakistan, Poland, Romania, Saudi Arabia, Serbia, Türkiye, United Kingdom, Vietnam

Total Accepted Articles: 138

Number of Rejected Papers: 25

The Number of Accepted Papers from Türkiye: 59

The Number of Accepted Full Papers from Other Countries: 79

Index in

Index of Academic Documents (IAD), Open AIRE, Google Scholor, ResearchGate, Britishindex Scientific Database

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October 29-30-31, 2025
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- Metin DEMİR - Atatürk University, Faculty of Architecture ve Design, Department of Architecture, Erzurum-Türkiye
- Mine Hashas-DEĞERTEKİN - North Carolina State University, Community and Environmental Design Program. USA.
- Mohammad Jafar CHAMANKAR - The Department of History of Urmia University, Iran
- Mohammad WAHEEB - Department of Cultural Resource Management (CRM), Queen Rania Faculty of Tourism and Heritage (QRFTH), The Hashemite University
- Muhammet KURUCU - Fırat University, Faculty of Architecture, Diyarbakır -Türkiye
- Mustafa ERGEN - Sakarya App. Sciences Univ. Faculty of Agriculture, Department of Landscape Architecture, Sakarya-Türkiye
- Mustafa GÜLEN - Van Yüzüncü Yıl University, Faculty of Architecture and Design, Department of Architecture, Van-Türkiye
- Mustava VAR - Yıldız Technical University, Faculty of Architecture, Department of City Regional Planning, İstanbul - Türkiye
- Müberra PULATKAN - Karadeniz Technical University, Faculty of Architecture, Department of Architecture, Trabzon- Türkiye
- Nafiya GÜDEN - School of Tourism and Culinary Arts, Final International University, Girne - TRNC
- Naif HADDAD - Department of Conservation Science, Queen Rania Faculty of Tourism and Heritage, Hashemite University, Jordan
- Nermeen Adnan DALGAMONİ - Jordan University of Science and Technology, Department of City Planning and Design, Irbid, Jordan
- Neslihan DALKILIÇ - Dicle University, Institute of Science and Technology, Department of Architecture, Diyarbakır-Türkiye
- Neslihan YILDIZ - Istanbul Gedik University Faculty of Fine Arts and Architecture Department of Architecture, Istanbul-Türkiye
- Neşe Yılmaz BAKIR - Erciyes University, Faculty of Architecture, Department of City and Regional Planning, Kayseri -Türkiye
- Nihal Arda AKYILDIZ - Balıkesir University, Faculty of Architecture, Department of Architecture, Balıkesir-Türkiye

- Nilay COŞGUN - Gebze Technical University, Faculty of Architecture, Department of Architecture, Gebze-Türkiye
- Nilgün GÖRER TAMER - Gazi University, Department of City and Regional Planning, Ankara-Türkiye
- Nilüfer KART AKTAŞ - Istanbul University-Cerrahpasa, Faculty of Forest, Department of Landscape Architecture, Istanbul -Türkiye
- Nur BELKAYALI - Kastamonu University, Faculty of Engineering and Architecture, Department of Landscape Architecture, Kastamonu-Türkiye
- Nur ÇAĞLAR - TOBB ETU Faculty of Architecture and Design, Architecture, Ankara- Türkiye
- Nuray BENLİ YILDIZ - Düzce University, Faculty of Art and Design, Department of Architecture, Düzce-Türkiye
- Nurdil ESKİN - Istanbul Technical University, Department of Mechanical Engineering, Istanbul, Türkiye
- Oğuz KURDOĞLU - Karadeniz Technical University, Faculty of Forestry, Department of Forest Engineering, Trabzon -Türkiye
- Oleksandr ZINENKO - V. Karazin Kharkiv National University, Kharkiv, 61022, Ukraine
- Osman ATTMANN - The University of Colorado Denver, College of Architecture and Planning, Department of Architecture, Denver-USA
- Ömer Faruk UZUN - Sakarya App. Sciences Univ. Faculty of Agriculture, Department of Landscape Architecture, Sakarya-Türkiye
- Ömer Lütfü ÇORBACI - Recep Tayyip Erdoğan University, Faculty of Engineering and Architecture, Department of Landscape Architecture, Rize-Türkiye
- Ömer MİMAROĞLU - Istanbul Sabahattin Zaim University Faculty of Engineering and Natural Sciences Department of Architecture, Türkiye
- Özlem SAĞIROĞLU - Gazi University, Faculty of Architecture, Department of Architecture, Ankara-Türkiye
- Pelin ŞAHİN KÖRMEÇLİ - Çankırı Karatekin University, Faculty of Forestry, Department of Landscape Architecture, Çankırı-Türkiye
- Pınar KILIÇ ÖZKAN - İzmir Demokrasi University, Faculty of Architecture, Department of Architecture İzmir -Türkiye
- Pervin YEŞİL - Ordu University, Faculty of Agriculture, Department of Landscape Architecture, Ordu-Türkiye
- Piyush SHARMA - Amity University, Hindistan/ Prof. Dr., Amity University, India
- Rosa Anna LA ROCCA - The University of Naples Federico II, Department of Civil, Architectural and Environmental Engineering, Napoli, Italy
- Rolando VOLZONE DINÂMIA'CET-iscte - ISCTE-Instituto Universitário de Lisboa, Lisboa, Portugal

- Ruhan Aşkın UZEL - Yasar University, Director of Vocational College, İzmir Türkiye
- Rüya ARDIÇOĞLU - Firat University, Faculty of Architecture, Department of Architecture, Elazig-Türkiye
- Sadia FAROOQ - University of Home Economics, Lahore, Pakistan
- Saliha TAŞÇIOĞLU - Kilis 7 Aralik University Technical Sciences Vocational School Department of Park and Horticulture - Türkiye
- Sara DEMİR - Bursa Technical University, Faculty of Forestry, Department of Landscape Architecture, Bursa -Türkiye
- Seden ACUN ÖZGÜNLER - Istanbul Technical University, Faculty of Architecture, Department of Architecture, Building Science Program, İstanbul-Türkiye
- Seden TURAMBERK ÖZERDEN - Final International University, Girne -TRNC
- Seema Mehra PARIHAR - Department of Geography, Kirori Mal College, University of Delhi, India
- Serap KAYASÜ - Middle East Technical University, Faculty of Architecture, Department of City and Regional Planning, Ankara-Türkiye
- Serdar SELİM - Akdeniz University Faculty of Science, Department of Space Science and Technologies, Department of Distance Education, Antalya-Türkiye
- Serdar Oktay - Final International University, School of Tourism and Culinary Arts, Department of Tourism, TRNC
- Serpil ÖNDER - Selçuk University, Faculty of Architecture and Design, Department of Landscape Architecture, Konya-Türkiye
- Sibel ACAR - TOBB ETU Faculty of Architecture and Design, Architecture. Türkiye
- Silvia ROSSETTI - The University of Parma, Department of Engineering and Architecture, Parma Italy
- Sima POUYA - İnönü University, Faculty of Fine Arts and Design, Department of Landscape Architecture, Malatya-Türkiye
- Soad ABOKHAMIS MOUSAVI - Final International University, Faculty of Architecture and Fine Arts, Department of Architecture
- Swetha MADHUSUDANAN - MGR University, School of Architecture, Chennai, India
- Şevket ALP - Van Yüzüncü Yıl University, Faculty of Architecture and Design, Department of Landscape Architecture, Van-Türkiye
- Şeyda EMEKCİ - Ankara Yıldırım Beyazıt University, Faculty of Architecture and Fine Arts, Architecture Department, Ankara- Türkiye
- Şirin DÖNMEZ - Süleyman Demirel University, Faculty of Architecture, Department of Landscape Architecture, Isparta-Türkiye
- Şule KISAKÜREK - Kahramanmaraş Sütçü İmam University, Faculty of Forestry, Department of Landscape Architecture, Kahramanmaraş-Türkiye

- Taner ÖZDİL - The University of Texas, College of Architecture, Planning and Landscape Architecture, Arlington-ABD
- Tonguç AKIŞ - İzmir Institute of Technology, Faculty of Architecture, Department of Architecture, İzmir -Türkiye
- Tuğba DÜZENLİ - Karadeniz Technical University, Faculty of Forestry, Department of Landscape Architecture, Trabzon-Türkiye
- Vagif MEMMEDOV - Baku Engineering University, Baku- Azerbaijan
- Yasin ÜNAL - Isparta Unıversıty of Applıed Scıences, Faculty of Forestry, Department of Wildlife Ecology and Management, Isparta-Türkiye.
- Yasin XƏLİLOV - Baku Engineering University, Baku- Azerbaijan
- Yenal AKGÜN - Dokuz Eylül University Faculty of Architecture, Department of Architecture, İzmir -Türkiye
- Yılmaz ARI - Bandırma Onyedi Eylül University Faculty of Humanities and Social Sciences, Head of Geography Department, Bandırma/Balıkesir- Türkiye.
- Zeidan KAFAFI - Emeritus of Archaeology of Yarmouk University, Jordan
- Zeynep PİRSELİMOĞLU BATMAN - Uludağ University, Faculty of Forestry, Department of Landscape Architecture, Bursa -Türkiye

I[st]. International Nature & Environment Conservation and Protected Areas Congress

"(INECPAC 2025)"

October 29-30-31, 2025

https://www.iksadkongre.com/inecpac

Face to face and online

CONGRESS SCHEDULE

Join Zoom Meeting
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Meeting ID: 859 7119 7642
Passcode: 293031

PARTICIPATING COUNTRIES

Afghanistan, Albania, Algeria, Azerbaijan, Bangladesh, Iran, India, Indonesia, Kosovo, Morocco, Nigeria, Pakistan, Poland, Romania, Saudi Arabia, Serbia, Türkiye, United Kingdom, Vietnam

TOTAL ACCEPTED ARTICLES: 138

Türkiye: 59
Other Countries: 79

Congress General Program Framework

October 29, 2025 (Wednesday)

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Meeting ID: 859 7119 7642

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	OPENING SPEECHES (Demre Municipality Cultural Center Conference Hall) Demre Belediyesi Kültür Merkezi Konferans Salonu
Antalya (Demre)- Türkiye Time 14:00-15:30	**Prof. Dr. Atila GÜL** **Dr. Mustafa Latif EMEK** **Prof. Dr. Nevzat ÇEVİK** **Assist. Prof. Dr. Ahmet FİDAN** **Prof. Dr. Öner DEMİREL** **Fahri DURAN** **Emin BAĞLI** **Ertuğrul GÜNAY**
15:30- 16:00	**Presentation of Plaques (Plaket Takdimi)**

Antalya (Demre)- Türkiye Time 16:30-18:30	**PANEL** *The Cultural Tourism Potential and Future of Demre District)* *(Demre İlçesinin Kültürel Turizm Potansiyeli ve Geleceği)* (Face to Face and Online) Congress Venue: Demre Municipality Cultural Center Conference Hall, Demre Antalya (Demre Belediyesi Kültür Merkezi Konferans Salonu)			
Moderator	**Prof. Dr. Öner DEMİREL**			
Invited Speakers	**Prof. Dr. Nevzat ÇEVİK**	**Prof. Dr. Şebnem ERTAŞ BEŞİR**	**Lect. Dr. İsmail Gökay KIRTIL & Lect. Serdar UZUN**	**Lect. Zekiye Tuçe GÜNGÖR**

October 30, 2025 (Thursday) (Online)

Join Zoom Meeting
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Meeting ID: 859 7119 7642
Passcode: 293031

Antalya (Demre)-Türkiye Time 9:00-10:45	SESSION 1 (Online) HALL-1	SESSION 2 (Online) HALL-2	SESSION 3 (Online) HALL-3	SESSION 4 (Online) HALL-4
Moderators	Assoc. Prof. Dr. Ceren Selim	Prof. Dr. Samina Nasim	Dr. Krishnaji S. Patıl	M. B. Busari
Antalya (Demre)-Türkiye Time 11:00-12:45	SESSION 5 (Online) HALL-1	SESSION 6 (Online) HALL-2	SESSION 7 (Online) HALL-3	SESSION 8 (Online) HALL-4
Moderators	Prof. Dr. Mehmet Akif Irmak	Gbenga Akomolafe	Assoc. Prof. Dr. Zeqir Veselaj	Dr. M.K. Ganeshan
Antalya (Demre)-Türkiye Time 13:00-14:45	SESSION 9 (Online) HALL-1	SESSION 10 (Online) HALL-2	SESSION 11 (Online) HALL-3	SESSION 12 (Online) HALL-4
Moderators	Prof. Dr. Sevgi Yılmaz	Prof. Dr. Sima Pouya	N. G. Nwachukwu,	Dr. Duong To Quoc Tha
Antalya (Demre)-15:00-16:45	SESSION 13 (Online) HALL-1	SESSION 14 (Online) HALL-2	SESSION 15 (Online) HALL-3	SESSION 16 (Online) HALL-4
Moderators	Prof. Dr. Şevket Alp	Prof. Dr. Ertan Düzgüneş	Rabiu Ahmad Abubakar	Dr. K.S. Patil Sir

Antalya (Demre)-17:00-18:45	SESSION 17 (Online) HALL-1	SESSION 18 (Online) HALL-2		
Moderators	Assoc. Prof. Dr. Sultan Sevinc Kurt Konakoğlu	Prof. Dr. Ivan Pavlovıć		

October 31, 2025 (Friday) (Face to Face)

Congress Venue:: Mediterranean Fisheries Research, Production and Training Institute Directorate Demre Training Centre- Demre, Antalya (Akdeniz Su Ürünleri Araştırma, Üretme ve Eğitim Enstitüsü Müdürlüğü Demre Eğitim Merkezi- Demre, Antalya)

Antalya (Demre)-Türkiye Time	Face to Face SESSIONS October 31, 2025 (Friday)		
9:00-10:45	SESSION 19 (Likya Hall)	SESSION 20 (Myra Hall)	
Moderators	Prof. Dr.Murat AKTEN	Prof. Dr. Tendü Hilal GÖKTUĞ	
11:00-12:45	SESSION 21 (Likya Hall)	SESSION 22 (Myra Hall)	
Moderators	Prof. Dr. Öner DEMİREL	Prof. Dr. Ufuk ÇOŞGUN	
13:00-14:00	Lunch (Öğle Yemeği)		

IMPORTANT

- To be able to make a meeting online, log in via **https://zoom.us/join** site, enter ID instead of "Meeting ID or Personal link Name'' and solidify the session.
- **Each presentation is limited to a maximum of 15 minutes.**
- **Session times should never be exceeded. It must be completed on time before the next session starts.**
- **Presentations can be presented in "English or Turkish". However, visual presentations must be "English text".**
- The Zoom application is free and no need to create an account.
- The Zoom application can be used without registration.
- The application works on tablets, phones, and PCs.
- Speakers must be connected to the session **15 minutes before** the presentation time.
- All Symposium participants can connect live and listen to all sessions.
- During the session, your camera should be turned on at least %70 of the session period
- Moderator is responsible for the presentation and scientific discussion (question-answer) section of the session.

TECHNICAL INFORMATION

- Make sure your computer has a microphone and is working.
- You should be able to use the screen sharing feature in Zoom.
- Attendance certificates will be sent to you as a pdf at the end of the Symposium.

Before you, log in to Zoom indicate Session and Hall number and your surname
(SESSION 1-HALL-1, XXXX)

Important Notice:

• The Protocol Opening and Panel event on October 29, 2025, in the Congress Program will take place at the Demre Municipality Culture Center Conference Hall.

•The in-face to face sessions of the Congress (October 31, 2025) will be held at the accommodation venue, the Mediterranean Fisheries Research, Production, and Education Institute Directorate Demre Education Center (Demre, Antalya).

ÖNEMLİ

- Sempozyumda Yazım Kurallarına uygun gönderilmiş ve bilim kurulundan geçen bildiriler için online (video konferans sistemi üzerinden) sunum imkanı sağlanmıştır.
- Online sunum yapabilmek için **https://zoom.us/join** sitesi üzerinden giriş yaparak "Meeting ID or Personal Link Name" yerine ID numarasını girerek oturuma katılabilirsiniz.
- **Her bir sunum en fazla 15 dakika ile sınırlandırılmıştır.**
- **Oturum süreleri kesinlikle aşılmamalıdır. Bir sonraki oturum başlamadan önce zamanında tamamlanmalıdır.**
- **Sunumlar "İngilizce veya Türkçe" sunulabilir. Ancak görsel sunumlar mutlaka "İngilizce metin" olmalıdır.**
- Zoom uygulaması ücretsizdir ve hesap oluşturmaya gerek yoktur.
- Zoom uygulaması kaydolmadan kullanılabilir.
- Uygulama tablet, telefon ve PC'lerde çalışmaktadır.
- Sunum yapacakların sunum saatinden **15 dk önce** oturuma bağlanmış olmaları gerekmektedir.
- Tüm katılımcılar oturumlara online katılıp dinleyebilir.
- Oturumdaki sunumlardan ve bilimsel tartışmalardan (soru-cevap) Moderatörler sorumludur.

TEKNİK BİLGİLER

- Bilgisayarınızda çalışır durumda mikrofon bulunmalıdır.
- Zoom'da ekran paylaşma özelliği kullanılabilmelidir.
- Katılım belgeleri Sempozyum sonunda tarafınıza pdf olarak gönderilecektir.
- Sempozyum programında yer ve saat değişikliği gibi talepler dikkate alınmayacaktır.

Zoom'a girişte sırayla Oturum ve Salon numarasını ve Soyadınızı yazınız
(OTURUM 1-SALON-1, XXXXX)

Önemli Açıklama:

- **Kongre Programındaki 29 Ekim 2025 tarihindeki Protokol Açılışı ve Panel etkinliği Demre Belediyesi Kültür Merkezi Konferans Salonunda gerçekleşecektir.**
- **Kongrenin Yüzyüze Oturumları ise Konaklama yeri olan Akdeniz Su Ürünleri Araştırma, Üretme ve Eğitim Enstitüsü Müdürlüğü Demre Eğitim Merkezinde (Demre, Antalya) gerçekleştirilecektir.**

OPENING SPEECHES

Date: October 29, 2025

Antalya (Demre)-Türkiye Time: 11:30 -12:30

Face to Face and Online

Join Zoom Meeting

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Meeting ID: 859 7119 7642

Passcode: 293031

Congress Venue:

Demre Municipality Cultural Center Conference Hall, Demre Antalya

(Demre Belediyesi Kültür Merkezi Konferans Salonu)

Prof. Dr	SPEAKERS	AFFILIATION
Antalya (Demre)-Türkiye Time 14:00-15:30	Prof. Dr. Atila GÜL	President of the Organizing Board (IArcSC-2025) and Chief Editor, *Journal of Architectural Sciences and Applications*, Isparta-Türkiye
	Dr. Mustafa Latif EMEK	President of the Economic Development and Social Research Association (IKSAD), Türkiye
	Prof. Dr. Nevzat ÇEVİK	Akdeniz University Department of Archaeology Antalya, Türkiye
	Assist. Prof. Dr. Ahmet FİDAN	Chairman of Federation of Culture-Art, Research, Nature and Environment Associations (KADOÇED) Ordu-Türkiye
	Prof. Dr. Öner DEMİREL	Kırıkkale University, Faculty of Fine Arts, Department of Landscape Architecture, Kırıkkale- Türkiye
	Fahri DURAN	Mayor of Demre Municipality, Demre, Türkiye
	Emin BAĞLI	Demre District Governor, Demre Türkiye
	Ertuğrul GÜNAY	Former Minister of Culture and Tourism of Türkiye
15:30- 16:00	Presentation of Plaques (Plaket Takdimi)	

Invited Speakers for "INECPAC 2025"
PANEL

The Cultural Tourism Potential and Future of Demre District
(Demre İlçesinin Kültürel Turizm Potansiyeli ve Geleceği)

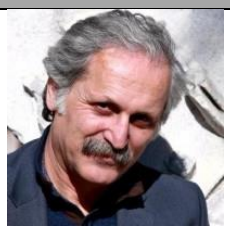
October 29, 2025 (Wednesday)

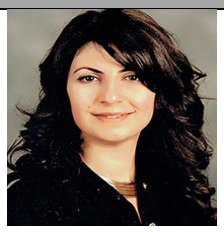
Antalya Time: 16:30 -18:30

Panel Venue	**Join Zoom Meeting**
Demre Municipality Cultural Center Conference Hall (Demre Belediyesi Kültür Merkezi Konferans Salonu)	**https://us02web.zoom.us/j/85971197642?pwd=N7LMLeaCiKtblaZX4Lbj2eMSG4JRd0.1** **Meeting ID: 859 7119 7642** **Passcode: 293031**



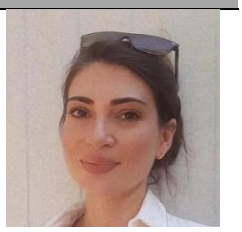
Moderator:
Prof. Dr. Öner DEMİREL
Kırıkkale University Faculty of Fine Arts, Department of Landscape Architecture











Prof. Dr. Nevzat ÇEVİK	**Prof. Dr. Şebnem ERTAŞ BEŞİR**	**Lect. Dr. İsmail Gökay KIRTIL & Lect. Serdar UZUN**	**Lect. Zekiye Tuçe GÜNGÖR**
Myra-Demre: Doğal ve Tarihsel Çevre ve Modern Yerleşimler	**Demre Yöresinin Kültürel Mirasın Korunması ve Turizme Kazandırılması: Tekil Dönüşüm Örneğinden Fiziksel Yenileme Projelerine Genel Bir Bakış**	**"Yerel Miras için Yapay Zeka (AI) Sohbet Robotlarının İnce Ayarı: Aziz Nikolaos Örneği"**	**Demre'nin Sürdürülebilir Turizm Potansiyeli**
Myra-Demre: Natural and Historical Environment and Modern Settlements	**Preservation of Cultural Heritage and Promotion of Tourism in the Demre Region: An Overview of Physical Renovation Projects from a Single Transformation Example**	**Fine-Tuning Artificial Intelligence (AI) Chatbots for Local Heritage: Case of St. Nicholas**	**Demre's Sustainable Tourism Potential**
Akdeniz University, Faculty of Letters, Archaeology, Department of Classical Archaeology	**Akdeniz University, Faculty of Architecture, Department of Interior Architecture**	**Akdeniz University, Demre Dr. Hasan Ünal Vocational School, Travel Tourism and Entertainment Services**	**Akdeniz University, Demre Dr. Hasan Ünal Vocational School, Travel Tourism and Entertainment Services**

ONLINE SESSIONS

October 30, 2025 (Thursday)

Join Zoom Meeting

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Meeting ID: 859 7119 7642
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October 30, 2025 (Thursday)

Antalya (Demre)-Türkiye Time: 9:00-10:45

(Online)

SESSION-1, HALL-1 / OTURUM 1, SALON-1

• MODERATOR: Assoc. Prof. Dr. Ceren SELİM

TITLE	AUTHORS	AFFILIATION
Assessments of Protected Area Problems From Different Professional Disciplines	• Damla Güneş • Şule Kisakürek	Kahramanmaraş Sütçü İmam University, Türkiye
The Relationship Between Urban Agriculture and Nature Conservation	• Funda Ankaya • Kübra Karaman • Bahriye Gülgün	Manisa Celal Bayar University, Türkiye Yozgat Bozok University, Türkiye Ege University, Türkiye
Protection and Sustainable Management of Cultural Landscapes	• Funda Ankaya • Kübra Karaman • Bahriye Gülgün	Manisa Celal Bayar University, Türkiye Yozgat Bozok University, Türkiye Ege University, Türkiye
The Presence of Indoor Plants in Elderly Care and Rehabilitation Centers: The Case of Antalya City	• Ceren Selim • Elif Öncü • Eyüphan BAL	Akdeniz University, Türkiye
Evaluation of Children's Playgrounds in Terms of Plant Species, Constructıon Materials, and Landscape Maintenance Practices: The Case of Antalya	• Ceren Selim • Esmanur Gülser • Ayhan Erdem	Akdeniz University, Türkiye
Nature-Based Solutions for Reducing Tourism Pressure on Coastal Settlements: A Perception-Based Approach To Aveiro and Sığacık	• Zeynep Şergi Marım • Seda Kundak	Istanbul Technical University, Türkiye

October 30, 2025 (Thursday)

Antalya (Demre)-Türkiye Time 09:00-10:45

(Online)

SESSION-2, HALL-2 / OTURUM 2, SALON-2
MODERATOR: Prof. Dr. Samina NASİM

TITLE	AUTHORS	AFFILIATION
Cultural Heritage and Environmental Protection: Tracing Mughal, Colonial and Contemporary Landscape Architectural Design Elements	• Samina Nasim	University of the Punjab, Lahore, Pakistan.
Cultural Heritage and Natural Landscapes as a Foundation For Sustainable Tourism Development	• Alberta Tahiri • Idriz Kovaçi	University Haxhi Zeka” University of Applied Sciences in Ferizaj
Sustainable Consumption in Emerging Economies: Beyond Greenwashing in Marketing Practices	• C.Vijai, • Ms. Sindhuja S	Vel Tech Rangarajan Dr. Sagunthala R&D Institute of Science and Technology, India.
Genetic Diversity and Genome Size Variation in Tillandsia Revealed By Scot Markers And Flow Cytometry	• Aleksandra Szczepanak • Monika Rewers • Iwona Jedrzejczyk	Bydgoszcz University of Science and Technology, Poland
Economic Development and the Sustainable Development Goals in Africa: Urban Challenges, Opportunities, and Policy Perspectives	• Nixer Mohibe, • Nasratallah Malikzada, • Homaira Mohibe, • Mansoor Ali Mohammadi, • Ali sina Hakimi	IELTS JAGHURI, Afghanistan
Impact of Drip Irrigation in Pomegranate Cultivation in Chitradurga District of Karnataka, India	• Thippeswamy N	University Jnanasahyadri Shankaragatta

October 30, 2025 (Thursday)

Antalya (Demre)-Türkiye Time 09:00-10:45

(Online)

SESSION-3, HALL-3/ OTURUM 3, SALON-3
MODERATOR: Dr. Krishnaji S. PATIL

TITLE	AUTHORS	AFFILIATION
Re-Skilling Rural Workers to Operate and Maintain Smart Agriculture Technologies	• Vaibhav Gound, • Prajakta Desai, • Vibhavari Shinde, • Ankita Yadav	Rajarambapu Institute of Technology, Rajaramnagar, Sangli, India
Youth Entrepreneurship in Rural Areas: Challenges and Opportunities in Sanglı District	• Dr. Vidya Kadam, • Priyanka Mali, • Akshata Kumbhar, • Asad Tamboli, • Sakshi chougule	Rjarambapu Institute Of Technology, Rajaramnagar, India
Flood Impact in Krishna and Panchganga River Basins: Economic and Social Aspects	• Dr. Krishnaji S. Patil, • Yogita Pawar, • Akshata Rajmane, • Sanika Mohite	Rajarambapu Institute of Technology, Rajaramnagar, India
Rhagadiolus Stellatus: Data Compilation On A Mediterranean Asteraceae With Phytochemical and Systematic Potential	• Jaayefar Fatima-Ezzahra, • Dahmani Jamila	Ibn Tofail University, Laboratory of Plant, Animal Productions and Agro-Industry, Kenitra, Morocco
Pulicaria Odora a Promising Mediterranean *Asteraceae* :Data Compilation	• Jaayefar Fatima-Ezzahra, • Dahmani Jamila	Ibn Tofail University, Laboratory of Plant, Animal Productions and Agro-Industry, Kenitra, Morocco
Leveraging Artificial intelligence and Emerging Technologies for Sustainable Conservation and Climate-Resilient Rural Landscapes	• Samim Biswas	Bidhan Chandra Krishi Viswavidyalaya, Faculty of Agriculture, Nadia, India

October 30, 2025 (Thursday)

Antalya (Demre)-Türkiye Time 09:00-10:45

(Online)

SESSION-4, HALL-4/ OTURUM 4 SALON-4
MODERATOR: Busari M. B.

TITLE	AUTHORS	AFFILIATION
Comparative in Vitro Antioxidant and Trypanocidal Activities of N-Hexane And Ethylacetate Extracts of Nicotiana Tabacum Leaves on Trypanosoma Brucei Brucei	• Busari M. B. • Yusuf R. S. • Yunusa I. O. • Yahaya A. S. • Dickson J • Lawal I. O. • Egbeyale M. O.	Federal University of Technology Minna, Nigeria, Sa'adu Zungur University (SAZU), Gadau, Bauchi, Nigeria Abdulkadir Kure University Minna, Niger, Nigeria Federal University Dutsin-Ma Katsina State, Nigeria
Antidiabetic Activities of Methanol Extract of Polyalthia Longifolia Stem Bark in Alloxan-Induced Diabetes in Mice	• Yusuf R. S. • Busari M. B. • Yahaya A. S. • Akinola M. • Abubakar H. • Haladu A. • Bulus L.	Sa'adu Zungur University Bauchi State, Nigeria Federal University of Technology Minna, Nigeria Federal University Dutsin-Ma Katsina State, Nigeria
How Birth Type and Goats' Gender Play With Weight and Growth Traits Under Environmental Conditions of Southern Punjab, Pakistan	• Abdul Waheed, • Asma Bibi	Bahauddin Zakariya University, Multan, Pakistan
Green Urban Architecture and Climate Resilience: Building Sustainable Cities for The Future	• Ali Jan Sharifi, • Ahmad Farid Qasemi, • Mohammad Bashir Ashrafi, • Hamed Mohammadi, • Mohammad Yasin Rezaei	International İslamic University, İslamabad
Optimization of Essential Oils Extraction Via Şşmultaneous Distillation Using Citrus Peels as a Green Solvent	• Amal Ramzi	Sidi Mohamed Ben Abdellah University, Morocco
Sustaınable Waste Management Practıces in Urban Areas	• Ahmed Attahiru, • Abubakar Umar Birnin-Yauri, • Abubakar Yahaya	Fodiyo University of Science and Technology, Aliero. Kebbi, Nigeria

October 30, 2025 (Thursday)

Antalya (Demre)-Türkiye Time 11:00-12:45

(Online)

SESSION-5, HALL-1 / OTURUM 5, SALON-1

MODERATOR: Prof. Dr. Mehmet Akif IRMAK

TITLE	AUTHORS	AFFILIATION
Thermal Camera Analysıs of the Potential of Herbaceous Plants Around Sidewalks to Influence Outdoor Thermal Comfort	• Betül Nur Bayraktar • Mehmet Akif Irmak	Atatürk University, Türkiye
The Impact of Temporal and Spatial Changes in Land Use and Cover in Isparta Cıty Center on Urban Ecosystem Servıces: A GIS-Based Analysis	• Çağla Aydemir • Seda Örücü	Süleyman Demirel University, Türkiye
A Thermal Imaging-Based Assessment of the Effect of Herbaceous Vegetation on Outdoor Thermal Comfort in Sloping Areas: The Case of Atatürk University	• Feyzanur Aksak • Hasan Yılmaz	Atatürk University, Türkiye
Botanical Gardens Approach to Ecological Restoration of Abandoned and Derelict Lands	• Figen Altiner • Beyza Erbalci	Balıkesir University, Türkiye
Thermal Camera Analysis of The Effect of Different Flower Colors of Ground-Coverıng Herbaceous Natural Plants on Outdoor Temperature: Atatürk Unıversity Campus	• Hüsna Gülkar • Sevgi Yılmaz	Atatürk University, Türkiye
Thermal Camera Analysis of The Effect of Natural Herbaceous Plants Along Sidewalks on Outdoor Thermal Comfort in Relation to Orientation: A Case Study of Atatürk University Western Campus	• Rümeysa Kazaz • Sevgi Yılmaz	Atatürk University, Türkiye

October 30, 2025 (Thursday)

Antalya (Demre)-Türkiye Time 11:00-12:45

(Online)

SESSION-6, HALL-2 / OTURUM 6, SALON-2
MODERATOR: Gbenga AKOMOLAFE

TITLE	AUTHORS	AFFILIATION
The Significance of Education in The Next Generation Economy	• Dr. Roxana Mihaela Moisoiu	Prof. German Goethe College, Bucharest, Romania
Spatio-Temporal Changes in The Land Use And Vegetation Health Of Two Protected Areas in North-Central Nigeria	• Gbenga Akomolafe	Federal University of Lafia, Nasarawa State, Nigeria
Damage Interaction and Critical Defect Spacing in Hdpe Pipes: Implications For Sustainable İnfrastructure Design	• Djebbara Benzerga, • Faycal Sotehi, • Adel Chouiter, • Nahla Benzerga	LSCMI, University of Sciences and Technology of Oran, Algeria University Constantine 1, Algeria French Higher School of Commerce and Management, Algeria
Checklist of Spiders of (*Arachnida: araneae*) of Serbia	• Boban Stanković	University of Kragujevac, Serbia
Pumpkin Farming From Climate Change Adaptation Perspective: A Case Study in The Coastal Area of Vietnamese Mekong Delta	• Nguyen Thanh Binh • Ngo Thi Thanh Thuy • Tong Thi Anh Ngoc	Can Tho University, Vietnam
Skyscrapers of Sustenance: Integrating Vertical Farming into Urban Architectural Systems	• Melik Sami, Khelil Sara, • Tallal Abdel Karim Bouzir	Mohamed Khider Biskra University, Biskra, Algeria. LACOMOFA Biskra laboratory. Algeria.

October 30, 2025 (Thursday) Antalya (Demre)-Türkiye Time 11:00-12:45 (Online) SESSION-7, HALL-3 / OTURUM 7, SALON-3 • MODERATOR: Assoc.Prof. Dr. Zeqir VESELAJ		
TITLE	**AUTHORS**	**AFFILIATION**
Enhancing Macroeconomic Forecasting Through Big Data-Driven Business İntelligence	• Jora Banda • Iges Banda	European University of Tirana, Faculty of Engineering, Informatics and Architecture, Department of Informatics and Technology, Tiranë, Albania
Historical Dimensions of Nature Conservation in Kosovo- Conservation, Policy, Managerial and Institutional Dimensions	• Assoc.Prof. Dr. Zeqir Veselaj • Assoc.Prof. Dr. Ethem Ceku	University of Prishtina, Republic of Kosovo
Spatio-Temporal Assessment and Simulation of Carbon Dynamics Under Anthropogenic Pressure in Kainji Lake National Park, Nigeria	• Shuaıbu Umar, • Samson Mamman, • Abdullahı Abdulwahab	Federal University of Technology Minna, Niger state, Nigeria.
Sustainable Waste Management Practices in Urban Areas	• Ahmed Attahiru, • Abubakar Umar Birnin-Yauri, • Abubakar Yahaya	Fodiyo University of Science and Technology, Aliero, Kebbi, Nigeria
Economıc Implications of Climate Change on Rice (Oryza Sativa) Production in Bangladesh	• Most. Mokarroma • Arifa Yeasmin • Md. Salauddin Sohan • Md.Habibul Basar • Md. Sakhawat Hosen Sourav • Md.Alshahria • Md. Sazzadul Islam Farjana Akter Rani • Md. Mizanur Rahman	University of Rajshahi, Rajshahi, Bangladesh
Socioeconomic Impacts of Sundarbans Degradation on Local Communities in West Bengal, India: A Systematic Review	• Samim Biswas	Bidhan Chandra Krishi Viswavidyalaya, India

October 31, 2025 (Friday)

Antalya (Demre)-Türkiye Time 11:00-12:45

(Online)

SESSION-8, HALL-4 / OTURUM 8, SALON-4

- **MODERATOR: Dr. M.K. Ganeshani**

TITLE	AUTHORS	AFFILIATION
Artificial Intelligence-Powered Remote Sensing for Sustainable Environmental Management	• Dr. M.K. Ganeshan	AMET University, India
Integrating Machine Learning Algorithms for Predictive Modeling of Tourist Flow Patterns Toward Sustainable Management of Smart Ecological Cities	• O. H. Aliu • J. R. Olasina	Federal Polytechnic Ilaro, Nigeria Covenant University, Ota, ASPMIRE Lab, Ogun State, Nigeria
Modeling Marketing Dynamics and Seller Behaviour: A Pilot Study on Sustainable Livestock Systems in Akwa Ibom State, Nigeria	• Inibehe George Ukpong, • Eduma E. Essien, • Mirabel I. George	Federal Polytechnic, Nigeria. Uyo City Polytechnic Study Centre, Akwa Ibom State, Nigeria
Sustainable Development of Geopolymer Mortar Using Natural Pozzolana	• Benyahia Amar	Saad Dahlab University, Algeria
Urban Composting As a Sustainable Strategy for Waste Management, Green Space Development, and Economic Revitalization	• Akbar Soliemanzadeh	Soil and Water Research İnstitute, Iran
Urban Renewal Approaches For The Revitalization of Tudun Nupawa Neighborhood, Kaduna, Nigeria	• Aliyu Hassan	Air Force Institute of Technology, Nigerian Air Force, Kaduna-Nigeria

October 30, 2025 (Thursday) Antalya (Demre)-Türkiye Time 13:00-14:45 (Online) SESSION-9, HALL-1 / OTURUM 9, SALON-1 MODERATOR: Prof. Dr. Sevgi YILMAZ		
TITLE	**AUTHORS**	**AFFILIATION**
The Role of Solar Energy in Rural Development: An Environmentally Friendly Solution to Energy Poverty	• E. Su Turan	Çukurova University, Türkiye
Gender-Responsıve Strategıes For Climate Resilience in Rural Agriculture: the Case of Bolu, Türkıye	• Gamze Doğdu Yücetürk • Ali Emrah Şahin • Emine Didem Evci Kiraz • Nuray Karatepe • Zekeriya Ar • İsmail Altıntaş	Bolu Abant İzzet Baysal University, Türkiye Bolu Provincial Directorate of Agriculture and Forestry, Bolu, Türkiye Adnan Menderes University, Türkiye
Artificial Intelligence-Based Monitoring of Insect Biodiversity	• Mürşit Ömür Koyuncu • Vedat Görmez	Gaziantep University, Türkiye
Spatio-Temporal Distribution and Effects of Tornadoes in Alanya (2004–2024)	• İlyas Sadık Tekkanat	Çankırı Karatekin University, Türkiye
Climate-Smart Agriculture in Protected Areas: Synergies of Vertical Farming, Agro-Voltaic Systems, and Nature-Based Water Management	• Gülay ÖZKAN	Nottingham Trent University, United Kingdom
Thermal Imaging Analysis of the Effect of Flower Color in Herbaceous Plants On Outdoor Thermal Comfort: A Case Study of Atatürk University Western Campus	• Yaren Doruk • Sevgi Yılmaz	Atatürk University, Türkiye

October 30, 2025 (Thursday)

Antalya (Demre)-Türkiye Time 13:00-14:45

(Online)

SESSION-10, HALL-2 / OTURUM 10, SALON-2
MODERATOR: Prof. Dr. Sima POUYA

TITLE	AUTHORS	AFFILIATION
A Study on The Implementatıon of Horticultural Therapy for Children Wıth Specıal Needs	• Zeynep Taylan • Sima Pouya	Inonu University, Türkiye
Post-Occupancy Evaluation of Urban Open and Green Spaces After the 2023 Türkıye Earthquake	• Gamze Öner • Sima Pouya	Inonu University, Türkiye
Mıchael Marder's Plant-Thınkıng: A New Perspectıve To Understandıng The Lıves Of Plants	• Tuğçe Gül Babacan	Istanbul Gelişim University, Türkiye
The Potentıal Use of Aeroponıc Systems in Urban Landscapes	• Zeynep Dumanoğlu • İlknur Yazıcı • Ayşenur Akbana	Bingol University, Türkiye
Enviromental Examinatıon of The Rehabilitation Process in İvrindi Gold-Silver Mine	• İrem Koç • Yasin Özay • Nadir Dizge	Mersin University, Türkiye Tarsus University, Türkiye
Eco-Anxiety Levels Among Adults Living in Areas Affected by the Manavgat Forest Fire	• Gülsüm Korkmaz Kahraman • Arzu Akcan	Akdeniz University, Türkiye

October 30, 2025 (Thursday) Antalya (Demre)-Türkiye Time 13:00-14:45 (Online)		
SESSION-11, HALL-3 / OTURUM 11, SALON-3 MODERATOR: Nwachukwu, N. G.		
TITLE	**AUTHORS**	**AFFILIATION**
Development of a Sustainable Ag-AgI/TiO2/Cellulose Bıocomposite Film For Environmental and Biomedical Applications	• Mouheb Sboui • Youssef O. Al-Ghamdi	University of Sfax, Tunisia College of Science Al-Zulfi, Majmaah University, Saudi Arabia
Regional Bioassay-Based Indicators of Sediment Quality Along The Moroccan Atlanticcoast	• Khatami Salma, • El Haimeur Bouchra • Bouhallaoui Mina, • Errhif Ahmed	Faculty of Sciences Ain Chock Casablanca. National Institute of Fisheries Research Casablanca.
Examining the Impacts of Water and Hygiene on Child Mortality Rates in Nigeria: Empirical Exploration and Implications	• Abdulkabir N. Adedeji	University of Maiduguri, Nigeria Borno State University, Maiduguri, Nigeria
The Economic Feasibility of Meeting the Demand for Animal Feed in Nigeria Using Microbial Products	• Nwachukwu, N. G., • Olukotun, G.B.	National Biotechnology Research and Development Agency (NBRDA), Abuja, Nigeria.
A Circular Economy-Oriented Approach in Cashew Processing Plants in Vietnam	• Nguyen Xuan Duy, • Nguyen Duong Hong Anh	Nha Trang University University of Economics Ho Chi Minh City
Sustainable Packaging Alternative to Plastic	• Dr. K.S. Patil Sir, Rutuja Damame, Sakshi Petare, Aditya Bagewade	Rajarambapu Institute of Technology, Rajaramnagar Sakhrale, Tal- Walwa , Dist- Sangli

October 30, 2025 (Thursday)

Antalya (Demre)-Türkiye Time 13:00-14:45

(Online)

SESSION-12, HALL-4 / OTURUM 12, SALON-4
MODERATOR: Dr. Duong To Quoc Tha

TITLE	AUTHORS	AFFILIATION
Analysis of Cattle Breed and Age in Breeding Programs Within the Siska System	• Nurliani Erni • Suhardi • Karenina Dwi Yulianti • Akhmat Rizkuna	Mulawarman University, Agriculture Faculty, Department of Animal Science
Economic Efficiency of the Thai Frog (Rana Tigerina) Farming in Mekong Delta	• Tien Dung Khong, • Tran Thi Thu Duyen, • Vu Thuy Duong, • Huynh Thi Kim Uyen	Can Tho University, Vietnam
Sustainable Packaging Alternative to Plastic	• Dr. K.S. Patil Sir, • Rutuja Damame, • Sakshi Petare, • Aditya Bagewade.	Rajarambapu Institute of Technology, Rajaramnagar Sakhrale, Tal- Walwa , Dist- Sangli
Unlocking the Economic Potential of Mustard Cultivation in Bangladesh: Profitability, Inefficiencies, and Institutional Gaps	• Md. Mobarok Hose • Most. Mokarroma • Syed Imad Zaman • Pias Ahmed • Md. Sahadat Hossain • Airin Jahan Urmi • Mst.Upoma Shobnom Raicha • Md. Mahbub Alam	University of Rajshahi, Rajshahi, Bangladesh
Performance Evaluation of Local Goat (Capra Aegagrus Hircus) Production Fed By Echinochloa Polystachya and Introduction of Pineapple Trash (Ananas Comosus) And Wet Market Garbage for an Enhanced Agricultural Economy	• Suhardi, Nurliani Erni, • Fadhil Muharram, Anhar • Faisal Fanani, • Ari Wibowo	Mulawarman University, Indonesia
Economic Policies on Agriculture of the Government of The Republic of Vietnam in South Vietnam (1955-1965)	• Dr. Duong To Quoc Thai • M.A. Nguyen Thanh Tuan	Dong Thap University Vinh Nhuan Middle and High School

October 30, 2025 (Thursday) Antalya (Demre)-Türkiye Time: 15:00-16:45 (Online)		
SESSION-13, HALL-1 / OTURUM 13, SALON-1 • **MODERATOR: Prof. Dr. Şevket ALP**		
TITLE	**AUTHORS**	**AFFILIATION**
Utilization of Greenhouse Wastes in Demre: Environmental and Economic Perspectives	• **Hakan Leventoğlu**	**İndependent Researcher Sakarya-Türkiye**
Environmental impacts of Excessive Pesticide and Chemical Fertilizer Use in Greenhouse: The Case of Demre District (Antalya)	• **Hakan Leventoğlu**	**İndependent Researcher Sakarya-Türkiye**
Effects of Improper Pruning on Urban Ecosystems: A Case Study From Van	• **Şevket Alp** • **Muhammed Emir Göral** • **Muzaffer Bayram**	**Van Yüzüncü Yıl University, Türkiye**
Topiary Art As a Tool for Developing Urban Identity aAnd Tourism Potential in Van	• **Şevket Alp** • **Merve Nur Taşdemir**	**Van Yüzüncü Yıl University, Türkiye**
How Environment Shapes the Leaves of *Quercus macranthera* Ssp. Macranthera	• **Gullu Aliyeva** • **Zumrud Mammadova** • **Saleh Maharramov** • **Vusala Ismayilova** • **Vusala Badalova** • **Minara Hasanova**	**MSE AR, Institute of Dendrology Azerbaijan, Baku**
Germination Characteristics of Nicotiana Glauca Graham	• **Özgenur Aykın** • **Salih Parlak**	**Bursa Technical University, Türkiye**

October 30, 2025 (Thursday) Antalya (Demre)-Türkiye Time: 15:00-16:45 (Online)		
SESSION-14 HALL-2 / OTURUM 14 SALON-2 • MODERATOR: Prof. Dr. Ertan DÜZGÜNEŞ		
TITLE	**AUTHORS**	**AFFILIATION**
The Role of Cultural Routes in the Conservation of Cultural Heritage and the Advancement of Sustainable Tourism	• Ertan Düzgüneş • Arzu Köksal	Karadeniz Technical University, Türkiye
Challenges in The Implementation of Conservation Policies for Historic Urban Streets: A Case Study of Mutlu Street, Mut District	• Ayşe Manav	Toros University, Türkiye
Cost/Benefit Analysis Of Improvements in Recreational Areas (Case Study: Bursa Atatürk Forest)	• Cihat Yıkıcı, • Neşat Erkan	Orman Bölge Müdürlüğü, Türkiye Bursa Technical University, Türkiye
Between Celebration and Conservation: Rethinking the Stork Festival in Eskikaraağaç Village	• Osman Zeybek	Bursa Uludag University, Turkiye
Monumental Religious Buildings From an Environmental Impact Perspective: The Case of Anatolian Seljuk Mosques in Konya	• Neriman Gül Çelebi • Ümit Arpacıoğlu	Mimar Sinan Fine Arts University, Türkiye
Geotourism Activities in Geoparks and Their Relationship with Nature Conservation Areas	• Ertan Düzgüneş • Sedef Şükür Özdoğan • Arzu Köksal	Karadeniz Technical University, Türkiye

October 30, 2025 (Thursday)

Antalya (Demre)-Türkiye Time 15:00-16:45

(Online)

SESSION-15 HALL-3/ OTURUM 15, SALON-3

- **MODERATOR: Rabiu Ahmad Abubakar**

TITLE	AUTHORS	AFFILIATION
Seeing and Selling the City: Visual Consumption and the Erosion of the 'Right to the City'	• Melik Sami, • Khelil Sara, • Tallal Abdel Karim Bouzir	Mohamed Khider Biskra University, Biskra, Algeria. LACOMOFA Biskra laboratory. Algeria.
Cross Ventilation in Desert Homes: Spatial Strategies for Passive Cooling in Biskra	• Melik Sami, • Khelil Sara, • Tallal Abdel Karim Bouzir	Mohamed Khider Biskra University, Biskra, Algeria. LACOMOFA Biskra laboratory. Algeria.
Façade Glazing Ratios and Their Role in Heating and Cooling Loads in High-Rise Architecture	• Melik Sami, • Khelil Sara, • Tallal Abdel Karim Bouzir	Mohamed Khider Biskra University, Biskra, Algeria. LACOMOFA Biskra laboratory. Algeria.
Architectural Design And Structural Evaluation of Arched Window Features in Residential Buildings	• Rabiu Ahmad Abubakar	Audu Bako College of Agriculture, Danbatta, Kano, Nigeria
Modeling of 1D SMA Spring Under Thermal and Mechanical Loadings Using COMSOL Multiphysics	• Rabiu Ahmad Abubakar	Audu Bako College of Agriculture, Danbatta, Kano, Nigeria
Feasibility Design for Two-Post Car Lift From Locally Available Material	• Rabiu Ahmad Abubakar	Audu Bako College of Agriculture, Danbatta, Kano, Nigeria
Sustainable Packaging Alternative to Plastic	• Dr. K.S. Patil Sir, • Rutuja Damame, • Sakshi Petare, • Aditya Bagewade	Rajarambapu Institute of Technology, Rajaramnagar Sakhrale, Tal- Walwa , Dist- Sangli

October 30, 2025 (Thursday)

Antalya (Demre)-Türkiye Time 15:00-16:45

(Online)

SESSION-16 HALL-4/ OTURUM 16, SALON-4

- **MODERATOR: Dr. K.S. Patil Sir**

TITLE	AUTHORS	AFFILIATION
From Soil Wisdom to Smart Farming: Examining India's Agricultural Transformation	• Kiruthika L N. • Dr. Shalini R.	CMS Business School, Jain University
Marine Algae-Derived Activated Adsorbents for the Removal of Cationic Dyes from Wastewater	• Salima Attouti, • Mourad Termoul, • Benaouda Bestani, • Noureddine Benderdouche	Abdel Hamid Ibn Badis University, Algeria
Eco-Design Inspired by Natural Wetlands for Circular Water Management in Agriculture	• El Oualı Ouijdane, • El Hajjaji Souad, • Zouahrı Abdelmjid, Labjar Najoua, • Houria Dakak • Benıken Lhou • Omari Fatimaezahra	Mohammed V University- Rabat-Morocco National Institute for Agronomic Research-Rabat-Morocco
Students and the Protection of the Environment: An Ecofeminist Discourse Analysis of a Text from a Secondary School Textbook	• Franck Amoussou • Ayodele Adebayo Allagbe • Abdou Maiguero	Université André Salifou (UAS) de Zinder
Driving Forces of Farmers' Awareness on Climate Change: A Study in the South-West Coastal Region of Bangladesh	• Habibur Rahman	Khulna University, Khulna-9208, Bangladesh
Livelihood Coping Strategy of Women in Flood-Prone Areas in Bangladesh	• Habibur Rahman	Khulna University, Khulna-9208, Bangladesh
Study of the chemical composition and antioxidant and antimicrobial activities of the essential oil of the aerial part of Satureja calamintha from Morocco	• EL BRAHIMI Rajae, • BARI Amina	Sidi Mohammed Ben Abdallah University, Fez.
Electricity Production from Nature (Aloe Vera)	• Mahdi Tajalian Mofrad • Dr. Jafar Massah	College of AbuRaihan, University of Tehran, Iran

October 30, 2025 (Thursday) Antalya (Demre)-Türkiye Time: 17:00-18:45 (Online)		
SESSION-17, HALL-1 / OTURUM 17, SALON-1 • MODERATOR: Assoc. Prof. Dr. Sultan Sevinc Kurt Konakoğlu		
TITLE	**AUTHORS**	**AFFILIATION**
Assessment of Tangible Cultural Heritage Elements of Çorum City From A Tourism Perspective	• Gülnur Kardan, • Kübra Hanoğlu, • Sultan Sevinc Kurt Konakoğlu	Amasya University, Türkiye
Assessment of The Contributions of Immovable Cultural Heritage to Urban Tourism In Kocaeli City"	• Kübra Hanoğlu, • Gülnur Kardan, • Sultan Sevinc Kurt Konakoğlu	Amasya University, Türkiye
Agroecology and Environmental Protection	• Gümüş Funda Gökçe Demirci • Öner Demirel • Sude Nergiz Alemdar	Düzce University, Türkiye Kırıkkale University, Türkiye
Temporal Change Analysis of Lake İznik Water Surface Area Using Remote Sensing and Gis	• Ali AKIN • Fatihhan YILDIRIM • Turan SÖNMEZ • Burhan GENCAL	Bursa Technical University, Türkiye
A Multidimensional Framework for Urban Green Space Quality	• Meryem Bihter Bingül Bulut • Öner Demirel • Bilgenur Ak	Kırıkkale University, Türkiye
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October 30, 2025 (Thursday) Antalya (Demre)-Türkiye Time: 17:00-18:45 (Online)		
SESSION-18, HALL-2 / OTURUM 18, SALON-2 • MODERATOR: Prof. Dr. Ivan Pavlović		
TITLE	**AUTHORS**	**AFFILIATION**
Development and Evaluation of a Novel Biopolymer-Based Superabsorbent Hydrogel on plants growth under Different Hydric Stress Conditions for Sustainable Agriculture	• Yousra BELAYACHI, • Yahya BACHRA, • Mohamed ZAHOUILY	Hassan II University, Casablanca, Morocco Mohammed VI Polytechnic University, Ben Guerir, Morocco
Patterns and Socioeconomic Drivers of Fuelwood Dependency in Households Adjacent to Rema-Kalenga Wildlife Sanctuary, Habiganj, Bangladesh	• Shahruk Khan HIMU • Md. Saifuzzaman BHUIYAN	Shahjalal University of Science and Technology, Bangladesh
Morphological characterization and in vitro management of Aspergillus niger: a major fungal contaminant of prawn balachao in Bangladesh	• Tamanna, Ismot Ara, • Md. Sabbir Ahmmed, • Nuhu Alam	Jahangirnagar University, Savar, Dhaka
Biological and Ecological Characteristics of Hilsa (Tenualosa ilisha): Essential for Sustainable Management	• Tahsin Muhtady	Institute of Natural Resources Research and Development, Rajshahi-6206, Bangladesh
Applying Meta-analysis in Plant Science: Synthesizing Evidence and Identifying Research Gaps in Stress Physiology and Crop Improvement	• Md. Tahjib-Ul-Arif	Bangladesh Agricultural University, Mymensingh 2202, Bangladesh
Occurence of Trichuris ovis in Goats in Serbia	• Ivan PAVLOVIĆ • Jovan BOJKOVSKI • Aleksandra TASIĆ • Ivanka HADŽIĆ	Scientific Institute of Veterinary Medicine of Serbia, Belgrade,Serbia Univerisity in Belgrade, Belgrade, Serbia Care and Therapy of Cattle Foot of Serbia

FACE TO FACE SESSIONS

October 31, 2025 (Friday)

Congress Venue: Mediterranean Fisheries Research, Production and Training Institute Directorate Demre Training Centre- Demre, Antalya
(Akdeniz Su Ürünleri Araştırma, Üretme ve Eğitim Enstitüsü Müdürlüğü Demre Eğitim Merkezi-Demre, Antalya)

FRIDAY– October 31, 2025 Antalya (Demre)-Türkiye Time 9:00-10:45 (Face to Face)		
SESSION-19, LİKYA Hall / OTURUM-19, LİKYA SALON MODERATOR: Prof. Dr.Murat AKTEN		
TITLE	**AUTHORS**	**AFFILIATION**
Assessment of the Ecotourism Potential of Döşemealtı District, Antalya Province	• **Ozan Yılmaz** • **Murat Akten**	**Süleyman Demirel University, Türkiye**
The Importance of Carbon Farming and Agroforestry Systems Practices in Combating Climate Change	• **Atila Gül** • **Sibel Akten** • **Hüseyin Batuhan Dündar**	**Süleyman Demirel University, Türkiye Isparta University of Applied Sciences, Türkiye**
Ecological Planning and Spatial Strategy Strategies as a Sustainable Urbanization Approach in The Döşemealtı District Example	• **Ozan Yılmaz** • **Murat Akten**	**Süleyman Demirel University, Türkiye**
In The Process of Mitigating Climate Change Impacts Importance and Relationship of Land Uses	• **Sibel Akten** • **Atila Gül** • **Hüseyin Batuhan Dündar**	**Süleyman Demirel University, Türkiye Isparta University of Applied Sciences, Türkiye**
Examination of the Current Spatial Status of Legally Protected Areas in Demre (Antalya) District	• **Hüseyin Batuhan Dündar** • **Atila Gül** • **Sibel Akten**	**Süleyman Demirel University, Türkiye Isparta University of Applied Sciences, Türkiye**
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FRIDAY– October 31, 2025 Antalya (Demre)-Türkiye Time 9:00-10:45 (Face to Face) SESSION-20, MYRA HALL / OTURUM-20, MYRA SALONU MODERATOR: Prof. Dr. Tendü Hilal GÖKTUĞ		
TITLE	**AUTHORS**	**AFFILIATION**
A CBS-Supported Analysis of the Transformation Between Natural and Built-Up Areas in Arnavutköy, Istanbul	• Duygu Minaz • Kamile Zeren	Karabük University, Türkiye
Fire Risk Analysis in Protected Areas Using CBS and Remote Sensing Supported Best-Worst Method: The Case of Göksu Delta	• Duygu Minaz	Karabük University, Türkiye
Integrated Intervention Strategies for the Development of Potential Ecosystem Services in The Hatip Stream Basin	• Yağmur Öcal • Feriha Yıldırım • Figen Dilek	Gazi University, Türkiye Ankara University, Türkiye
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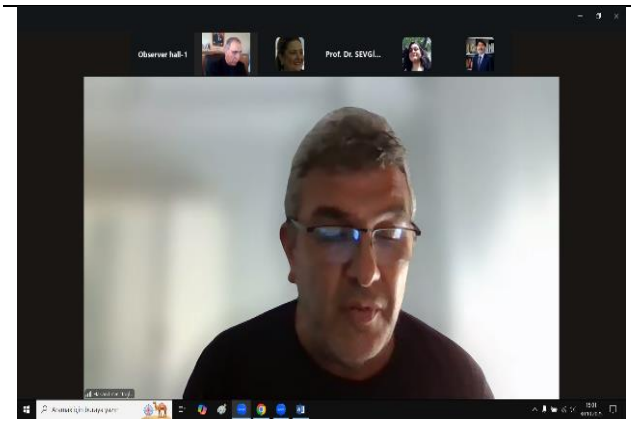


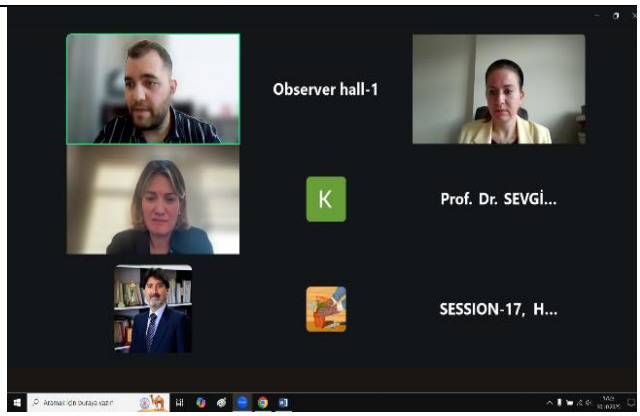


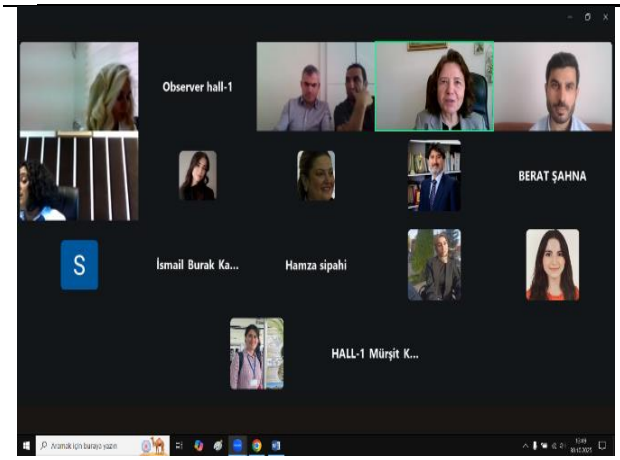


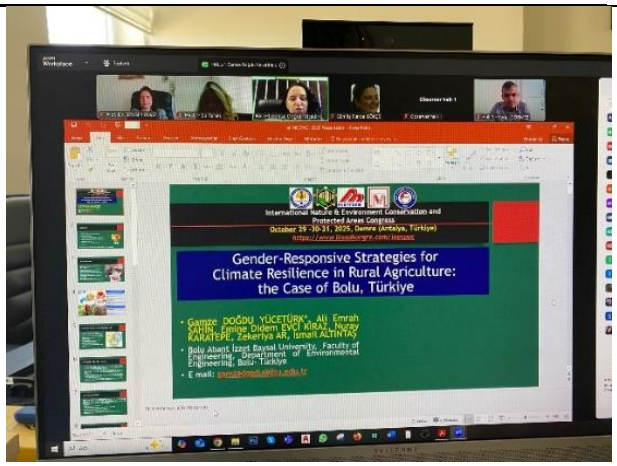


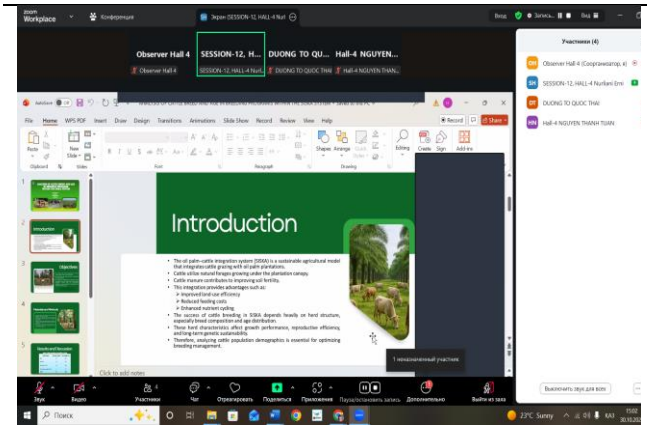


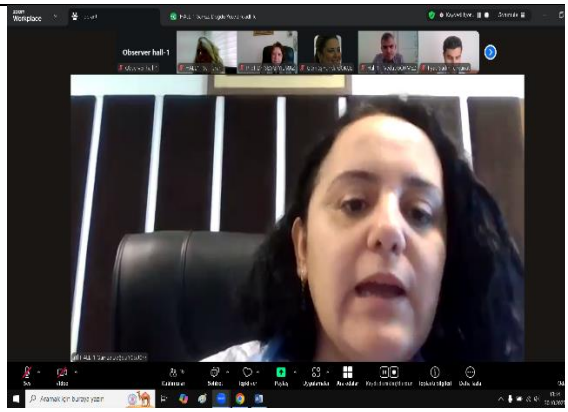

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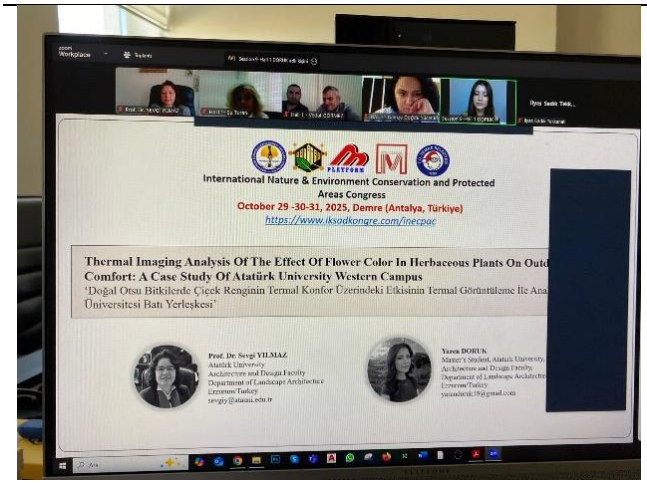

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The Significance of Education in The Next Generation Economy

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Abstract

Education has always been a fundamental resource for human development, but in the 21st century it becomes the core of the knowledge-based economy. The transformations generated by the digital revolution, the green transition and globalization launch unprecedented challenges for societies and individuals. [1]

Education represents the foundation of the next generation economy, having a triple significance: it is an investment in human capital, a mechanism for adapting to technological changes and a vector of social inclusion. It ensures not only individual progress, but also the collective resilience of societies. To capitalize on its potential, public policies must support curricular innovation, equitable access and partnerships between education, research and the economy.

The next generation will be competitive only to the extent that education becomes a strategic priority and infrastructure of the future.

Keywords: Education, globalization, transition, the next generation.

[1] https://www.consilium.europa.eu/ro/policies/digital-transition/

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Enhancing Ecological Awareness and Artistic Creativity Through National Projects: Evidence from the Prodes "Child Artist in Nature"

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Abstract

This study aims to examine the impact of nature- and ecology-based projects, carried out within the scope of national programs, on high school students. As a case study, the project "The Child Artist in Nature", implemented under PRODES, was analyzed. In today's world, where environmental problems are increasing, it is essential that young individuals gain ecological awareness, sustainable living skills, and cultural sensitivity. In this context, nationally developed environmental projects are considered to contribute significantly not only to students' environmental consciousness but also to their social and personal development.

The study employed a qualitative research design to evaluate the experiences of high school students participating in the project. Data were collected through face-to-face interviews, focusing on students' experiences during the project, their relationship with nature, and their reflections on artistic production processes. The data obtained were analyzed using content analysis.

The project was coordinated by the International Children's Rights Senate Association, with SURMOT Search and Rescue and Nature Sports Club serving as the implementing organization. The Kocaeli Provincial Directorate of Family and Social Services and the Kocaeli Provincial Directorate of Culture and Tourism supported the project as partner institutions. The initiative was launched with the grant support of the Ministry of Interior, Directorate General of Relations with Civil Society.

Findings indicate that participation in "The Child Artist in Nature" project enhanced students' environmental awareness, increased their sensitivity toward nature, and strengthened their artistic creativity through nature-based activities. Additionally, the project contributed to the development of teamwork, communication, and problem-solving skills.

In conclusion, the project can be considered an innovative educational model that enriches ecological awareness and cultural sensitivity among high school students

Keywords: Ecological awareness, national projects, high school students, environmental education, the child artist in nature

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Challenges in The Implementation of Conservation Policies for Historic Urban Streets: A Case Study of Mutlu Street, Mut District

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Abstract

Historic urban streets are significant indicators of both urban identity and cultural heritage. However, shortcomings or dilemmas in the implementation of current conservation policies may lead to disruptions in continuity at the street scale. As a result, the traditional street, along with the cohesive texture of cultural heritage and the perception of local identity, is progressively eroding over time. This study examines the current state of Mutlu Street, situated in the Mut district, through the lens of cultural heritage continuity and within the framework of conservation policies. Mutlu Street constitutes the boundary of archaeological sites of varying degrees, while being situated within a broader archaeological site zone. At the same time, the traditional houses, vacant plots, and archaeological assets along the street constitute the historic texture of Mutlu Street. The study examined traditional housing typologies on the street, demolitions of unregistered buildings, or new buildings, analyzing their impact on the historic texture and perception of the street. The findings indicate that conservation policies remain insufficient in practice and that the continuity of street identity has been disrupted. Undefined vacant areas and the transformation of traditional buildings have emerged as key factors affecting the continuity of cultural heritage. In conclusion, it is important that local governments meticulously implement cultural heritage protection policies and that locals and experts are included in planning and monitoring mechanisms through participatory methods. This study aims to reveal the practical implications of conservation policies in the case of Mut district and to propose strategies for the sustainability of street textures.

Keywords: Cultural heritage, conservation policies, historic urban streets, mut, traditional houses

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Gender-Responsive Strategies for Climate Resilience in Rural Agriculture: The Case of Bolu, Türkiye

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Abstract

Rural women farmers are among the groups most vulnerable to the adverse impacts of climate change, yet they play a vital role in sustainable food production and community resilience. Global research demonstrates that gender inequalities in access to knowledge, resources, and decision-making intensify women's vulnerability, particularly in developing countries. Addressing these disparities is essential for effective adaptation strategies and biodiversity conservation. This study mainly aims to develop a gender-responsive framework in Bolu province, Türkiye, designed to strengthen women's resilience to climate-related challenges in agriculture. The framework integrates technical, social, environmental, and health dimensions. Its core components include workshops on climate change impacts, such as heat stress, vector-borne diseases, and malnutrition, along with training on climate-smart agricultural practices, renewable energy applications, and guidance on sustainable waste management and circular economy models. Complementary activities such as peer mentoring networks and user-friendly handbooks support knowledge transfer among women farmers, ensuring that learning and capacity building extend beyond the project's duration. By combining participatory learning, digital dissemination platforms, and cross-sectoral collaboration, the initiative contributes simultaneously to environmental protection and gender equality. While empirical data collection is ongoing, the expected outcomes include enhanced adaptive capacity, improved access to resources, and stronger participation of women in agricultural decision-making. The study concludes that empowering rural women in agriculture is not only a matter of equity but also a key driver of sustainable development and climate adaptation. Gender-sensitive interventions of this kind align with international conservation agendas and help foster more inclusive, resilient, and climate-ready rural landscapes.

Keywords: Bolu; gender; climate change; climate resilience; sustainable development

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Artificial Intelligence-Based Monitoring of Insect Biodiversity

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Abstract

This study examines the transformative role of artificial intelligence (AI) technologies in overcoming the limitations of traditional monitoring methods in the face of the global decline in insect biodiversity. It presents an integrative approach that combines satellite-based remote sensing with citizen science platforms. While satellite data provide macro-scale insights into species distributions through habitat suitability modeling across broad geographic areas, citizen science applications such as e-Butterfly and iNaturalist generate high-resolution species-level data via AI-assisted image recognition algorithms.

The analyses demonstrate that hybrid models integrating these two data sources yield more robust and accurate outcomes compared to single-method approaches. Furthermore, emerging strategies such as multimodal data integration and real-time dynamic monitoring are highlighted for their potential to advance ecological research and conservation practices. Nonetheless, challenges including data quality imbalances, algorithmic biases, and financial constraints are discussed, along with potential solutions. In conclusion, AI-enabled integrated monitoring systems are identified as a critical foundation for more effective and proactive interventions against global biodiversity loss.

Keywords: Artificial intelligence (AI), biodiversity monitoring, citizen science

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A CBS-Supported Analysis of the Transformation Between Natural and Built-Up Areas in Arnavutköy, Istanbul

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Abstract

This study aims to examine the dynamics of natural and built-up areas in the Arnavutköy district of Istanbul using remote sensing and Geographic Information Systems (GIS) techniques. Rapid urbanization in recent years, large-scale infrastructure projects, and the construction of new residential areas have led to significant changes in land use in the region. Landsat satellite images from 1999, 2009, 2019, and 2024 were used to quantitatively determine these changes. Low cloud cover and high seasonal comparability were prioritized as criteria for selecting the images. The study applied the Normalized Built-up Area Index (NBAI) to identify urban areas and the Normalized Difference Vegetation Index (NDVI) to determine vegetation density.

The analysis results reveal that urbanization in Arnavutköy increased rapidly, especially after 2009, and that urbanization progressed more intensively between 2019 and 2024. NDVI analyses show that vegetation cover has been fragmented due to urbanization and has completely disappeared in some areas. This process confirms that large-scale infrastructure projects and new settlement areas have significantly altered land use. The findings of the study show that the environmental impacts of rapid urbanization are traceable and that strategies for protecting green spaces need to be developed.

The results emphasize the critical role of sustainable urban planning in preserving ecological balance and highlight the importance of effectively implementing environmental management policies. The research provides a scientific basis for preventing natural area loss, strengthening green infrastructure, and supporting planned urbanization decisions, based on findings specific to Arnavutköy.

Keywords: Remote sensing, Geographic Information Systems, NDVI, NBAI, Arnavutköy

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Fire Risk Analysis in Protected Areas Using CBS and Remote Sensing Supported Best-Worst Method: The Case of Göksu Delta

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Abstract

The Göksu Delta, protected under the Ramsar Convention, is one of Turkey's most important wetland ecosystems. This area, which attracts national and international attention due to its rich biological diversity, endemic species, and strategic importance for migratory birds, is also subject to environmental pressures due to intensive agricultural activities and human settlements. Increasing temperatures in recent years, the drying up of reed beds, and climatic variability have led to an increased risk of fire in the delta. In this context, the Best Worst Method (BWM), one of the multi-criteria decision-making methods, was applied using Geographic Information Systems (GIS) and Remote Sensing techniques to determine the fire risk in the Göksu Delta, which has protected area status.

The study utilized eight parameters for risk assessment: land surface temperature (LST), normalized difference vegetation index (NDVI), wind, air temperature, solar radiation, precipitation, distance to built-up areas, and elevation. The parameters were weighted according to expert opinions, spatial data layers were produced in a GIS environment, and risk levels were spatially mapped. The findings reveal that the risk of fire is high, particularly around Akgöl and in areas with dense reeds, and that the risk increases significantly in areas close to human settlements.

The study utilized eight parameters for risk assessment: land surface temperature (LST), normalized difference vegetation index (NDVI), wind, air temperature, solar radiation, precipitation, distance to built-up areas, and elevation. The results provide important data for developing fire management strategies aimed at protecting the Göksu Delta. It is necessary to implement protective measures, especially in high-risk areas, develop fire-resistant ecosystem management models, and prepare sustainable use plans. This study demonstrates that the combined use of GIS and BWM methods in protected areas provides an effective approach to fire risk analysis and presents an applicable model for similar wetland ecosystems.

Keywords: Göksu Delta, protected area, fire risk, GIS, Best Worst Method (BWM)

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Cultural Heritage and Environmental Protection: Tracing Mughal, Colonial and Contemporary Landscape Architectural Design Elements

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Abstract

Lahore, as a historical city of South Asian region embodies a rich tapestry of landscape architecture reflecting its complex tradition and cultural Heritage development. The present qualitative research explores obvious styles of landscape architecture in Lahore – Mughal, Colonial, and Contemporary, decoding their design narratives and experiential dimensions. Through in-depth study and interviews with local community, analysis between all these styles, their design elements, environmental protection, benefits on health and significance of architectural landscape in busy city will open new dimensions in the field. Through historical documents, and observational studies of key sites like the cultural heritage architectural landscape of Shalimar Gardens, Lahore Fort, Tomb of Jahangir, Hiran Minar, Lawrence Garden, Gillani Park and the impact of their elements on the contemporary parks and play grounds of the region is vital part of the study.

The research investigates the architectural planning and design elements of cultural heritage, colonial legacies, and contemporary urban dynamics. Innovations and impacts of landscape architecture built during the above-mentioned different time periods. Findings reveal how Mughals represent water features, symmetry and expressions of royalty; Colonial-era green area like Lawrence Garden reflects blending of design utility for common men; and Contemporary designs navigate challenges of urbanization, sustainability, and identity surrounded by globalization. The study highlights perceptions of local communities, designers, and heritage custodians regarding these spaces' meanings, and uses. Inspiring history, design innovation, and inclusive placemaking in urban landscape architectural planning is highlighted to discuss the versatile elements and health benefits for the community. Lahore's landscape architecture as a collection of historical and innovative layers with cultural innovations are a part of the research.

Keywords: Landscape architecture, Lahore, Mughal, Colonial, contemporary, urban heritage

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Michael Marder's *Plant-Thinking*: A New Perspective to Understanding the Lives of Plants

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Abstract

In the Western philosophical discourses, plant life has been largely overlooked or ignored. They have been explained mostly through their associations with others. The reason may be stemming from the constant comparison between their animal others or from their nature which is far from the human nature. Therefore, Western perceptions tended to disregard plant life or demean its existence in the philosophical contexts. In order to make a shift in this perspective, it is crucial to develop a new way of perceiving plant life. In accordance, cultivating a "vegetative point of view" is of utmost importance. This study aims to introduce this new perspective as proposed by Michael Marder in his prominent work, Plant-Thinking: A Philosophy of Vegetal Life, which is one of the key works to understand the vitality of plants in an age of "plant-turn," where contemplations on liveliness extends to include that of non-human beings. The perspective arises from the common setback of "plant-blindness," which forms one of the underlying reasons behind the disregard of vegetal life. By extending beyond the limits of plant blindness, this study will focus on the importance of creating a perspective that vitalizes plants' point of view by removing the human-centered perspectives aside. This particular way of perceiving plant life is non-anthropocentric in the sense that it proposes a plant-centric look to the vegetal world. This research showcases the importance of looking at vegetal life from their point of view, which channels a sensible solution in the ongoing environmental crisis.

Keywords: Michael Marder, critical plant studies, plant life, vegetal vitality

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Between Celebration and Conservation: Rethinking The Stork Festival in Eskikaraağaç Village

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Abstract

Eskikaraağaç, situated on the shores of Lake Uluabat—a designated Ramsar site in Bursa, Türkiye—has been recognized as the country's inaugural European Stork Village since 2011. The village has garnered international popularity, particularly through the narrative of "Yaren," a stork that returns annually to the village and develops a friendship with a local fisherman, thus embodying the intricate relationship between humans and wildlife. Since 2005, the Annual Stork Festival has served as a platform for celebrating this connection, emphasizing ecological awareness via birdwatching, educational workshops, and cultural activities. However, recent iterations of the festival have transitioned towards large-scale open-air concerts and commercialized attractions, leading to heightened concerns regarding noise pollution and ecological disturbance within this sensitive wetland ecosystem.

Scientific literature substantiates that anthropogenic noise adversely affects avian communication, elevates stress levels, diminishes foraging efficiency, and may compromise reproductive success. Notably, neither the Ramsar Convention nor the criteria for European Stork Village designation explicitly address the challenges posed by acoustic pollution. This study elucidates the dissonance between the festival's purported eco-friendly ethos and its ecological repercussions. It critically assesses existing policy deficiencies in noise management and advocates for reimagining festival practices.

Alternatives such as birdwatching tours, silent performances, ecological workshops, and nature-based storytelling could sustain cultural vitality while mitigating ecological detriment. The evaluation culminates in the assertion that sustainable nature-based events necessitate the incorporation of acoustic ecology into their planning and management frameworks. Such an integrative approach holds the potential to harmonize cultural celebrations with conservation objectives, thereby safeguarding the long-term ecological integrity of wetlands while preserving their socio-cultural significance.

Keywords: Eskikaraağaç, stork festival, noise pollution, acoustic ecology, Ramsar site, European Stork Village, cultural landscape.

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How Environment Shapes the Leaves of *Quercus macranthera* ssp. *macranthera*

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Abstract

Global climate change imposes diverse effects on plant systems, particularly through shifts in water availability and temperature, which result in morphological and functional variability. This study investigated leaf morphological and functional traits of Quercus macranthera subsp. macranthera across different regions of Azerbaijan. Two populations, Shaki and Goygol, were selected to represent contrasting environmental conditions in terms of annual precipitation, elevation, and mean annual temperature. Ten mature leaves per tree were sampled from 10 trees per population, and traits including leaf area (LA), leaf length (LL), leaf width (LW), length-to-width ratio (LL/LW), shape factor (F), leaf mass per area (LMA), water content (WC), relative water content (RWC), and succulence (S) were measured. Significant interpopulation variation was observed, with LA and LW showing the highest variability (CV=44.56% and 25.58%, respectively). Leaves from the Goygol population were larger and exhibited higher LMA and RWC, indicating better water availability, whereas Shaki leaves experienced greater water stress. Notably, leaf size was not strongly constrained under limited water conditions, demonstrating the high adaptive capacity of this species. Morphological and functional leaf traits correlated closely with climatic gradients, mainly influenced by precipitation and elevation. The findings highlight the key role of leaf morphological and physiological plasticity in the ecological adaptability of Quercus macranthera subsp. macranthera, offering insights into long-lived tree species' responses to environmental variability. These results are essential for understanding adaptive mechanisms and informing conservation strategies under future climate change scenarios.

Keywords: *Quercus macranthera* subsp. macranthera, leaf morphology, leaf functional traits, environmental gradients, phenotypic plasticity

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Cultural Heritage and Natural Landscapes as a Foundation for Sustainable Tourism Development

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Abstract

Tourism that is developed in harmony with nature and cultural heritage holds the key to sustainable local development. This paper explores the intersection between protected natural areas and intangible cultural values in the context of tourism planning. Drawing from examples in the Dukagjini and Rugova regions of Western Kosovo, the study emphasizes the importance of preserving natural landscapes while promoting cultural expressions such as traditional music, crafts, gastronomy, and oral history. These assets not only shape the identity of the region but also represent significant drivers for community-based tourism.

The research highlights the need for participatory governance, capacity-building of local actors, and legal frameworks that support both heritage conservation and responsible tourism. Furthermore, the study discusses nature-based tourism solutions that respect ecological balance and contribute to climate resilience. By integrating cultural heritage protection with environmental stewardship, the paper advocates for a holistic tourism model that enhances both visitor experience and local livelihoods.

Keywords: Sustainable tourism, cultural heritage, nature conservation, local development, community participation

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Post-Occupancy Evaluation of Urban Open and Green Spaces After the 2023 Türkiye Earthquake

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Abstract

In Turkey, particularly after earthquakes, the lack of safe gathering and shelter areas for the public significantly complicates critical post-disaster activities like ensuring safety, providing health services, shelter, and emergency aid. Furthermore, over time, the physical and functional deterioration of designated open and green spaces used as assembly areas has led to a decrease in user satisfaction.

In this context, this research aims to examine the usage patterns of open and green spaces in Malatya before, during, and after the earthquake that occurred on February 6, 2023. The study focuses exclusively on open and green spaces in the city of Malatya that were classified as emergency assembly areas.

To achieve its objective, the study employed the Post-Occupancy Evaluation (POE) method. This method utilized three different techniques: on-site observation and photography, surveys, and interviews. The research included interviews with representatives from local governments and surveys with users. A total of 60 people were interviewed, with 10 officials from each area. Additionally, 240 surveys were administered to determine user satisfaction levels, learn about pre-disaster usage habits, and identify problems encountered after the earthquake.

The study's findings reveal the assessed areas' performance in terms of both their post-disaster emergency assembly function and their identity as urban open and green spaces. Based on these findings, various recommendations were developed for the planning and design processes of open and green spaces used as assembly areas, especially in earthquake-prone regions.

Keywords: Earthquake, post-earthquake emergency assembly areas, open and green space

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A Study on the Implementation of Horticultural Therapy for Children with Special Needs

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Abstract

This study investigated the therapeutic effects of horticultural therapy (HT) on children with special needs who have learning difficulties. Horticultural therapy is a therapeutic method that supports individuals' cognitive, emotional, physical, and social development through interaction with nature. The research was conducted at the Dora Special Education Center on the Inonu University campus in Malatya. A total of 18 students, aged 4-18, participated in the study; 9 were assigned to the treatment group and 9 to the control group. The treatment group received 45-minute horticultural therapy sessions once a week for six weeks, while the control group received no intervention.

The therapy process included activities such as planting seedlings and flowers, sensory integration exercises, planting bean seeds, and creating terrariums. Throughout the sessions, students' development in academic, motor, attention-memory, language, and social skills were evaluated using observation forms. Data was collected using a pre-test/post-test method and statistically analyzed with SPSS. According to the results, the group that received horticultural therapy showed significant improvement in reading, writing, attention-memory, comprehension, and language skills. Positive differences were also observed in their overall observation scores ($p<0.05$). However, no statistically significant changes were found in mathematics, motor skills, or auditory-visual-tactile perception. The control group showed no notable development.

In conclusion, horticultural therapy made a significant contribution to certain cognitive, emotional, and language skills of children with special needs and supported their social adaptation and self-confidence. These findings suggest that HT can be used as a complementary rehabilitation method in special education institutions.

Keywords: Horticultural therapy, learning difficulties, children with special needs, rehabilitation, education

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Rhagadiolus Stellatus: Data Compilation on a Mediterranean Asteraceae with Phytochemical and Systematic Potential

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Abstract

Rhagadiolus stellatus., a Mediterranean plant belonging to the Cichorieae tribe within the Asteraceae family, exhibits a geographical distribution spanning Southern Europe, North Africa, and Western Asia. Traditionally utilized as a food plant, it represents a significant connection between regional biodiversity and potential scientific applications. This study aims to comprehensively compile and analyze the existing phytochemical and systematic data concerning this species, drawing upon a foundation of established scientific research. Phytochemical investigations have identified several important secondary metabolites in R. stellatus, including flavonoid compounds such as kaempferol 3-O-β-glucoside, kaempferol 3-O-β-rutinoside (nicotiflorin), quercetin 3-O-β-glucoside, and luteolin. Additionally, phenolic acids like chlorogenic acid and 3,5-dicaffeoylquinic acid have been detected. These compounds were characterized using advanced analytical techniques, including repeated column chromatography and spectroscopic methods (NMR, MS). The identified phytochemical profile holds considerable value for chemosystematics, providing evidence that helps distinguish the genus Rhagadiolus from closely related genera such as Crepis, thereby supporting its taxonomic status as a separate genus. Beyond its taxonomic significance, the presence of these bioactive compounds suggests considerable potential for pharmaceutical, nutraceutical, or other biotechnological applications, although the biological and ecological properties of R. stellatus remain underexplored. This systematic review and data compilation serve as a crucial initial step towards the sustainable valorization of Rhagadiolus stellatus. It also underscores the importance of promoting conservation strategies for this species within its native habitats, particularly the vulnerable Mediterranean ecosystems it inhabits.

Keywords: Rhagadiolus stellatus, Asteraceae, Cichorieae, flavonoids, chemosystematics, phenolics, biodiversity, Mediterranean.

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Pulicaria odora a Promising Mediterranean Asteraceae: Data Compilation

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Abstract

Pulicaria odora, a plant belonging to the Asteraceae family, is widely distributed in Africa, Europe, and Asia, with a notable presence in the Mediterranean basin. Used in traditional medicine for its therapeutic properties, this species represents a valuable link between ancestral practices and modern scientific applications. This study aims to compile existing phytochemical and biological data on Pulicaria odora, focusing on its antioxidant and antimicrobial potential. Results from existing studies show that leaf extracts, rich in phenolic compounds (protocatechuic, chlorogenic, and caffeic acids, and quercetin-3-glucoside), exhibit significant antioxidant activity, as evaluated by ORAC, ABTS, DPPH, and FRAP assays. Furthermore, these extracts demonstrate promising antimicrobial activity against several bacterial strains (Escherichia coli, Pseudomonas aeruginosa, Staphylococcus aureus, Listeria innocua) and fungal strains (Aspergillus flavus, Aspergillus niger, Trichoderma reesei), with minimum inhibitory concentrations as low as 0.78 mg/mL. These biological properties, combined with its richness in secondary metabolites, position Pulicaria odora as a promising natural resource for pharmaceutical and cosmetic applications, or as a natural preservative agent. This compilation of existing knowledge provides a solid foundation for future research aimed at the sustainable valorization of this species within the context of Mediterranean biodiversity conservation.

Keywords: *Pulicaria odora, Asteraceae, Phenolic Compounds, Antioxidant Activity, Antimicrobial Activity, Biodiversity, Mediterranean.*

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Integrated Intervention Strategies for the Development of Potential Ecosystem Services in the Hatip Stream Basin

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Abstract

The term ecosystem services (ES) is defined as all the products, services, and benefits that ecosystems on Earth provide to humans and other living beings. Determining and developing ES potential is a key element for environmentally conscious urban planning. Cities' ability to become resilient to the climate crisis and self-sufficient depends largely on the ecosystem services they possess. Pollution, deforestation, and climate change are the most significant threats to ecosystem services, and when combined with improper land use and land degradation, urban ecosystems become uninhabitable. This study aims to present comprehensive recommendations aligned with spatial ecological processes for enhancing the potential ecosystem services provided by ecological units in the Hatip Çayı Basin, located within the boundaries of Ankara Province, based on land use. The potential ecosystem services identified in the 460 km² river basin area are primarily food, air quality/climate regulation, erosion control, genetic resources, pollination, photosynthesis, soil formation, nutrient cycling, water cycling, and recreation. It is understood that the ecological integrity providing these services is threatened by the climate crisis, urbanization, and unsustainable land management. As a means of balancing these risks and current degradation, the development of "nature-based holistic proposals" in the Hatip Çayı Basin will contribute to the maintenance or restoration of fundamental ecosystem services. Nature-based solutions planned to be developed in the study area based on ecological integrity include blue-green infrastructure/ecological corridors, ecosystem restoration in mining areas, strengthening ES production in forest areas, holistic pasture management, rain harvesting, community gardens, and restorative and protective agricultural practices.

Keywords: Ecosystem services, nature-based solutions, hatip stream basin, holistic approach.

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Assessments of Protected Area Problems from Different Professional Disciplines

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Abstract

Nature is one of the most important sources from which human beings obtain the basic needs they need to survive. Population growth, rapid urbanization, and industrialization are increasing the damage to ecosystems and biodiversity. Nature conservation areas have important functions in preventing this destruction of biodiversity and ensuring life. Although the number of nature conservation areas is increasing daily, the destruction is also increasing. This demonstrates that simply increasing the number of protected areas is not a solution. In addition to increasing the number of protected areas, it is crucial to also improve their quality. Identifying problems is the foundation for creating solutions. To this end, the study was primarily conducted to identify the problems encountered in protected areas and to assess the perspectives of relevant professional disciplines on these areas. Within this scope, academic studies conducted between 2020 and 2025 in the professional disciplines of Landscape Architecture, Urban and Regional Planning, and Forest Engineering were examined. As a result of the study, the problems experienced in protected areas were examined under the headings of problems arising from planning, problems related to legal frameworks, issues concerning management and monitoring processes, problems related to local communities, and confusion of authority.

Accordingly, solution proposals were developed, emphasizing the necessity of a participatory planning approach, effective monitoring mechanisms, and the integration of local communities into the process. Furthermore, gaps in the literature were identified, and suggestions for future research were offered.

Keywords: Planning issues, legislation, landscape architecture, forest engineering, urban and regional planning

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The Relationship Between Landscape and Therapy in Post-Disaster Recovery: A Literature-Based Analysis

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Abstract

Earthquakes not only cause physical destruction in urban areas but also lead to long-term effects on individuals' psychological well-being and social welfare. Accordingly, the therapeutic functions of urban open green spaces in post-disaster individual and collective recovery are critically important. This study evaluates how planning and design principles for urban green spaces particularly plant design elements (form, size, scale) and sensory characteristics (color, scent, texture) affect medium- and long-term psychological rehabilitation and social recovery in disaster-affected contexts.

A two-stage analysis was undertaken: (1) bibliometric mapping of 43 publications identified in the Scopus database (2005–2024) to chart research trends and key concepts; and (2) content analysis of those publications alongside complementary national and institutional sources to derive context-sensitive, practice-oriented recommendations.

Bibliometric findings show a marked increase in scholarly activity in recent years, highlighting "therapeutic landscape," "health and well-being," and "disaster psychology" as central concepts. Content analysis emphasizes the pivotal role of multi-sensory landscape components (color, scent, texture, sound) and of accessibility and inclusive design principles in supporting psychological recovery and social cohesion after disasters.

The evidence indicates that urban green spaces should operate not merely as recreational settings but as therapeutic environments that promote individual restoration and collective healing. Design interventions ought to integrate multi-sensory planting palettes, seasonal color sequencing, and natural soundscapes while guaranteeing universal accessibility and inclusivity. Additionally, virtual landscapes and digital technologies may function as complementary therapeutic tools for populations with limited access to nature.

Keywords: Therapeutic landscape/environment, urban green spaces, environmental psychology, disaster psychology

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Leveraging Artificial Intelligence and Emerging Technologies for Sustainable Conservation and Climate-Resilient Rural Landscapes

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Abstract

Global ecosystems and rural landscapes face unprecedented challenges from climate change, biodiversity loss, and unsustainable land-use practices. Emerging technologies, particularly artificial intelligence (AI), remote sensing, and digital monitoring systems, offer innovative approaches to support sustainable conservation, optimize resource management, and enhance climate resilience. This review systematically examined peer-reviewed literature following PRISMA guidelines, along with case studies and policy reports, ensuring a transparent and comprehensive selection of relevant studies on technology-driven conservation strategies worldwide. Findings indicate that AI and related digital tools enable real-time biodiversity monitoring, predictive modeling of climate risks, optimization of soil and water management, and informed ecosystem restoration and rehabilitation. Integrating these technologies with traditional ecological knowledge and community-led initiatives strengthens adaptive capacity, fosters stakeholder participation, and improves ecosystem resilience. Despite their potential, barriers such as limited digital infrastructure, high technology costs, and gaps in local capacity hinder broad adoption. To address these challenges, policies promoting affordable access to digital tools, targeted community training, and collaborative frameworks among researchers, policymakers, and local stakeholders are essential. In conclusion, applying AI and emerging technologies in tandem with conventional conservation practices presents a forward-looking pathway toward sustainable, climate-resilient rural landscapes, safeguarding biodiversity, ecosystem services, and human well-being in the face of global environmental change.

Keywords: Artificial intelligence, remote sensing, sustainable conservation, climate-resilient rural landscapes, biodiversity monitoring

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Enhancing Macroeconomic Forecasting Through Big Data-Driven Business Intelligence

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Abstract

In today's rapidly evolving digital economy, timely and accurate macroeconomic forecasts are critical for effective policymaking and strategic planning. This study explores the integration of Business Intelligence (BI) tools with Big Data analytics to improve the precision and responsiveness of economic forecasting. By leveraging real-time economic indicators such as inflation, employment, and trade, BI dashboards provide actionable insights that enable dynamic monitoring of economic trends. Furthermore, predictive analytics and machine learning models are employed to simulate economic scenarios and enhance the accuracy of forecasts. The research draws on data from national statistical agencies, financial markets, IoT platforms, and BI software outputs to evaluate the effectiveness of this integrated approach. Findings are expected to demonstrate how BI and Big Data can transform traditional forecasting methods, offering policymakers and businesses a robust framework for navigating the complexities of modern economic dynamics.

Keywords: Business Intelligence (BI), big data analytics, macroeconomic forecasting, predictive analytics, real-time economic indicators, digital economy, machine learning, economic policy

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Historical Dimensions of Nature Conservation in Kosovo-Conservation, Policy, Managerial and Institutional Dimensions

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Abstract

This paper presents an historical perspective on the development of nature conservation sector in the Republic of Kosovo following conservation sites, legal, managerial and institutional dimensions. The first nature conservation sites as a category of nature reserves were legally designated in 1953, marking the beginning of the history of protected areas. Until war in Kosovo in 1998-99, the protected area network covered about 4.36 % of territory. After the war, protected areas network increased rapidly, covering 126,115.8 ha or 11.6% of territory.

From the institutional perspective, in 1968 the Nature Protection Unit was formed within former Kosovo Institute for the Protection of Cultural Monuments, later developed into the Kosovo Institute for the Protection of Nature. The first Law on the Protection and Development of Natural Values and Values Created by Human Work in the Environment, was adopted by the Assembly of Kosovo in 1988. This law defines the Institute as key policy and managerial body to carry nature conservation efforts in Kosovo. A year later, the Assembly of Kosovo passed the Law on the Kosovo Institute for the Protection of Nature and Environment.

Even with a well-consolidated network of protected areas, with established and functional institutions and management bodies, nature conservation is facing major functional challenges in the field.

Keywords: Conservation, history, policy, protected areas, management

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Integrative Morphological, Micromorphological, and Anatomical Study of *Chamaesciadium acaule* (Apiaceae), A Rare Alpine Taxon

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Abstract

Chamaesciadium C.A. Mey. is a monotypic genus of Apiaceae, distributed in Iran, Turkiye, and the southern Caucasus. Its only species, Chamaesciadium acaule (M.Bieb.) Boiss., is an intriguing alpine taxon occurring above 2000 m in rocky habitats. This study aimed to examine the morphology, pollen and fruit micromorphology, and fruit anatomy of C. acaule to improve current knowledge of the genus, particularly regarding its diversity and diagnostic features.

Morphological studies were made on living and herbarium specimens. Pollen and fruit surface micromorphology were examined using light microscopy (LM) and scanning electron microscopy (SEM). For LM observations, pollen slides were prepared following Wodehouse (1935), and measurements were taken from 20 pollen grains. For SEM analyses, pollen grains and fruits were mounted on stubs using double-sided adhesive carbon tape, coated with gold using a Polaron SC7620 sputter coater, and subsequently examined and photographed under SEM. The terminology applied in descriptions follows Erdtman (1952) and Faegri & Iversen (1975). For anatomical studies, mericarps were rehydrated, fixed in FAA (1:1:8), and embedded in paraffin. Sections were cut at 10 µm thickness using a microtome and stained with safranin. Photomicrographs were then obtained under LM.

Chamaesciadium acaule is a perennial, acaulescent (rarely shortly caulescent), polycarpic herb, with mostly simple umbels on long strips that usually spread along the ground. Mericarps of C. acaule are homomorphic and nearly semi-circular in transverse section; they contain 2–3 intercostal vittae and 4–6 commissural vittae. Pollen grains are monads, isopolar, radially symmetric, and tricolporate.

This study provides novel morphological, micromorphological, and anatomical data on C. acaule, contributing to a better understanding of this poorly known genus within Apiaceae.

Keywords: *Umbelliferae*, *Chamaesciadium acaule*, *Apiaceae*, monotypic genus, Türkiye

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Damage Interaction and Critical Defect Spacing in Hdpe Pipes: Implications for Sustainable Infrastructure Design

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Abstract

High-density polyethylene (HDPE) pipes used in gas and water transportation systems are often exposed to superficial corrosion-like degradation resulting from environmental or chemical effects. When multiple surface defects occur in close proximity, their interaction can significantly influence the local stress distribution and accelerate damage propagation. This study investigates the critical distance between two adjacent superficial corrosion defects beyond which the defects act independently. A combined numerical and analytical approach was employed to evaluate the stress concentration factor and the strain energy density in the ligament region between the defects. The results highlight a threshold distance that depends on defect geometry (depth, length, and spacing) and pipe wall thickness. The findings contribute to establishing a predictive criterion for integrity assessment and lifetime estimation of aged HDPE pipelines.

Keywords: HDPE pipes, superficial corrosion, defect interaction, critical distance, damage

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Development of a Sustainable Ag-AgI/TiO_2/Cellulose Biocomposite Film for Environmental and Biomedical Applications

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Abstract

The development of a bio-composite material with photocatalytic properties, using a natural material such as cellulose, is an important issue in the field of environmental sustainability. In this work, Ag-AgI/TiO_2/cellulose biocomposite was prepared in a two-step process at a moderate temperature. The first step involved coating the cellulose structure with TiO_2, followed by the second step where Ag-AgI was deposited onto the TiO_2/cellulose via an immersion method. The successful loading of both Ag-AgI and TiO_2 onto the cellulose matrix was confirmed by Raman spectroscopy, XRD, and XPS. Scanning electron microscopy (SEM) images further demonstrated that the cellulose matrix was coated with a TiO_2 layer decorated with Ag-AgI nanoparticles. Photometric measurements showed that the resulting biocomposite material exhibits enhanced visible light absorption and high charge separation efficiency, thanks to the synergistic interaction between the Ag-AgI and TiO_2. The developed biocomposite demonstrated high activity in removing the carcinogenic compound aniline from water. It also completely removed alcoholic gases from the air. Furthermore, it proved effective in killing pathogenic bacteria (Escherichia coli). The superior performance of this biocomposite can be attributed to its unique properties, such as charge separation, high visible light absorption, and its pure and homogeneous structure. This study presents a promising new strategy for preparing a highly efficient, sustainable, and multifunctional biocomposite material for environmental and biological applications. This work represents the first of its kind in utilizing the Ag-AgI /TiO_2/cellulose material as a multifunctional and sustainable biocomposite.

Keywords: Ag-AgI/TiO_2/cellulose; sustainable biocomposite; water treatment; air purification; antibacterial property.

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Sustainable Waste Management Practices in Urban Areas

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Abstract

Rapid urbanization has led to a dramatic increase in municipal solid waste (MSW) generation, posing significant environmental, social, and economic challenges for cities worldwide. Traditional waste management systems in urban areas, often reliant on landfilling and incineration, are proving unsustainable, contributing to greenhouse gas emissions, pollution, and resource depletion. This paper sightsees sustainable waste management practices that aim to minimize waste generation, enhance resource recovery, and promote circular economy principles in urban settings. Through a comprehensive literature review and analysis of case studies from cities across the globe, such as San Francisco, Amsterdam, and Pune, this study identifies effective strategies including waste segregation at source, composting of organic waste, recycling programs, extended producer responsibility (EPR), and waste to energy (WTE) technologies. The paper also examines the role of public awareness, policy frameworks, and technological innovation in improving the efficiency and adoption of these practices. Special attention is given to the integration of informal waste workers, smart waste monitoring systems, and decentralized waste processing solutions. The findings reveal that successful sustainable waste management in urban areas requires a multistakeholder approach involving local governments, private sector, civil society, and citizens. Key policy recommendations are proposed to support long term environmental sustainability, reduce landfill dependency, and create green jobs in the waste sector. By drawing on global best practices and identifying scalable solutions, this paper aims to contribute to the development of resilient and sustainable urban waste management systems aligned with the United Nations Sustainable Development Goals (SDGs), particularly SDG 11 and SDG 12.

Keywords: Sustainable Waste Management, urban waste, municipal solid waste (MSW), circular economy, waste segregation, recycling

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How Birth Type and Goats' Gender Play with Weight and Growth Traits Under Environmental Conditions of Southern Punjab, Pakistan

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Abstract

In this research, weight and growth attributes of goats were evaluated phenotypically, to analyze the impact of non-genetic factors (birth type and sex) on these performance traits because growth is important for commercial rearing of goats. Growth data were gathered and examined using the mathematical models where some factors with fixed effects were analyzed how they influenced the weight traits. The traits included birth weight and monthly weights along with pre- and post-weaning average daily gains. It was found that types of birth significantly influenced all weights and growth traits whereas sex of goats also affected all the traits significantly excluding pre-weaning average daily gain. Hence these factors have shown their vital importance in making selection for breed's improvement programs.

Keywords: Goats, growth traits, weight traits, environmental factors, fixed effects, fixed effects model.

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Green Urban Architecture and Climate Resilience: Building Sustainable Cities for the Future

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Abstract

As the effects of climate change continue to intensify, the need for sustainable and climate-resilient cities has become an urgent global priority. Urban areas are responsible for more than two-thirds of global energy consumption and greenhouse gas emissions, making architecture and urban design central to climate action. This paper explores the concept of green urban architecture as a key strategy for building climate-resilient cities. It examines how environmentally conscious design, renewable energy integration, and smart construction technologies can contribute to reducing environmental degradation while enhancing social and economic well-being.

The study focuses on the relationship between architectural innovation and sustainable urban development, analyzing how design decisions can promote energy efficiency, waste reduction, and community health. Through case studies from cities in Asia, Europe, and Africa, the paper identifies practical examples of eco-friendly building models, including green roofs, passive cooling systems, and low-carbon materials that have successfully mitigated urban heat and improved resource efficiency.

Moreover, the research emphasizes the importance of policy frameworks that support green infrastructure and sustainability-oriented investments. It argues that collaboration between architects, engineers, policymakers, and citizens is essential for creating inclusive and adaptive urban environments. The findings conclude that green urban architecture not only reduces the impact of climate change but also enhances the quality of life by promoting harmony between people and nature. By rethinking the way cities are planned and built, humanity can transition toward a more sustainable, resilient, and equitable future.

Keywords: Green architecture, climate change, urban sustainability, environmental design, smart cities, resilience

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Optimization of Essential Oils Extraction Via Simultaneous Distillation Using Citrus Peels as a Green Solvent

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Abstract

Hydrodistillation, which can last up to 3 hours, as well as the acidity of the extraction medium, can cause various reactions. Therefore, the search for alternatives is actually required. Citrus peels, which are available in large quantities, can be considered a co-solvent because they contain a high limonene content (>90%). This approach allows the valorization of Citrus peels and optimization of the essential oil yield of the distilled plants. Thus, this study aims to enhance the yield of Lavandula officinalis through simultaneous distillation method using Citrus sinensis L. peels. The optimization process was assessed using the Box-Behnken response surface design. The factors studied were all quantitative factors, such as the quantity of peel used, the extraction time, and the drying time of the citrus peel. The Essential oils (EOs) obtained were analyzed by Gas chromatography-mass spectrometry (GC-MS). The results of the optimization of the extraction indicated that the maximum yield (2.27 ± 0.98%) was achieved using 35g of Citrus peels, with a drying period of 2 days, and an extraction time of 140 minutes. These findings may promote the development of sustainable green processes that show positive impacts on energy consumption, reduction of solvent residues, low cost, and the production of higher-quality extracts. They may also contribute to reduced reliance on synthetic chemicals.

Keywords: Optimization, yield, EOs, simultaneous distillation, response surface design.

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Genetic Diversity and Genome Size Variation in *Tillandsia* Revealed by SCoT Markers and Flow Cytometry

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Abstract

The genus Tillandsia L. (Bromeliaceae) includes more than 700 species and natural hybrids distributed from the southern United States to Argentina and Chile. These plants exhibit considerable morphological and physiological variability, largely shaped by broad ecological range and frequent natural hybridization. Such diversity complicates taxonomic classification, as morphological-based traits provide limited resolution for species delimitation. Integrative approaches that combine molecular and cytogenetic data have therefore become increasingly important in studies of Tillandsia. İn this study, genetic and cytogenetic variation was assessed in 17 species: Tillandsia abdita, T. argenta, T. baileyi, T. bulbosa, T. butzii, T. capitata, T. caput medusae, T. ionantha, T. ionantha var. rubra, T. juncea, T. juncifolia, T. magnusiana, T. melanocrater, T. multiflora (red), T. multiflora (green), T. oaxacana, and T. streptophylla. Genomic DNA was amplified with 12 Start Codon Targeted (SCoT) primers, which generated reproducible and polymorphic banding patterns suitable for genetic similarity analysis and clustering of taxa. Nuclear DNA content (2C) was assessed by flow cytometry, resulting in genome size estimation across the analyzed taxa. The combination of molecular marker data and flow cytometric genome size analysis provides a comprehensive perspective on genetic and cytogenetic variation in Tillandsia. Such integration supports more precise species delimitation, facilitates taxonomic clarification, and underpins further systematic and applied research.

Keywords: Tillandsia, SCoT markers, flow cytometry, genome size, genetic diversity

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Urban Renewal Approaches for the Revitalization of Tudun Nupawa Neighborhood, Kaduna, Nigeria

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Abstract

Urban renewal has emerged as a vital strategy for addressing the challenges of physical decay, environmental degradation, and socioeconomic decline in many inner-city neighborhoods. This study examines the strategies for urban renewal aimed at revitalizing the Tudun Nupawa neighborhood in Kaduna, Nigeria. The research assesses the existing physical, social, and economic conditions of the area and identifies the key factors contributing to urban deterioration, such as inadequate infrastructure, poor housing quality, and ineffective land-use management. Using a mixed-method approach that integrates field surveys, spatial analysis, and stakeholder interviews, the study evaluates current renewal initiatives and explores sustainable models applicable to the local context. Findings reveal that effective urban renewal in Tudun Nupawa requires an integrated framework involving community participation, public–private partnership, improved infrastructure provision, and inclusive planning policies. The study concludes that revitalizing Tudun Nupawa through context-specific and participatory renewal strategies will enhance the neighborhood's livability, economic productivity, and environmental resilience. Recommendations are made for urban policymakers and planning authorities to adopt inclusive, sustainable, and adaptive renewal approaches to transform Tudun Nupawa into a functional and vibrant urban community.

Keywords: Urban renewal, neighborhood revitalization, Tudun Nupawa, Kaduna, sustainable urban development, urban planning, public–private partnership, community participation.

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Economic Development and the Sustainable Development Goals in Africa: Urban Challenges, Opportunities, and Policy Perspectives

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Abstract

The pursuit of sustainable development in Africa remains a pressing challenge that intertwines economic growth, urbanization, and environmental management. As African nations strive to achieve the Sustainable Development Goals (SDGs) set by the United Nations, they face significant structural and policy barriers that hinder progress. Rapid population growth, inadequate urban planning, and insufficient infrastructure have intensified inequalities and environmental degradation across many regions. This paper explores the intersection between economic development and the SDGs in Africa, with a specific focus on the role of sustainable urbanization, architecture, and policy innovation in advancing inclusive growth.

The study examines how urban design and sustainable construction can serve as catalysts for achieving multiple SDGs, including poverty reduction, clean energy, climate action, and sustainable cities and communities. It highlights the challenges faced by policymakers in balancing economic expansion with ecological preservation and social well-being. Furthermore, it investigates the opportunities presented by emerging green technologies, renewable energy systems, and community-based development models that promote environmental resilience

Drawing on comparative case studies from selected African countries, this research identifies effective policy frameworks and architectural approaches that have successfully integrated sustainability principles into economic development plans. The findings emphasize the need for cross-sectoral collaboration between governments, architects, urban planners, and civil society organizations. The paper concludes that aligning economic policies with sustainable architectural and urban practices is essential for achieving long-term prosperity in Africa. By fostering innovation, inclusive governance, and eco-friendly infrastructure, African nations can transform their cities into resilient, equitable, and sustainable spaces that reflect the true vision of the 2030 Agenda for Sustainable Development.

Keywords: Economic development, sustainable development goals (SDGs), Africa, urban planning, architecture, environmental sustainability

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Sustainable Development of Geopolymer Mortar Using Natural Pozzolana

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Abstract

This study investigates the influence of natural pozzolana content on the fresh and mechanical properties of geopolymer mortars. Four mortar formulations were prepared with fixed amounts of glass powder and increasing levels of natural pozzolana (0, 100, 200, and 300 g). All specimens were thermally cured at 80 °C for 24 hours. The properties assessed include slump flow, dry density, compressive strength, and flexural strength. Results show that increasing the natural pozzolana content slightly reduced workability and dry density due to its high surface area and reactive nature. However, compressive strength improved significantly with the addition of up to 200 g of pozzolana, attributed to enhanced geopolymerization and matrix densification.

Keywords: Natural pozzolana, geopolymer mortar, glass powder, alkaline activation, compressive strength, thermal curing.

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Urban Composting as a Sustainable Strategy for Waste Management, Green Space Development, and Economic Revitalization

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Abstract

As cities grow rapidly, the amount of urban waste has significantly increased, making waste management a vital challenge for urban planners and policymakers. This study examines composting as an effective method for managing biodegradable urban waste while also improving urban landscapes and local economies. Approximately 40 percent of municipal solid waste consists of organic materials, such as food scraps and fruit waste, which can be converted into valuable compost through proper waste separation at the source. Implementing composting not only lessens the strain on landfills, reducing greenhouse gas emissions and groundwater pollution, but also offers an eco-friendly way to develop green spaces in densely populated urban areas. Using compost as an organic fertilizer and soil amendment supports urban farming, rooftop gardens, and community green spaces, resulting in improved urban design and enhanced ecological resilience. Additionally, small-scale home and community composting programs enable residents to engage in sustainable practices, raise environmental awareness, and save money at the household level. Ultimately, incorporating composting into urban waste systems promotes a circular economy, improves the visual and ecological quality of cities, and boosts the social and economic well-being of residents.

Keywords: Biodegradable urban waste, circular economy, composting, urban architecture

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Traditional Uses of Some Medicinal and Aromatic Plants in the Southeastern Villages of Dirmil District (Burdur), Türkiye

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Abstract

Traditional knowledge about the use of medicinal and aromatic plants plays an essential role in preserving cultural heritage and guiding modern pharmacological research. The southeastern villages of the Dirmil district, located in Burdur Province, southwestern Türkiye, host a rich diversity of plant species traditionally used for therapeutic and aromatic purposes. This study aimed to document the plant species used in the region for medicinal and aromatic purposes. Data were collected through interviews with local residents during fieldwork conducted between 2020 and 2024. For each species, information on local names, methods of preparation and production, uses, and modes of application was obtained from informants and systematically recorded. The collected data were then compared with existing literature to evaluate similarities and differences between local knowledge and scientific sources.

As a result, it was determined that the most commonly used plants, both as spices and teas, belong mainly to the Lamiaceae family, including the genera Salvia L., Origanum L., Sideritis L., Satureja L., Thymus L., and Tymbra L. In addition, the genus Rhus L. (Anacardiaceae) was found to be used for the preparation of sumac, while Laser trilobum L. Borkh. (Apiaceae) was reported to be utilized as a spice in the region.

Keywords: Medicinal and aromatic plants, Dirmil District, Burdur- Türkiye, *Lamiaceae*

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Eco Anxiety Levels of Adults Living in Areas Affected by the Manavgat Forest Fire

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Abstract

Objective: The aim of this study is to examine the eco-anxiety levels of adults living in areas affected by the Manavgat forest fire.

Method: The study is a descriptive and analytical study. It was conducted between August 2024 and April 2025 with 261 people living in four neighborhoods in the Manavgat district of Antalya that were completely evacuated due to a forest fire that occurred in the summer of 2021. Data was collected by using a Personal Information Form and the Eco Anxiety Scale (EAS). SPSS 23.0 was used in the analysis of the data obtained in the study, and the significance level was accepted as 0.05. Results: The participants' overall EAS score average was determined as 0.76±0.62, and the means of its sub-dimensions were determined as 0.91±0.70, for emotional symptoms, 0.93±0.82 for repetitive thoughts, 0.67±0.71 for behavioral symptoms, and 0.50±0.70 for personal anxiety. While some EAS sub-dimension score averages showed significant differences across various variables, the overall EAS score averages were found higher for younger individuals, those with a higher level of education, those whose income exceeded their expenses, those who observed changes in the environment before the fire, those considered migration, those who reported changes in their health after the fire, those who said the fire was related to climate change, and those who were concerned about climate change. Climate change was found to cause anxiety in 82.4% of the study participants.

Conclusion: It was determined that the eco-anxiety levels of the participants differed due to various variables. The effects of climate change on mental health should be taken into account, and environmental awareness and coping mechanisms should be developed through environmental education, and environmentally sensitive behavior should be fostered in order to transform eco-anxiety into a manageable concern.

Keywords: Eco anxiety, public health nursing, climate change, forest fire

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Youth Entrepreneurship in Rural Areas: Challenges and Opportunities in Sangli District

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Abstract

This research looks at changes in youth entrepreneurship in rural areas of Sangli District, Maharashtra. Agriculture, a traditional occupation, sees more insecurity because of changing weather and changing prices. Rural young people often choose entrepreneurship for a job and community betterment. The study finds problems, such as hard-to-get money, poor facilities, lack of education as well as cultural issues. It also finds possibilities, including industries based on farming, energy that can be renewed, internet sites next to government help programs. A detailed look shows the important part young entrepreneurs do in changing rural economies. They bring new ideas, lower movement to cities along with support growth that includes everyone. The research offers plans and doable answers to give power to youth plus make the rural entrepreneur system better.

The research concludes youth entrepreneurship in Sangli shows promise. It can create local jobs and lower migration. In addition, it can improve community strength and economic independence. For sustainable expansion we need a joined method. It needs policy changes, digital knowledge, skill development as well as a helpful entrepreneur system. Through use of local assets and youth creativity, Sangli has the potential to become a standard for countryside entrepreneur development through India.

Keywords: Sangli District, rural areas, challenges and opportunities

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Flood Impact in Krishna and Panchganga River Basins: Economic and Social Aspects

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Abstract

Floods are among the most destructive natural disasters, with profound socio-economic and environmental impacts. This study examines the economic and social consequences of recurrent floods in the Krishna and Panchganga river basins of western Maharashtra, focusing particularly on Shirol taluka in Kolhapur district. Using a mixed-methods approach, data were collected from 400 households through structured surveys, complemented by secondary sources such as government reports and meteorological data. The analysis reveals that the 2019 flood was the most devastating, with over 68% of respondents reporting severe or extremely severe impacts. Median household financial losses were estimated, with crop damage emerging as the dominant economic setback, followed by livestock and property losses.

Social impacts were equally critical, with widespread displacement, education disruption, health crises, and psychological stress. Institutional responses were found inadequate, as only one-third of households received compensation and just 20% had insurance coverage. The study underscores the need for integrated flood management strategies that combine resilient infrastructure, inclusive insurance schemes, early warning systems, and community-based adaptation initiatives. Findings contribute to academic discourse on disaster management while offering policy-relevant insights for government bodies, NGOs, and development agencies. Ultimately, the research highlights that building long-term resilience requires a shift from reactive relief measures to proactive socio-economic and environmental planning.

Keywords: Krishna and Panchganga River Basins, flood impact, economic and social aspects

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Economic Implications of Climate Change on Rice (*Oryza sativa*) Production in Bangladesh

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Abstract

Rice (Oryza sativa), the golbal staple food, is increasingly vulnerable to the economic and agronomic pressures of climate change. Rising temperatures, erratic rainfall, and extreme events are reshaping production conditions and farmer livelihoods. This study explores how rice farmers in Rajshahi and Naogaon districts of Bangladesh perceive these changes and adapt their practices, with an emphasis on economic sustainability. Data were collected through convenience sampling and analyzed using SPSS. Farmers reported sharp increases in production costs, water demand, and pest infestations, particularly cutworm and stem borer. Nearly half adopted resistant varieties such as BRRI 11, BRRI 81, and BRRI 71, while about three-quarters depended on motorized irrigation to secure adequate water. Yields ranged from 7–10 tons/ha using 14-21 kg seed inputs, yet rising costs continue to squeeze profit margins. These findings show that climate change not only disrupts agronomy but also reshapes the economic landscape of rice farming. Ensuring sustainability will require integrated approaches that link genetics, agronomic innovation, and socioeconomic strategies. Such measures can strengthen both productivity and resilience, helping farmers maintain their livelihoods in the face of growing climate stress.

Keywords: Rice production, climate change, economic sustainability, adaptation, Bangladesh

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Socioeconomic Impacts of Sundarbans Degradation on Local Communities in West Bengal, India: A Systematic Review

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Abstract

The Sundarbans mangrove forest in West Bengal, India, is a vital ecosystem that supports the livelihoods of millions of local people. This study aims to provide a clear understanding of how the degradation of the Sundarbans is affecting the socioeconomic conditions of these communities. To achieve this, a systematic review of the Scopus database was conducted following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. In total, 78 research papers and several government reports were carefully analyzed to identify patterns, trends, and evidence of impact. The review highlights the degradation of the Sundarbans is caused by a combination of climatic and human-induced factors. Climatic factors include rising sea levels, cyclones, changing rainfall pattern, and increased salinity, all of which damage mangrove ecosystems and reduce soil fertility. Human activities, such as overfishing, unsustainable harvesting of forest resources, and land conversion for aquaculture or settlements, further exacerbate the loss of forest cover and ecosystem health. These changes have serious socioeconomic consequences for local communities, including reduced incomes from agriculture, fishing, and forest products, loss of property due to extreme weather events, forced migration in search of work, and increased reliance on low-paying or risky alternative livelihoods. Over time, these impacts contribute to long-term economic instability, making communities more vulnerable to environmental and social shocks. The study emphasizes the importance of a holistic approach that combines adaptive infrastructure, sustainable livelihood strategies, and active community participation. Recommendations include addressing research gaps, involving local people in decision-making, implementing global frameworks such as the Fund for Responding to Loss and Damage, and adopting fair measures to manage climate-related migration. Protecting the Sundarbans requires integrated actions to build resilience, reduce vulnerability, and secure long-term sustainability, offering valuable insights for policymakers and stakeholders.

Keywords: Sundarbans, socioeconomic impacts, climate change, migration, adaptive strategies

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Spatio-Temporal Assessment and Simulation of Carbon Dynamics Under Anthropogenic Pressure in Kainji Lake National Park, Nigeria

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Abstract

This study assessed the effect of anthropogenic activities on carbon sequestration dynamics in the Borgu and Zugurma sectors of Kainji Lake National Park, North Central Nigeria. Geospatial and field-based approaches were employed to evaluate changes in land use/land cover (LULC), biomass, and carbon storage between 1990 and 2024, and to project carbon trends to 2040. Landsat and Sentinel satellite imagery were analyzed using supervised classification and Normalized Difference Vegetation Index (NDVI) to quantify vegetation dynamics, while allometric models were applied to estimate above-ground biomass and carbon stocks across dominant land use types. Results revealed substantial declines in forest and woodland cover, especially in the Zugurma sector, primarily due to logging, overgrazing, and agricultural encroachment. Between 1990 and 2024, total carbon stock declined by approximately 30%, with higher losses recorded in disturbed landscapes. Simulations for 2040 suggest further carbon depletion if anthropogenic pressures persist unchecked. Conversely, the Borgu sector, with more effective protection and park management, exhibited relatively stable vegetation and greater carbon sequestration potential. The study demonstrates the applicability of remote sensing for long-term ecosystem monitoring and provides empirical evidence supporting REDD+ and climate resilience initiatives.

Keywords: Carbon sequestration, anthropogenic activities, remote sensing, Kainji Lake National Park, land use/land cover, climate change.

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Artificial Intelligence-Powered Remote Sensing for Sustainable Environmental Management

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Abstract

Artificial intelligence has become a key tool in improving remote sensing for sustainable environmental management. It is now possible to monitor environmental changes in real time with higher accuracy and AI algorithms with satellite and sensor data. AI-powered remote sensing helps in identifying deforestation, tracking air and water quality, predicting natural disasters, and measuring the impacts of climate change. These technologies provide automated data analysis, reducing human effort and error while enabling quick decision-making. Machine learning and deep learning models process vast amounts of spatial and temporal data to detect trends that support sustainable resource management. In India and across the globe, AI-based remote sensing is being used in agriculture for soil monitoring, in forestry for biodiversity conservation, and in urban areas for pollution control. It aids policymakers and researchers in formulating effective environmental strategies. The combination of AI and remote sensing also improves early warning systems for floods, droughts, and forest fires, contributing to climate resilience. Moreover, it promotes sustainability by optimizing the use of natural resources and reducing environmental degradation. In conclusion, AI-powered remote sensing is transforming how environmental data are collected, analysed, and applied. It supports global sustainability goals by enabling smarter environmental management and ensuring a healthier planet for future generations.

Keywords: Artificial intelligence, remote sensing, environmental monitoring, sustainability, climate change, resource management.

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Integrating Machine Learning Algorithms for Predictive Modeling of Tourist Flow Patterns Toward Sustainable Management of Smart Ecological Cities

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Abstract

Tourism has a critical role to play in the socio-economic development of a smart and ecological city, but the problem with the unregulated tourist numbers is that they may cause overcrowding, problems with infrastructure, and environmental degradation. Proper predictability of the patterns of tourist flow is, thus, key to sustainable urban and environmental planning. This study introduces a predictive modeling architecture that uses machine learning algorithms to estimate and predict tourist dynamics of urban locations. The study incorporates the past records of tourism, transportation records, and the environmental indicators to form a comprehensive record. Three machine learning models, including Long Short-Term Memory (LSTM) to predict temporal sequences, feature importance analysis and nonlinear pattern learning with the help of the Random Forest (RF), and high-performance regression with the help of the Extreme Gradient Boosting (XGBoost), have been developed and evaluated after preprocessing and feature engineering. Standard metrics of evaluation were used to measure model performance, like the Root Mean Square Error (RMSE) and Coefficient of Determination (R^2). The initial results show that the models are capable of capturing both spatial and temporal changes in tourist activities, which are the periods of maximum visitation and possible urban hotspots. The offered framework shows how machine learning can be used to assist in data-driven decision-making in the sustainable tourism management, optimization of infrastructures, and ecological balance of smart cities. The paper will allow the evolution of smart cities by combining forecast analytics and sustainable urban planning.

Keywords: Machine learning, predictive modeling, smart cities, sustainable tourism

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Regional Bioassay-Based Indicators of Sediment Quality Along the Moroccan Atlantic Coast

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Abstract

Discharging anthropogenic activities into aquatic environments raises significant environmental and health concerns, as they can lead to long-lasting degradation of these critical resources. Industrial effluents often contain a mix of contaminants and pollutants, necessitating a thorough assessment of their potential dangers and risks before release into aquatic ecosystems. However, the ecotoxicological approach is used to determinate the toxic effects on organisms pertaining to various ecosystems and supplies information about the contaminants bioavailability, in different matrices as sediments.

The use of a single species for a correct evaluation of the toxicity levels can be reductive, concerning the complexity of the ecosystem. In this work, a bioassay battery consisting of three different species representing different trophic levels, algae Tetraselmis suecica, crustacean Artemia salina, and echinoids Paracentrotus lividus, has been used to assess the toxicity of sediment elutriate, porewater, and whole sediment. The sediment samples were collected from four sampling stations along the North Atlantic Coast of Morocco. The test battery used in this study allowed us to screen the ecotoxicological toxicity of the studied area. The species utilized for toxicity tests responded differently to the investigated samples, showing different sensitivity.

However, a difference in sediment toxicity is registered in different studied areas depending on the sedimentary phases. Indeed, the El Jadida site recorded the maximum effect of embryo-larval malformation in the pore water phase. For the whole sediment, the Sidi Abderrahmane site recorded the maximum effect, while for the algal growth inhibition bioassay, the Bouregreg site showed the most pronounced effect.

Keywords: Sediment, bioassays, Paracentrotus Lividus, embryo-toxicity, elutriate, pore water

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Examining The Impacts of Water and Hygiene on Child Mortality Rates in Nigeria: Empirical Exploration and Implications

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Abstract

Globally, governments are concerned about the high rate of child mortality, the rate of which is seen to be higher in developing countries, particularly in Africa. For example, the level of mortality rate under-5 children in Nigeria places the country among the top countries in Africa with high profile of child mortality rate. This has been traced to be the result from infectious diseases which commonly cause infant death, especially among the under-5 aged children. However, the source of causation, particularly water and hygiene, appear to have receive little attention. Thus, this study examines the impact of water and hygiene on child mortality in Nigeria.

Poisson technique was applied to analyze household survey data obtained from the Multiple Indicators Cluster Survey. The findings revealed that poor toilet facilities and hand washing are significant causes of death in under-5 children in Nigeria. Specifically, the mortality rate is high among age categories 3 and 4 with incidence range between 0.79 to 0.90 and 0.91 to 0.96 respectively. The study recommends policies that can be helpful for well-being and health protection of children generally in Africa.

Keywords: Water, hygiene, child mortality, children, Nigeria

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The Economic Feasibility of Meeting the Demand for Animal Feed in Nigeria using Microbial Products

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Abstract

The animal feed market in Nigeria is growing rapidly, driven by expanding demand for livestock and poultry products, and changing dietary habits (Pazos et al., 2019). One of the key challenges of meeting the demand for animal feed in Nigeria is the need for innovation and technology. To address this challenge, there is a need for investment in research and development, to develop new technologies and practices that can help farmers to improve the efficiency and sustainability of animal feed production. This can include the use of precision agriculture, feed quality, and other factors. This feasibility study aims to evaluate the viability of setting up a micro scale Agro-processing industry feed mill in Nigeria based on ingredients produces by microbial processes. Structured questionnaire was administered across a section of Lugbe population in the Federal Capital territory (FCT), Abuja, Nigeria. A total of 300 questionnaires was used to generate data which were analyzed. The results of the data analysis showed that the demand for animal feed is very high, 89.5%, the technical skills needed to drive the sustainable production is low, 23.6%. The knowledge needed for the processing of feed is also low, 37.7% while the overall cost harnessing the microbes for sustainable uses is high, 89.3%. Based on the market analysis, technical analysis, financial analysis, and marketing strategy, it may not be very feasible to set up a Micro-Scale Agro-Processing Industry Feed Mill in Nigeria whose raw materials would depend on microbial origin. More research is hereby needed to be able to utilize this bio-resources.

Keywords: Animal feed, questionnaire, microbial, sustainable, feeds and FCT

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A Circular Economy-Oriented Approach in Cashew Processing Plants in Vietnam

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Abstract

Cashew processing and export constitute one of the key contributors to Vietnam's agricultural export sector. Between 2022 and 2024, the export value of the cashew industry increased from 3.08 to 4.37 billion USD. However, this industry also generates considerable negative environmental impacts, particularly from by-products of the processing stage such as cashew shells and cashew meal. Improper utilization of these by-products has led to serious environmental challenges requiring urgent solutions. Several studies have demonstrated the potential of converting cashew processing by-products into valuable secondary products that can be repurposed for multiple applications. In this presentation, we highlight a circular economy-oriented approach in which cashew processing residues (shells, meal, and extracted oils) are recovered and transformed into useful products that can be reintegrated into agricultural production systems. This approach enables the effective and rational utilization of by-products, thereby reducing emissions and mitigating environmental damage. It represents a sustainable and circular solution for the cashew industry.

Keywords: Circular economy, cashew, cashew by-products, cashew processing

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Analysis of Cattle Breed and Age in Breeding Programs within the Siska System

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Abstract

This study aimed to analyze the breed and age composition of breeding cattle and their implications for breeding programs within the oil palm–cattle integration system (SISKA) at the Mitra Tani Sejahtera farmer group. The research material consisted of a beef cattle population comprising Bali, Madura, Brahman Cross, and Peranakan Ongole (PO). The research method employed a field survey through direct observation and recording of cattle numbers by breed and age group. Data were analyzed descriptively and quantitatively by calculating the number and percentage of each category. The results showed that the total cattle population was 51 head. By breed, Bali cattle dominated with 23 head (45.1%), followed by Madura (14 head/27.5%), Brahman Cross (10 head/19.6%), and PO (4 head/7.8%). By age group, the largest category was adult females (27 head/52.94%), followed by young cattle (11 head/21.57%), calves (9 head/17.65%), and adult males (4 head/7.84%). In conclusion, the dominance of Bali adult females indicates a strong potential for breeding programs; however, an increase in the number of males and other breeds is required to maintain genetic diversity and ensure the sustainability of the SISKA system.

Keywords: Breeding cattle; breeding program; SISKA system

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Sustainable Packaging Alternative to Plastic

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Abstract

Plastic packaging has been a part of contemporary life because it is inexpensive, light, and convenient. Nevertheless, over-reliance on plastic has posed serious environmental problems in the form of pollution, landfill waste, and the killing of marine animals. This has heightened the demand for eco-friendly, biodegradable, and nature- and human-friendly packaging alternatives that are sustainable. The research centers around the investigation of various substitutes for plastic like paper, bioplastics made from plants, edible films, glass, metal, and reusable products. It brings out the significance of minimizing plastic use by embracing sustainable alternatives that can meet consumer needs, costs, and environmental concerns. The research also points out the need for cooperation between industries, governments, and consumers to achieve the implementation of these alternatives. By encouraging sustainable packaging, society will be able to achieve a cleaner environment and lead to long-term ecological equilibrium.

Keywords: Plastic, packaging, sustainable

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Unlocking the Economic Potential of Mustard Cultivation in Bangladesh: Profitability, Inefficiencies, and Institutional Gaps

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Abstract

Mustard has long been an important crop in Bangladesh, valued both for its role in crop rotation and the steady demand for mustard oil. Yet, the full economic promise of mustard farming often remains out of reach for many farmers. This study explores how profitability, input management, and institutional support shape the realities of mustard cultivation across the country. The analysis showed that simply expanding the cultivated area brings only modest income gains ($r = 0.236$, $p = 0.024$). Surprisingly, higher spending on inputs does not always lead to better yields ($r = –0.273$, $p = 0.009$), pointing to mismanagement in fertilizer use and other practices. At the same time, investment still plays a strong role in overall earnings ($R^2 = 0.714$, $p < 0.001$), suggesting that mustard can be a profitable venture when resources are used wisely. Training programs do not seem to improve yields in any meaningful way, and more than 90% of farmers report receiving no institutional help. Even so, 72% believe mustard is more profitable than rice, wheat, or maize, thanks to lower input needs and strong market demand. For the remaining 26%, risks like climate shocks, pests, and input shortages keep profitability uncertain. Together, these findings reveal a crop with strong potential, but one that needs smarter training, better input management, and stronger institutional backing to truly deliver for farmers.

Keywords: Mustard cultivation, profitability, input efficiency, agricultural extension, Bangladesh

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Performance Evaluation of Local Goat (*Capra aegagrus hircus*) Production Fed by Echinochloa Polystachya and Introduction of Pineapple Trash (*Ananas comosus*) and Wet Market Garbage for an Enhanced Agricultural Economy

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Abstract

The rising global cost of commercial livestock feed, driven by factors like climate change and supply chain disruptions, poses a significant challenge to sustainable animal husbandry, particularly for small-scale farmers in developing regions (FAO, 2023). This economic pressure necessitates the urgent exploration of locally available, low-cost, and sustainable alternative feed sources. In Indonesia, agricultural by-products and organic market waste represent promising, underutilized resources that could mitigate feed expenses (Haryanto et al., 2022). This study investigated the effects of incorporating specific alternatives, specifically pineapple waste (Ananas comosus) and wet market garbage, combined with the native grass Echinochloa polystachya, into the diet of local goats (Capra aegagrus hircus). The research was conducted over forty days in March 2025 in the North Samarinda sub-district of East Kalimantan Province, Indonesia. Thirty goats were distributed in a randomized block design, organized by initial body weight, with three dietary treatments and three replications each. Data on growth and health parameters were analyzed using Analysis of Variance (ANOVA), with a multiple range test applied for post-hoc comparisons where significant differences were found. Contrary to expectations, the results indicated that the experimental diet led to a significant increase in goat mortality. The researchers hypothesize that this adverse outcome may be attributed to several factors, including challenging environmental conditions and critical issues with the feed itself. These issues potentially encompass bacterial contamination of the fresh waste materials, given their high susceptibility to spoilage, and the presence of high levels of complex, lignified fibers in the raw pineapple peel, which are difficult for ruminants to digest and can impair nutrient absorption.

Keywords: *Capra aegagrus* hircus, pineapple waste, wet market garbage, *Echinochloa polystachya*, agricultural by-products, organic waste utilization

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Economic and Agronomic Divers of Onion (Allium cepa) Productivity in Bangladesh

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Abstract

Onion (Allium cepa), a key cash crop in Bangladesh, supports household income and market stability but faces persistent agronomic and economic constraints. This study examined cultivation practices, storage methods, extension support, and farmer perceptions, with attention to the cost and profitability dimensions of onion farming. Data were collected from 67 farmers through a structured questionnaire and analyzed to identify key patterns. Results showed that onion was mainly grown in sandy-loam soils (50.8%) and clay soils (26.9%). Traditional storage dominated (95.5%), leading to substantial post-harvest losses that increased production costs and reduced net income. Farmers emphasized the need for modern training (49.3%), improved seed varieties, irrigation development, and loan facilities as essential supports to reduce risk and improve profitability. Good seed (46.3%) and high-yielding varieties (19.4%) were reported as critical for yield and income gains, alongside organic fertilizer use. Extension officers were the primary source of advisory services, reaching 80.6% of respondents. However, farmers noted that limited access to credit and volatile market prices constrained their ability to invest in improved practices. Overall, the findings underscore that strengthening farmer capacity, expanding access to quality seed and affordable credit, and promoting improved storage innovations are essential for raising productivity and stabilizing farmer incomes. Such measures can reduce reliance on onion imports, enhance profitability, and support the long-term sustainability of the onion sector in Bangladesh.

Keywords: Onion production, cost and profitability, market access, farmer capacity, Bangladesh

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The Economies of Agricultural Subsidies: Implications for Farm Incomes and Consumer Welfare (A Review)

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Abstract

The most widely used agricultural and food policy tool is Agricultural subsidies. Agricultural subsidies are financial assistance given to farmers, agribusinesses, or the agricultural industry by governments or international organizations with the intention of boosting agricultural output, maintaining market stability, guaranteeing food security, and safeguarding farmer's income. It can be tax exemptions and credit schemes, input/output subsidies. In times of unstable commodity pricing and unpredictable market conditions, these interventions boost food production while lowering the inherent risks that farmers, especially smallholders might experience. Notwithstanding, subsidies pose serious problems for consumer welfare, fiscal sustainability, and environmental management. This review gathers data to investigate the simultaneous impact of subsidies on farmers and consumers from developing and developed economies. It was discovered that subsidies increase farmers' access to cutting-edge technology, boost production, sustain rural incomes, lessen their susceptibility to market forces and seasonal fluctuations. However, subsidies frequently skew market signals, promote wasteful resource usage, and favour large scale farmers over small-scale growers who are more vulnerable. From the standpoint of the consumer, input subsidies, while potentially lowering production costs, often do not result in lower consumer prices because of waste and market leaks, while output price supports can raise retail food prices, making them unaffordable for low-income households. These advantages/disadvantages have been demonstrated by worldwide adventures.

Keywords: Agricultural subsidies, farm incomes, consumer welfare, food security, market distortions, sustainable agriculture

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Techno-Economic Efficiency of Circular Economy Models in Agriculture: A Case Study of Organic Fertilizer from Cattle Farming in the Mekong Delta

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Abstract

This study provides a comprehensive techno-economic analysis of circular economy (CE) models within the agricultural sector of Vietnam's Mekong Delta, focusing on the value chain of organic fertilizer derived from cattle farming by-products. The research aims to evaluate the financial viability and technical efficiency of current practices to propose scalable solutions for sustainable agricultural development.

Design/methodology/approach: The research employs a mixed-methods approach, utilizing secondary data from official reports and prior studies, alongside primary data from a survey of 360 stakeholders (including farmers, cooperatives, and businesses) across three representative provinces: An Giang, Vinh Long, and Tra Vinh. Key analytical tools include Value Chain Analysis, financial efficiency analysis (cost-benefit, profitability ratios), and Data Envelopment Analysis (DEA) to measure technical and scale efficiency.

Findings: The results indicate that while the adoption of formal CE models is still nascent, circular practices offer significant economic benefits. Financial analysis reveals that converting manure into organic fertilizer reduces input costs and creates new revenue streams for farmers, with cattle breeding models demonstrating superior capital efficiency over fattening models. Furthermore, DEA identifies substantial technical inefficiency, showing that farms have the potential to increase output by an average of 24-35% without increasing inputs. Key barriers to adoption are high initial investment costs, limited technical knowledge, and weak market linkages for circular products.

Practical implications: The study concludes that unlocking the full potential of the circular economy in the region requires targeted policy interventions. We propose a framework of actionable implications focusing on three core areas: (1) financial support mechanisms to overcome investment barriers, (2) strengthening agricultural extension services to improve technology transfer, and (3) developing robust markets for organic fertilizers to ensure profitability for all stakeholders.

Originality/value: This paper contributes empirical evidence to the limited literature on the techno-economic performance of agricultural CE models in a developing country context. By integrating financial analysis with DEA, it provides a multi-faceted assessment that is valuable for policymakers, businesses, and researchers aiming to foster a sustainable and circular bioeconomy.

Keywords: Circular economy, DEA, mekong delta

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User Accessibility in Nigerian Shopping Malls: Myth or Reality

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Abstract

According to 2030 United Nations Sustainable Goal 10, and 11 buildings are required to be accessible and ensure inclusivity of disabled persons. In light of this, the need to ascertain the extent public buildings such as shopping malls has featured architectural elements, and facilities that promote user accessibility becomes imperative. However, extant studies show dearth in research evaluating how accessible shopping malls in Nigeria are to persons with disabilities. Hence, this study examines the exterior and interior areas of 8 purposively sampled shopping malls in Nigeria with mixed research methods. Thereto, data was collected from 44 users using structured questionnaire of 21 questions, and observation check list, thus, comparatively analysed using the Persons with Disabilities (Accessibility) Regulations of the Federal Republic of Nigeria, Official Gazette. Descriptively presented, the study findings reveal that 66% of provisions of the regulations were not met across the cases studied. This result necessitates the quest to ameliorate user accessibility in Nigerian shopping malls. To achieve this, the study recommends shopping malls projects in Nigeria undergo accessibility check during design, approval, construction, commissioning, and post construction stages with accompanying certifications, and sanctions where applicable.

Keywords: Disabilities regulations, Nigeria, shopping malls, user accessibility

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Stakeholder Engagement and Project Performance in Abuja's Construction Sector: A Synthesized Review

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Abstract

This study examines the role of stakeholder engagement in shaping construction project performance within the sustainability discourse, with particular emphasis on the Nigerian context. A synthesis of the literature reveals that while stakeholder engagement is increasingly advocated, its adoption remains partial, often confined to token consultation rather than embedded governance practice. Key drivers of effective engagement such as client commitment, regulatory support, and transparent communication are frequently undermined by barriers including limited resources, power imbalances, and weak institutional capacity. The evidence demonstrates that projects with structured and inclusive engagement achieve stronger outcomes in time, quality, and stakeholder satisfaction, whereas inadequate engagement is linked to disputes, delays, and reputational risks. The review concludes that stakeholder engagement is indispensable not only for immediate project delivery but also for advancing social, environmental, and economic sustainability. It recommends institutionalising engagement frameworks, investing in capacity building, and embedding stakeholder-inclusive practices into project governance to enhance both project success and sustainable development in emerging economies.

Keywords: Stakeholder engagement, construction project performance, sustainability, project management, Abuja

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Seeing and Selling the City: Visual Consumption and the Erosion of the 'Right to the City'

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Abstract

Critically this paper examines, the increasing power of visual consumption in shaping the modern urban setting and its consequences of allegedly weakening the right to the city coined by Henri Lefebvre. The study investigates the modifications occur to perceptions of space, identity and belonging through the circulation of commodified imagery, through visual analysis, qualitative interviews, and quantitative surveys in multiple case studies across urban contexts. Results show that the visual representations are increasingly driven by aesthetics rather than authenticity and local narratives in more ways than not are placed on the periphery thus promoting the socio-spatial inequalities. Those who live in the city complain that they do not relate to urban visions sold to them on the market, instead, experiencing alienation and being deprived of the ability to construct their urban futures. In addition, the study also focuses on the emergence of grassroots movements that oppose the visual hegemonies and the effort of reclaiming representational and physical urban space. The article ends by urging the adoption of inclusive models of urban governance that are capable of challenging domination of visual commodification and joining together to enforce collectivity, rights to engage, producing, using, and shaping urban space.

Keywords: Visual consumption, right to the city, urban commodification, public space representation, grassroots urban resistance.

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Cross Ventilation in Desert Homes: Spatial Strategies for Passive Cooling in Biskra

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Abstract

This paper deals with examining a passive cooling tool of cross ventilation in the housing of the south east Algerian desert city of Biskra which is an arid city with intense heat, low humidity and little wind circulation in it. Evaluation of the use of space and architecture in vernacular housing and modern housing determines how design of the building, direction, location of windows, courtyards, and spatial distributions influence air movement and thermal comfort. By using the mixed-method research strategy that involves environmental monitoring, computational fluid dynamics (CFD) model, and occupant survey, the study demonstrates that traditional residential buildings designed against the inward facing appearance, utilizing high thermal mass, favorable opening orientation have far better cross ventilation and comfortable indoor environment than modern housing that largely ignores passive design strategies. The results strongly state the vital importance of spatial awareness and culturally-grounded design interventions toward improving the interior air conditions and minimizing the use of mechanical air-conditioning systems. The study will make an input in the general idea of the discourse on climate-sensitive building in the hot-arid regions by providing scientifically-researched findings on how to incorporate advantageous cross ventilation in contemporary desert residences. Finally, it supports a new design paradigm that balances climate sensitivity, logic in space, and physical comfort of the occupants, as the environmental issues continue to increase.

Keywords: Cross ventilation, desert architecture, vernacular housing, spatial configuration, sustainable residential design.

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Façade Glazing Ratios and Their Role in Heating and Cooling Loads in High-Rise Architecture

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Abstract

The high-rise buildings occupy a significant share of the modern skyline as the city grows denser and vertical living conditions become obligatory, so they require a closer examination of their energy efficiency. The façade glazing ratio, the ratio between glazed surface area and wall total area, is probably one of the most powerful determinants of the impacts in the given context and has a direct implication on heating and cooling loads. This paper looks into the energy consequences of different glazing proportions in high-rise buildings at different climatic conditions. Applying a mixed-strategy that combines dynamic simulation modeling approach and empirical assessment based on real life case studies, the study shows numerical contributors of elevated glazing to express important gain and loss of heat that commonly exacerbate cooling burdens in warmer destinations and heating loads in chillier ones. Results show that buildings whose glazing ratio is above 50% may reach a high energy-level of up to 30 percent during peak time, which calls the optimization of design strategies. The research helps to advance sustainable architecture by providing model designs and promoting energy-saving windows choices, which should be production-friendly using the balance between inhabitant comfort, aesthetic ideals, and energy performance. This knowledge can be really helpful to help architects, engineers and policymakers to reduce the environmental footprint of high-raised constructions whilst improving performance-based design.

Keywords: Glazing ratio, high-rise buildings, heating and cooling loads, sustainable architecture, climate-responsive design.

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Skyscrapers of Sustenance: Integrating Vertical Farming into Urban Architectural Systems

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Abstract

Vertical farming has increasingly become one of the most revolutionary foods to sustain the process of food production in urban cities as populations continue to flood the cities, and arable land in the countryside continues to diminish. A combination of vertical farming systems within the urban architectural context of the modern city will be explored in this research not just as an addition to the process of agricultural growth but as the essential part of designing future-proof buildings. In interdisciplinary research comprising of architectural analysis, models of environmental performance display and case study evaluation of such projects as Plantagon CityFarm, Sky Greens, and the Farmhouse Project, the study evaluates the spatial, energy, and resource optimization tactics of vertical agricultural buildings. The data point to the possibilities of hybrid architecture combining food production with living, working, and contributing to cities, which will allow cities to close the food miles, increase food security, and stimulate the flow of closed resources. Other aggravating issues addressed in the study are areas concerning regulatory framework, amount of energy used, and perception by the citizens and the researchers provide recommendations on the design and policy work in making the implementations scalable, context-sensitive. Finally, the study conceives the high-rise construction as a vehicle of ecological resilience and urban food sovereignty, strengthening the position of the building as a versatile ecosystem in times of climate change adaptation.

Keywords: Vertical farming, food-energy-water nexus, integrated building systems, climate-adaptive architecture, high-rise agriculture.

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Challenges of Urban Architecture in Bandarabbas City, Iran South: Managing the Invasion of *Prosopis juliflora* and Its Impact on Infrastructure through Sound Policymaking

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Abstract

The invasion of Prosopis juliflora, an aggressive and invasive tree species, poses significant threats to urban architecture and infrastructure in Bandarabbas city, located in southern Iran. This species, known for its rapid growth and extensive root system, has spread widely around and inside urban areas, leading to structural damage to roads, buildings, and underground utilities. The root intrusion and dense canopy of P. juliflora exert physical pressure on foundations and pavements, causing cracks, subsidence, and accelerated deterioration of critical infrastructure. This presents a pressing challenge for urban planners and municipal authorities, particularly in arid and semi-arid regions like Bandarabbas where urban development is already vulnerable to environmental stressors. This study highlights the need for sound policymaking to effectively address the ecological and infrastructural challenges posed by the invasive Prosopis juliflora. Policy measures should emphasize early detection, controlled removal, and the implementation of native species restoration programs to mitigate damage and restore ecological equilibrium. Additionally, integrating urban architecture planning with invasive species management can help safeguard critical infrastructure while promoting sustainable urban development. The collaboration between environmental scientists, urban planners, and policymakers is essential to develop adaptive strategies that protect Bandarabbas built environment from further degradation caused by this invasive species.

Keywords: *Prosopis juliflora*, Bandarabbas city, critical infrastructure, environmental stressors

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From Soil Wisdom to Smart Farming: Examining India's Agricultural Transformation

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Abstract

Agriculture in India is at a key point between its rich traditional heritage and rapidly advancing technology. This research paper compares traditional and modern agricultural systems, focusing on how each affects productivity, sustainability, and environmental resilience. Traditional agriculture, with practices like organic fertilization, crop rotation, and indigenous irrigation, reflects centuries of ecological wisdom that maintained soil health and biodiversity. In contrast, technology-driven agriculture uses tools like precision farming, AI-based crop monitoring, drones, and data analytics to improve efficiency and yield in today's world. The study looks at agricultural performance trends and budget allocations from 2000 to 2025 to understand how India's shift from traditional methods to technology has influenced overall agricultural revenue and output. By examining long-term data and growth patterns, this research aims to reveal the key factors that determine success and sustainability in both approaches. The goal is not to claim one system is better but to identify where they support or challenge each other. Ultimately, this paper aims to offer a balanced, data-based view on how India can blend traditional knowledge with new technologies to boost agricultural resilience and ensure long-term food security. The findings are expected to provide valuable insights for academic discussions and practical applications in sustainable farming practices for the future.

Keywords: Traditional agriculture, technological agriculture, sustainability, productivity, agricultural transformation.

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Marine Algae-Derived Activated Adsorbents for the Removal of Cationic Dyes from Wastewater

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Abstract

Efficient adsorbents were prepared from two marine algae species (green and brown seaweeds) through simple surface activation using chemical agents. The raw biomass was impregnated and stirred in hydrochloric acid (0.1 N) and calcium chloride (0.2 N) solutions. The resulting samples (AC-1, AC-2, AC-3, and AC-4) were evaluated for the removal of Basic Green and Basic Red dyes from synthetic wastewater. The effects of operational parameters such as solution pH, contact time, adsorbent dosage, and temperature were investigated in batch experiments.

Enhanced adsorption capacities of up to 500 mg g^{-1} for Basic Red and 188.68 mg g^{-1} for Basic Green were achieved. The adsorbents were characterized using FTIR, SEM, iodine number, methylene blue index, and pH (ZPC) analyses. The adsorption equilibrium data were best fitted by Langmuir, Freundlich, and Temkin isotherm models, while the adsorption kinetics followed a pseudo-second-order model.

Thermodynamic studies confirmed that the adsorption processes were spontaneous and endothermic. These findings demonstrate that chemically modified marine algae are promising, low-cost, and eco-friendly adsorbents for the efficient removal of cationic dyes from wastewater.

Keywords: Marine algae, adsorption, isotherms, dyes, wastewater treatment.

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Eco-Design Inspired by Natural Wetlands for Circular Water Management in Agriculture

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Abstract

Wetlands stand as living examples of balance between ecological function and visual harmony. This presentation explores how the natural design and self-regulating systems of Moroccan wetlands can inspire sustainable solutions in both environmental science and artistic creation. Based on field studies conducted in the Gharb region, the research demonstrates how these ecosystems not only remove nitrate pollution but also embody a unique form of aesthetic and structural design created by nature itself. By bridging scientific understanding and artistic perception, this work invites reflection on how natural systems can guide modern eco-design practices and reshape our cultural appreciation of environmental beauty.

Keywords: Wetlands, eco-design, sustainability, environmental aesthetics, nature-based solutions

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Driving Forces of Farmers' Awareness on Climate Change: A Study in the South-West Coastal Region of Bangladesh

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Abstract

Farmers' awareness of climate change is widely recognized as the first step toward building resilience and ensuring effective adaptation in agriculture. This study explores the factors that shape farmers' awareness in the south-western coastal region of Bangladesh, with a focus on Haridhali Union in Paikgacha Upazila, an area highly vulnerable to climate-induced hazards that threaten both livelihoods and food security. Data were collected from 325 farming households using a structured questionnaire administered through convenience sampling. The survey examined demographic and socio-economic characteristics, livelihood practices, access to institutions, and farmers' perceptions of changing climate patterns. A binary logistic regression model was used to identify the key factors influencing awareness, supported by descriptive and inferential analyses to assess overall awareness levels. The findings reveal that most farmers are aware of climate change, particularly changes in temperature and rainfall, and directly associate these with declining crop yields and greater production risks. Determinants of awareness include age, education, farming experience, participation in farmers' associations, access to agricultural credit, and extension services. Farmers with higher education levels and stronger institutional linkages demonstrated greater awareness and a stronger capacity to adopt adaptive practices. The study concludes that both socio-demographic and institutional factors significantly influence the degree of awareness among farmers. Strengthening education, enhancing access to institutions, and expanding extension services are therefore crucial to improving awareness and readiness for adaptation. These insights provide valuable guidance for policymakers and development organizations to design targeted awareness programs, capacity-building initiatives, and institutional support systems that can foster effective climate adaptation and mitigation in vulnerable coastal communities.

Keywords: Climate change, climatic hazards, institutional access, adaptation, mitigation, farmers' awareness, South-West Coastal Bangladesh

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Livelihood Coping Strategy of Women in Flood-Prone Areas in Bangladesh

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Abstract

This study explores how women in Rajnagor Bakaborshi village, Keshabpur Upazila, Jessore one of Bangladesh's most flood-affected areas cope with repeated flooding and its impact on their livelihoods. It aims to understand the challenges floods create for women and the strategies they develop to adapt and recover. A mixed-methods design was used, combining key informant interviews, structured surveys, and document analysis. From a flood-affected population of 480 women, 80 who were severely impacted were selected through purposive sampling. Four key livelihood areas were assessed using the Flood Coping Strategies Index (FCSI) housing and flood management, livestock rearing, cropping practices, and income diversification. Among housing strategies, preserving cow dung as fuel was most common (47%), while raising house plinths was rare (6%). In livestock management, floating agriculture was widely adopted (40%), while creating temporary animal shelters was less frequent (28%). In cropping, vaccinating livestock and poultry was widely practiced (55%), but storing feed remained uncommon (15%). For income, selling large trees was a frequent strategy (43%), whereas shifting to wage labor was less common (17%). The study finds that women aged 28–38 were the most proactive in adopting coping measures, while older women (50–60) were least responsive, often due to physical and social constraints. These findings highlight the importance of recognizing and strengthening women's knowledge and coping capacities in flood management. A gender-sensitive approach to disaster risk reduction and climate adaptation is essential to protect livelihoods and build resilience in vulnerable communities.

Keywords: Livelihood, flood, coping strategy, women, adaptation, vulnerability

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Study of the Chemical Composition and Antioxidant and Antimicrobial Activities of the Essential Oil of The Aerial Part of *Satureja calamintha* from Morocco

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Abstract

Medicinal and aromatic plants have long been used to combat a variety of illnesses. However, the discovery of synthetic antioxidants and antibiotics has led to the decline of herbal medicine. Indeed, the side effects of these synthetic products and the emergence of resistant bacteria led us to study the antioxidant and antibacterial activities of the essential oil of the aerial part of Satureja calamintha.

Satureja calamintha (S. calamintha) is successfully used in the treatment of bacterial and fungal diseases. The present study was designed to investigate the chemical composition and antioxidant and antimicrobial activities of essential oils extracted from S. calamintha. Hydrodistillation was used to extract essential oils (EOs), while GC/MS was used for chemical analysis. Antioxidant activity was studied using DPPH and FRAP assays. Antibacterial activity was tested against clinically resistant bacteria, namely Staphylococcus aureus, Escherichia coli, Bacillus subtilis and Proteus mirabilis. The antioxidant and antimicrobial activities of the main compounds in S. calamintha a EO were also studied. The yield obtained was 2.80%, with eucalyptol, pulegone and rotundifolone predominating. With regard to antioxidant power, the IC50 values recorded by the DPPH test is 23.03 ± 4.30µg/mL, while using the FRAP test, the EC50 value is 55.38 ± 2.16µg/mL. Importantly, S. calamintha essential oils showed good antibacterial activity against all the bacteria studied; notably, the zone of inhibition ranged from 12.67 ± 0.58 to 48.67 ± 1.15 mm, and MICs ranged from 1.49 ± 0.00 to 5.96 ± 0.00 µg/mL.

The results of this study suggest that S. calamintha EOs can be developed as alternative agents to treat drug resistance phenomena and infectious diseases.

Keywords : *Satureja calamintha*, antioxydant, antibacterial, essential oil

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Sustainable Packaging Alternative to Plastic

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Abstract

Plastic packaging has been a part of contemporary life because it is inexpensive, light, and convenient. Nevertheless, over-reliance on plastic has posed serious environmental problems in the form of pollution, landfill waste, and the killing of marine animals. This has heightened the demand for eco-friendly, biodegradable, and nature- and human-friendly packaging alternatives that are sustainable. The research centers around the investigation of various substitutes for plastic like paper, bioplastics made from plants, edible films, glass, metal, and reusable products. It brings out the significance of minimizing plastic use by embracing sustainable alternatives that can meet consumer needs, costs, and environmental concerns. The research also points out the need for cooperation between industries, governments, and consumers to achieve the implementation of these alternatives. By encouraging sustainable packaging, society will be able to achieve a cleaner environment and lead to long-term ecological equilibrium.

Keywords: Plastic, sustainable, packaging

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Development and Evaluation of a Novel Biopolymer-Based Superabsorbent Hydrogel on Plants Growth under Different Hydric Stress Conditions for Sustainable Agriculture

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Abstract

Agricultural activity is currently facing major challenges due to the increase in the world's population. Water is a crucial element in agriculture. In this context, water is one of the critical factors for a sustainable agricultural production. Therefore, the development of superabsorbent hydrogel, controlled water release is considered a valuable strategy to reduce excessive water use in agriculture.

This research project focuses on the synthesis and characterization of Biopolymer-Based superabsorbent hydrogels, designed to release water gradually in the soil under different hydric stress conditions. The hydrogels were prepared using biopolymers specifically polysaccharides. Polysaccharides are natural, biodegradable, nontoxic, renewable, inexpensive and environmentally friendly biopolymers.

The synthesized hydrogels will be characterized based on their physicochemical properties, including swelling and retention capacity in soil. Additionally, the biopolymers-based hydrogels provide an efficient for swelling and retention capacity.

Overall, this research project is focused on development of new controlled-release hydrogel, to offering a slow water release profile significantly improving water retention.

Keywords: Hydrogel, biopolymers, hydric stress conditions, sustainable agriculture

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Morphological Characterization and in vitro Management of *Aspergillus niger*: A Major Fungal Contaminant of Prawn Balachao in Bangladesh

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Abstract

Dry fishes were considered as one of the popular dietary sources for the people of Bangladesh but due to lack of proper hygiene of dry fish people are now liked to ingest processed dry fish called "Prawn Balachao". The research was done to isolate, identify and control the associated fungi that can cause health issues by using eco-friendly components either natural or chemical. After collecting the Prawn Balachao sample from Shwapno grocery shop, they were inoculated in PDA media to check the growth of fungi. Aspergillus niger was isolated and cultured in fresh media for further study and preservation. Aspergillus niger was cultured to observe the effect of media, pH, temperature and to find out it's in vitro control measures. The highest growth of Aspergillus niger was seen in MEA (89) and HEN (85.44mm) media. Up-to pH 6, the fungal growth gradually increased but dropped upto 8. The effects of different culture media and pH show a greater variation in their mycelial growth range. In case of study of effect of temperature, it was found that the lower temperature (10℃) showing almost no growth that means these fungi couldn't grow in freezing condition. But when they were exposed to higher temperature above 25℃, they grew very quickly. After that they were treated with phytoextract (Garlic-Allium sativum L., Turmeric-Curcuma longa L. and Ginger-Zingiber officinale L.) and chemical preservatives (Salt-NaCl, Sodium Benzoate-$C_7H_5O_2Na$ & Acetic Acid-CH_3COOH) to find out their capability of inhibition of mycelial growth. While Garlic and Ginger were found to be more effective for inhibition of growth for both fungi in 75%, turmeric was ineffective. High concentrations of NaCl were recognized as ineffective preservatives for controlling the growth of two fungi indicated their salt loving nature. On the other hand, 200mM sodium Benzoate and 0.5% Acetic Acid were found enough to inhibit the mycelial growth of the isolated fungi. All these fungi were found to be responsible for degrading the quality of the food and causing adverse impact on human health. So, the present study should be very important for demonstrating the optimum control measures required to inhibit the fungal growth.

Keywords: Prawn Balachao, *Aspergillus niger*, PDA, Sodium Benzoate, Acetic Acid, Turmeric (*Curcuma longa*), Ginger (*Zingiber officinale)*, Garlic (*Allium sativum*)

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Biological and Ecological Characteristics of Hilsa (*Tenualosa ilisha*): Essential for Sustainable Management

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Abstract

The Hilsa shad, Tenualosa ilisha*, represents Bangladesh's most valuable aquatic resource, supporting the nation's largest single-species fishery. This species plays a crucial role in national economic growth, employment generation, and providing protein-rich nutrition to the people of Bangladesh. Therefore, this research emphasized the biological and ecological characteristics of Hilsa and their significance for sustainable management strategies. Total length (TL), body weight (BW), and gonad weight (g) were recorded with an accuracy of 0.01 cm and 0.01 g. In this study, the maximum observed lengths of Hilsa were 42 cm in the Padma River, 55.5 cm in the Meghna River, and 53 cm in the Bay of Bengal, respectively. Most individuals reached sexual maturity at lengths of 23.31 cm, 30.08 cm, and 28.84 cm in the Padma River, Meghna River, and Bay of Bengal, respectively.* T. ilisha *spawns throughout the year; however, the highest gonadosomatic index (GSI) values were observed in October, indicating that this month marks the peak spawning period of the species. Based on the findings regarding peak spawning time, it is recommended that the fishing ban period be adjusted accordingly. Currently, the ban on Hilsa fishing extends from 12th October to 2nd November. According to the present results, this restriction should begin 3–4 days later in the Meghna River and 7 days later in the Padma River. A 30-day ban period is suggested for the Bay of Bengal. These outcomes are highly significant for formulating sustainable management policies aimed at conserving* T. ilisha *populations in the Padma River, Meghna River, and Bay of Bengal.*

Keywords: Banning period, management policy, Padma River, peak spawning season, Tenualosa ilisha

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Applying Meta-analysis in Plant Science: Synthesizing Evidence and Identifying Research Gaps in Stress Physiology and Crop Improvement

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Abstract

Meta-analysis has emerged as a powerful statistical approach, enabling researchers to integrate diverse experimental findings and derive quantitative insights across studies. Meta-analysis has been extensively employed in medical and ecological sciences; however, its use in plant physiology is still comparatively scarce. In recent years, we have applied meta-analysis techniques to synthesize data on a wide range of abiotic stress responses in plants and to evaluate the effectiveness of exogenous bio-stimulants such as salicylic acid (SA) and nitric oxide (NO) in improving stress tolerance and yield. These studies collectively reveal that (i) exogenous application of SA and NO significantly enhances plant growth, physiological performance, and yield under salinity stress, (ii) combined salinity–drought or salinity–waterlogging stress exerts more severe effects on plant growth, photosynthesis, and ionic balance than individual stresses, and (iii) tolerance to combined stress is largely governed by salinity tolerance mechanisms. Furthermore, our meta-analysis demonstrated that SA application is a cost-effective intervention for wheat cultivation in saline soils. These findings highlight the strength of meta-analysis in identifying consistent patterns, quantifying effect sizes, and uncovering research gaps that are often overlooked in individual studies. The approach allows for the assessment of treatment efficacy, optimal application conditions, and species-specific responses while providing evidence-based recommendations for agricultural practice. In conclusion, meta-analysis serves as a critical bridge between experimental plant physiology and applied crop improvement, offering a data-driven framework for guiding future research and sustainable management practices under changing climatic conditions.

Keywords: Abiotic stress, crop tolerance, meta-analysis, plant physiology, yield.

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Occurence of *Trichuris ovis* in Goats in Serbia

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Abstract

Trichuris ovis, commonly known as whipworm occurs in the caecum and colon of sheep, goats, cattle and other ruminants. This species of whipworm is white and is known to have a long, thin neck that composes two-thirds of its body, and a short, thick posterior. Its life cycle is direct and larvae develop to third stage inside the eggshell. When the dung pellet becomes moist and disintegrates, the larvae (still in the egg shell) are released onto the soil surface. Stock grazing close to the soil surface ingests the larvae contained within the eggshell. They are very resistant to desiccation and freezing. Goats acquired infection through ingestion of infective stage of L1 within the eggs which hatch in the small intestine and the released larvae burrow into the intestinal wall of the caecum and proximal colon where they develop to mature worms. Like all whipworms, T. ovis primarily inhabit the host's cecum. Infections with T.ovis are associated with several pathological conditions, including bloody colitis and diphtheritic caecitis, which can result in ulcerative and necrotic lesions on the intestinal mucosa. Severe infestations can lead to severe anaemia, dehydration, and even death in young or vulnerable animals. However, goats are rather resistant to the parasite infection and often do not experience many symptoms. If the host is heavily infected, a large portion of the blood vessels located in the cecal wall will be consumed. This eventually results in the thickening of the wall, thus preventing that region of the large intestine from absorbing fluids causing the host to have diarrhea. During our examination of gastrointestinal parasites of goats in various part of Serbia, Trichuris ovis was established only in 3.37% of examined goats. Findings of T.ovis were always in mixed infections with other GI helminths, and the infections were mostly subclinical.

Keywords: *Trichuris ovis*, goats, epidemiology

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Valorization of Local Cattle By-Products: Physicochemical Characterization of Tallow from Indonesian Ongole Crossbred Cattle for Enhanced Agricultural Economy

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Abstract

The livestock sector, a cornerstone of the agricultural economy, generates significant by-products whose underutilization represents a missed economic opportunity. Beef fat, a major by-product of slaughter, holds substantial potential for valorization into high-value food products like tallow, thereby creating additional revenue streams and reducing waste. This study investigates the efficacy of two rendering methods dry (heating at 90-100°C) and wet (heating with water at 90°C) in processing subcutaneous fat from locally sourced Indonesian Ongole Crossbred cattle (PO) into food-grade tallow. The research aims to comprehensively characterize the resulting tallow to determine its suitability for commercial use, directly contributing to efforts for improving the agricultural economy through by-product optimization. The tallow from both methods was rigorously evaluated for its physicochemical properties, fatty acid profile, and functional groups. Results indicated that the rendering methods produced tallow with significant differences ($P<0.05$) only in color intensity (0.61 for dry, 0.39 for wet) and acid value (0.67 for dry, 1.72 for wet). Crucially, all other parameters including yield, sedimentation, saponification value, peroxide value, iodine value, Thio barbituric acid, and heavy metal concentratio ns showed no significant differences ($P>0.05$). Most importantly, the physicochemical properties of tallow from both methods fully complied with the international food safety and quality standards set by the Codex Alimentarius for animal fats (CODEX-STAN 211-1999). The current study concludes that both dry and wet rendering are viable techniques for producing high-quality, food-grade tallow from local Indonesia n cattle by-products. The successful transformation of low-value slaughter waste into a standardized, marketable commodity demonstrates a practical pathway for enhancing profitability within the livestock valu e chain. By adopting such valorization strategies, local farmers and agro-processors can capture greater economic value from their operations, reduce environmental impact, and strengthen the resilience and productivity of the regional agricultural economy.

Keywords: Beef tallow, dry rendering, wet rendering, by-product valorization, ongole crossbred cattle, physicochemical properties

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The Importance of Carbon Farming and Agroforestry Techniques in Terms of Climate Change

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Abstract

One of the most significant causes of climate change is the disruption of the carbon cycle in nature due to human activities. On a global scale, reports by the Intergovernmental Panel on Climate Change (IPCC) indicate that unless rapid and deep cuts are made in greenhouse gas emissions, the likelihood of limiting global warming to 1.5°C is diminishing. In this context, carbon farming has become increasingly important in the fight against climate change, as part of sustainable agricultural management practices aimed at carbon sequestration and storage. The carbon farming approach is a new farmer business model and sustainable land management that creates multifaceted added value (e.g. promoting sustainable agricultural practices, enabling greater carbon sequestration and storage in soil and plants over a specific activity period, reducing greenhouse gas emissions into the atmosphere, supporting ecosystem conservation, improving soil health, strengthening local economies, creating employment, encouraging stakeholder participation, ensuring healthy food production and water management, etc). Within the scope of carbon farming, agroforestry practices are an approach that aims to provide environmental, economic and social benefits through sustainable agricultural practices in rural and urban areas. This model will reduce carbon emissions on agricultural land while offering farmers the opportunity to earn additional income through carbon credits. This study has examined and interpreted the importance and applicability of carbon farming and agroforestry systems within the context of sustainable land management aimed at reducing carbon emissions and adapting to climate change.

Keywords: Carbon farming, agroforestry systems, land use, climate change, carbon sequestration, ecology

1. Introduction

Since the beginning of the industrial revolution in the 18th century, humans began using fossil fuels, which had stored CO_2 for millions of years. Consequently, increased production and consumption activities resulted in the emission of even more greenhouse gases. Natural resources have been continually altered, reshaped, and irreversibly destroyed through human intervention for economic gain.

Today, climate change, resulting from the disruption of the carbon cycle in nature as a result of human activities, has become one of the most urgent and complex problems facing humanity. In this context, climate change threatens ecological balance, social structures, and economic systems on a global scale (Mccarty, 2001; Tol, 2018; Stock, 2020; Gül et al., 2024).

Reports from the Intergovernmental Panel on Climate Change (IPCC) indicate that the likelihood of limiting global warming to 1.5°C is diminishing unless rapid and deep cuts are made in global greenhouse gas emissions from human activities. These factors are driven by unsustainable energy use, land use and land-use change, lifestyles, and unequal and equitable consumption and production patterns across regions, countries, and within countries, as well as between individuals. This leads to widespread negative impacts on food and water security, human health, economies, and society, as well as losses and damages to nature and people (IPCC, 2023; Landscape Institute, 2008).

Countries and governments, along with official institutions, non-governmental organizations (NGOs), professional disciplines, and the public are closely involved in mitigating the negative impacts of global climate change and supporting the adaptation process (IPCC, 1990). In this context, various strategies, policies, and carbon pricing mechanisms are being implemented at the international and national levels. This new economic order is considered an ethical tool for the protection and sustainability of human health, natural ecosystems, and the cultural environment (Gül, 2024; Gül et al., 2023).

The negative impacts of climate change, now a global threat, and the struggle to adapt are not perceived solely as an environmental problem. On the contrary, the global transition to a low-carbon economy is envisioned as a fundamental transformation in people's lives, including economic, energy, health, agriculture, and food security policies, as part of countries' growth strategies.

In this context, one of the most significant factors contributing to the negative impacts or problems of climate change arises from the misuse and mismanagement of land. Land is a specific part of the earth's surface where all human production and consumption activities take place, affecting the current and future use of all land-related sectors and sub-sectors. Today, the demands of sectors and sub-sectors regarding land use have increased and diversified. Therefore, prioritizing appropriate uses based on land characteristics, capacity, and capabilities has become crucial.

Land use decisions made in the past and today have negative consequences, notably climate change and increased carbon emissions, as well as decreased biodiversity, environmental pollution, food crises, deterioration, water pollution, land degradation, erosion, and desertification, ultimately laying the foundation for global problems. Land and climate interact in complex ways through challenging changes at different spatial and temporal scales and numerous biophysical and biogeochemical feedbacks. Consequently, not only are land use patterns causing climate change, but climate change has also directly impacted land use.

According to the IPCC's Fifth Assessment Report, 25% of global greenhouse gas emissions originate from land use (IPCC, 2014). The agricultural sector accounts for a significant portion of these emissions. Misuse and inappropriate land use, in particular, are a fundamental factor contributing to and contributing to climate change. The IPCC report estimates that climate-smart land use could sequester between 7.2 and 10.6 Gt (Gigatons) of CO_2 equivalents annually by 2030 (UNCCD, 2015).

Carbon farming has become increasingly important to facilitate and promote the use of high-quality carbon removals and soil emission reductions, enhancing biodiversity as a complement to sustainable emission reductions. Sustainable Land Management (SLM)

policies include the protection and planned use of land through the use of Decision Support Systems (DSS), the creation of carbon sinks to reduce greenhouse gas emissions, and Carbon Farming (CF) practices. This approach provides an effective strategy for combating climate change by enabling the soil to store more carbon (Erpul et al., 2018; Erpul et al., 2020).

Carbon Farming is a holistic farm approach to optimizing carbon capture on working land by implementing practices known to improve the rate at which CO_2 is removed from the atmosphere and stored in plant material and/or soil organic matter. Carbon Farming is a framework for engaging with agro-ecosystem processes that drive systems change (Carbon Cycle Institute, 2022).

In this study, the importance and applicability of carbon farming and agroforestry systems in the climate change adaptation process and within the scope of sustainable land management to reduce carbon emissions are revealed and interpreted.

2. Relationship between Sustainable Land Management and Climate Change

Sustainable land planning/management, landscape improvement studies, practices that take into account carbon capture/storage functions, calculating the amount of sequestered carbon, monitoring changes in carbon stocks, nature-based solutions, etc. are among the primary strategic urgent actions for the global climate change adaptation process.

Using land in a climate-sensitive manner has significant potential to reduce greenhouse gas emissions. Sustainable Land Management (SLM) policies include soil conservation and planned use, the creation of carbon sinks (natural ecosystems, protected areas, and urban green spaces) to reduce greenhouse gas emissions, and Carbon Farming (CFP) practices. This approach provides an effective strategy for combating climate change by enabling soil to store more carbon (Erpul et al., 2018; Erpul et al., 2020).

In our country, according to Climate Law (İklim Kanunu) No. 7552, dated July 9, 2025, and numbered 32951, activities for reducing greenhouse gas emissions are stipulated as follows: "Article 5.5.: *Measures shall be taken by relevant institutions and organizations to prevent carbon sink losses in forests, agricultural lands, pastures, and wetlands to balance emissions aimed at achieving the net zero emissions target. Sink areas and protected areas shall be protected and increased*" (İklim Kanunu, 2025).

Sustainable Land Management approaches are divided into four main categories, providing holistic solutions to increase land productivity, store carbon, reduce land degradation, improve and protect ecosystem services, and reduce erosion severity:

- Administrative measures: Guide land use through legal regulations and strategic plans.
- Cultural measures: Involve the adoption of sustainable techniques in agricultural and forestry practices.
- Vegetative measures: Manage and enhance vegetation.
- Structural measures: Include physical infrastructure projects such as terracing and water harvesting.

Agriculture, forestry, and other land use (AFOLU) is a significant source of net greenhouse gas emissions. It contributed approximately 23% of total carbon dioxide (CO_2), methane (CH4), and nitrous oxide (N_2O) emissions between 2007 and 2016. AFOLU contributes to the

emissions of CO_2, CH_4, and N_2O into the atmosphere and the removal of these gases from the atmosphere. These flows are simultaneously influenced by natural and anthropogenic factors, making it difficult to distinguish natural flows from anthropogenic flows (IPCC, 2019).

Agricultural production in Turkey is largely carried out using traditional methods. Organic farming accounts for 1.5 percent of the total cultivated agricultural area, and Good Agricultural Practices (GAP) apply to 2.8 percent (T.C. Tarım & Orman Bakanlığı, 2025).

Agricultural Sector Strategies within the Scope of the 2053 Net Zero Emissions Target are envisaged as follows (T.C. Çevre, Şehircilik ve İklim Değişikliği Bakanlığı, 2025).

- Strategy 1. Improving soil and water management,
- Strategy 2. Promoting climate-friendly agricultural practices,
- Strategy 3. Improving the management of loss, waste and residues in agricultural production,
- Strategy 4. Promoting education, awareness-raising and capacity-building activities with a focus on gender balance.

2. The Concept of Carbon Farming

Carbon farming is a land use model that aims to reduce carbon emissions over a specific activity period, sequester and store carbon in the atmosphere, improve soil health, and protect natural ecosystems as part of sustainable land management agricultural practices. This model enables farmers to generate income by reducing their environmental impact, while also aiming to add financial value to carbon credits through the carbon market. Ultimately, it is expected to play a significant role in combating climate change due to its multifaceted services and contributions. Carbon Farming is a land management approach that gained global attention following the entry into force of the Kyoto Protocol in 2004 (Erpul et al., 2024).

Carbon farming encompasses a range of agricultural practices, including land use changes as well as more technological solutions. In particular, practices such as agroforestry systems, multi-purpose plantations, and land rehabilitation are linked to natural processes in agricultural ecosystems. They can also provide numerous benefits, such as increasing production intensity per hectare, preventing land from being left fallow, enhancing the sustainability of ecological agriculture, improving yield stability by increasing resilience to climate impacts, soil and water conservation, producing fodder crops, more efficient use of animal feeding regimes, and increasing product diversity.

Carbon farming refers to the management of carbon pools, flows and GHG fluxes at farm level, with the purpose of mitigating climate change. This involves the management of both land and livestock, all pools of carbon in soils, materials and vegetation, plus fluxes of carbon dioxide (CO_2) and methane (CH_4), as well as nitrous oxide (N_2O) (which is included among relevant fluxes of GHGs in the agricultural sector by the Intergovernmental Panel on Climate Change (IPCC) and therefore is considered part of carbon farming) (COWI, Ekoloji Enstitüsü ve IEEP, 2021a).

Carbon farming is an agricultural management system that helps the soil store more carbon and reduce the amount of greenhouse gases released into the atmosphere. It is a type of

carbon sequestration process. In this process, not only CO_2 but also other forms of CO_2 are stored. This practice helps the soil store carbon, remove greenhouse gases from the atmosphere, and benefit nearby water sources. At the same time, the implementation of fertiliser reduction strategies such as organic compost fertiliser and green manure can also help reduce emissions by decreasing the amount of greenhouse gases accumulated in plant cover.

Carbon farming also refers to a new farmer business model that provides incentives for farmers to adopt agricultural practices that deliver climate benefits at the farm level. Land operated and managed through carbon farming has significant potential and capacity for voluntary carbon credit schemes. These incentives may come from public funds, private payments, or a combination of both, within the scope of carbon crediting and certification. After completing the necessary procedures by applying to platforms that provide carbon credit accreditation and sales (Gold Standard, Global Carbon Council, etc.), it may be possible to generate income from this area through carbon trading. Following the certification of carbon credits, credit holders are offered the opportunity to sell their sales rights on the voluntary carbon market.

2.1. Carbon Farming Practices

Carbon farming encompasses practices that increase carbon sequestration and storage in rural and urban areas or reduce greenhouse gas emissions from soils. The Carbon Removal and Carbon Farming (CRCF) Regulation (EU/2024/3012) proposes the following practices (European Commission, 2025):

- **Agricultural Forestry (Mixed) Farming**: Within the scope of carbon farming, the aim is to use agricultural forestry systems on land, combining trees, shrubs and herbaceous plants in different patterns. These systems aim to produce multiple products per unit area, generate multifunctional ecosystem services, capture and store carbon, support biodiversity, and mitigate the adverse effects of climate change.
- **Sustainable Soil Management Practices**: These are projects that aim to increase carbon storage in the soil, reduce nitrous oxide emissions, and increase fertiliser use efficiency through sustainable practices in agriculture and techniques for soil improvement and protection, using methods such as cover crops, grassland and pasture planting.
- **Afforestation/Reforestation Projects**: These are initiatives that promote carbon sequestration and enhance ecosystem services by planting new trees on land or reforesting damaged forest areas, thereby supporting biodiversity and sustainable forest management.
- **Forest Protection Projects (REDD+):** These are initiatives undertaken to protect existing forests, ensure their sustainable management, prevent deforestation, reduce carbon emissions, and ensure the sustainability of forest ecosystem services.
- **Sustainable Water Management Practices**: These are practices for the protection, rehabilitation and improvement of water resources, wetlands, peatlands and degraded areas.

2.2.**Advantages of Carbon Farming Practices** (COWI, Ecologic Institute and IEEP, 2021; Erpul et al., 2024).

- It offers economic opportunities by encouraging innovation and entrepreneurship among landowners and investors.
- It also increases economic diversity by providing the opportunity to obtain multi-purpose products.
- It offers mixed system patterns that enhance ecosystem services through a combination of trees, shrubs and herbaceous plants.
- It has the potential to create employment for local communities.
- It plays an important role in combating climate change with its capacity to sequester carbon over the long term.
- It provides high reliability and appeal by establishing a clearer link between payments and carbon impacts for buyers.
- It contributes to local development by making unproductive and degraded land more productive through afforestation.
- It raises awareness among local communities and plays an educational role.
- It promotes social solidarity by fostering a culture of mutual aid and cooperation.

Carbon farming provides mutual benefits to farmers and society, but there are also uncertainties and risks associated with its widespread adoption in our country: (COWI, Ecologic Institute and IEEP, 2021; Erpul et al., 2024)

- There is uncertainty regarding financial support and incentives for projects, which creates risk for investors.
- Carbon farming practices may involve high transaction costs.
- The difficulty in obtaining high-quality, standardised seedling materials can hinder the implementation of projects.
- There is a risk that the costs of carbon certification, monitoring, reporting and verification (MRV) and auditing accuracy will be high.
- There are difficulties in applying reliability criteria in carbon calculation and verification processes.
- Problems in ensuring the permanence of carbon effects may threaten the long-term sustainability of carbon farming.
- The lack of technical advisory support may also hinder the effective implementation of CF projects.
- Carbon stored in soils and biomass may be released back into the atmosphere, either intentionally or unintentionally, reducing the positive climate benefits of carbon farming.

2.3. Carbon Farming in the European Union

Carbon farming has been recognised in recent years as a necessity for both sustainable agriculture and adaptation to climate impacts, particularly in EU countries.

In this context, the Carbon Removal and Carbon Farming Regulation (CRCF) (EU/2024/3012), published in Europe on 6 December 2024, has established the first EU-wide voluntary framework for the certification of carbon removal, carbon farming and carbon storage in products across Europe. EU quality criteria, monitoring and reporting processes have been defined. The CRCF Regulation envisages investment in innovative carbon removal technologies and sustainable carbon farming solutions to promote carbon farming in a manner that meets the EU Green Deal targets (European Commission, 2025).

Within the context of this Regulation, it is anticipated that the widespread adoption of sustainable agricultural practices, with the support of all actors in the agri-food value chain, could help improve farm resilience, income stability and food security while reducing greenhouse gas emissions and increasing carbon sequestration. The variable environment in which EU farmers operate will require greater policy certainty and better solutions for a more predictable future, and market-based climate policies or standards are considered to have the potential to play an important role in achieving this goal. Such measures are expected to provide farmers with fairer rewards, increase climate resilience and environmental integrity, and create new potential job opportunities for sustainable agriculture-food value chains (European Commission, 2025).

Under the European Green Deal Agreement, the aim is to reduce greenhouse gas emissions by 55 per cent compared to 1990 levels by 2030 and to achieve carbon neutrality by 2050. According to the latest report by the Food and Agriculture Organisation of the United Nations (FAO), livestock farming (all species and sectors combined) is responsible for 14.5 per cent of global anthropogenic greenhouse gas emissions. In this context, the LIFE Carbon Farming project aims to reduce the carbon footprint of 700 European farms in six countries by 15% (European Commission, 2025).

Three tools are used in the LIFE Carbon Farming project. These are: (European Commission, 2025).

- CAP2ER in France, Belgium, Italy and Germany
- AgNav in Ireland
- BovidCO_2 in Spain
- ArdiCarbon and SheepLCA are tools used specifically in the LIFE Green Sheep project.

2.4.Carbon Credits & Certification and Carbon Farming

The UN Climate Change Conference (COP21) held in Paris marked a significant turning point for market-based approaches such as carbon pricing in the fight against global climate change (UNFCCC, 2023).

Carbon pricing aims to reflect the costs associated with greenhouse gas emissions by pricing the amount of CO2 released, thereby passing these costs on to those responsible and reducing the potential for new costs to arise. To this end, protocols signed at the state level envisage a carbon market that will operate according to market rules and mandatory and voluntary project and market-based flexibility mechanisms to achieve greenhouse gas reduction and

limitation targets and reduce the cost of emission reduction measures (Ülgen & Günes, 2016; The World Bank, 2022; Gül & Akten, 2022).

I. Mandatory mechanisms: (a. Project-based mechanisms b. Market-based mechanisms (Emissions Trading System, ETS, and Carbon tax)

II. Voluntary Mechanisms: (a. Project-based Voluntary Carbon Market, b. Market-based)

A carbon credit is a financial value attributed to an organisation or country for reducing its carbon footprint. There are two types of carbon markets: mandatory and voluntary. Depending on the type of market, carbon credits can be traded, sold or resold. This financial value depends on the carbon market and the degree of reduction in CO_2 equivalent emissions. The UN defines carbon credits as 'a transferable and assignable credit recorded in an emissions account after a reduction in greenhouse gas emissions has been verified for a company, institution, or country.' However, the remainder of the definition provided in relation to the Kyoto Protocol only concerns the mandatory carbon market (European Commission, 2025).

Carbon certification refers to the process of officially recording plant carbon in metric tons (Erpul et al., 2024). Carbon certification methodologies are expected to establish standardised core values that represent the standard performance of applications and processes to a high degree, based on similar social, economic, environmental, regulatory and technological conditions, and taking into account the geographical context, including local cultural and regulatory conditions. In the context of carbon farming, carbon crediting and certification of practices and processes aimed at carbon sequestration and storage, particularly for a specific period, beyond existing agricultural practices, is envisaged. Carbon crediting mechanism categories can be summarised as follows (European Commission, 2025).

- International Crediting Mechanisms: These are mechanisms controlled by international climate agreements and typically managed by international institutions (e.g. CDM and Joint Implementation).
- Independent Crediting Mechanisms: Independent crediting mechanisms are programmes not controlled by national or international agreements (e.g. VCS, Gold Standard, CC as a voluntary market). These are managed by independent third-party organisations.
- Regional, National And Local Crediting Mechanisms: These are programmes governed by the rules of the relevant jurisdiction (e.g. Tokyo Offset Programme, Quebec Offset System, Japan Joint Crediting Mechanism, CCER).

Carbon certification refers to the system established for the official recording of carbon to be retained, in metric tonnes, subject to certain conditions and a schedule. In the management process of the carbon farming project, the total amount of carbon is measured and recorded from the first year of establishment. The registration of the land in the registry system, the certification of carbon, and the processing of these certificates in the registry system form the legal and administrative infrastructure of the process. The carbon emissions captured within the framework of carbon farming activities must be measured and reported in metric tonnes, linked to a carbon emissions certificate issued by accredited and independent organisations,

and verified. A substantive and standardised certificate format is established here. The project is certified according to internationally recognised standards (VCS or Gold Standard). The form, content, issuer, beneficiary, etc. of this certificate are specified in a specially created valuable document. The plant carbon recorded in the registry and certified must be monitored in all respects, both in the legal system and in carbon sequestration practice, and the relevant individuals and institutions must be audited throughout the process until it is ultimately commercialised. In this context, monitoring and supervision refer to recording all the characteristics of the project area from the outset and repeating this process at regular intervals.

3. Agroforestry Systems

Within the scope of carbon farming practices, one of the most important practices that increase carbon sequestration and storage or reduce greenhouse gas emissions from soils is the implementation of agroforestry systems.

Agroforestry systems are a land use technique that maximises profit from the ecological and economic interactions between trees, agricultural crops and livestock on the same land, within the same time and space framework (Nair, 1993.

Agroforestry promotes biodiversity and produces many ecosystem services by integrating trees and shrubs, agricultural crops and/or livestock on the same land. This is not a new application; on the contrary, food, fodder, fiber and fuel have been widely produced by mixing trees and crops throughout human history. The promotion and development of agroforestry for food production can help reduce problems such as climate change, environmental degradation and biodiversity loss (Agroforestry Network, 2020)

Agroforestry systems are a planned and continuous land use technique that increases the income level of the community by combining trees, shrubs and herbaceous plants on the same land to produce at least two products, within the scope of carbon sequestration and storage, soil and water conservation and improvement. Woody and herbaceous plants used in agroforestry applications enable carbon to be stored in above-ground biomass and in the soil (Gül, 2022).

The carbon sequestration and storage potential of agroforestry depends on its intended use, the type of system implemented, the plant species used, climatic and soil conditions, and previous land use (Gül, 2024). Systems integrating forestry into fields and forestry-related systems, particularly areas with dense fast-growing trees (Feliciano et al. 2018), offer high reduction potential; hedges or field boundary tree cover offer lower reduction potential. Systems with lower mitigation potential may be easier to integrate into the landscape as they affect only a small portion of agricultural land (Drexler et al., 2021).

The fundamental principles of agroforestry are as follows (Nair, 1993; Tolunay et al., 1997; Ellis et al., 2005; Gül, et al., 2011).

1- It is a distinct land use system that combines various production systems such as agriculture, forestry, horticulture, fruit growing, and animal husbandry.

2- It involves producing trees, agricultural products and livestock as a whole on a specific piece of land in order to increase productivity and reduce production risks.

3- Agroforestry practices have much more product diversity than monoculture. Production is spread over a longer period. In this case, farmers have a more regular income throughout the year. The ability to produce continuously or sustainably is the most important feature of agroforestry.

4-When forest trees are grown alongside agricultural products, all plants have the opportunity to utilise more sunlight, soil moisture, and nutrients in the soil than in monoculture. This is because in this system, forest trees, agricultural products, and animals generally utilise different parts of the biosphere. As a result, total biomass production increases. Trees compete with annual or perennial agricultural products for sunlight, nutrients and soil moisture. Nevertheless, the impact of trees in agroforestry systems is positive.

In agroforestry practices, in addition to obtaining multiple products, productivity, sustainability, economic efficiency, soil and water conservation, erosion control, enrichment of the growing environment with organic matter, improvement of its physical and chemical properties, and increased yield potential are taken into consideration (Şefik 1995, Young, 1989). It also contributes to mitigating and adapting to the adverse effects of climate change. The main criteria in the evaluation of TOS are: a-Productivity, b-Sustainability, c-Adaptability, and d-Acceptability (Nair, 1993).

3.2. Benefits and Challenges of Agroforestry Systems

The benefits of Agroforestry Systems can be summarised as follows (Geray & Görcelioğlu, 1983; Young, 1986; Kang et al., 1990; Nair, 1993; Sefik, 1995, Peters, 2000; Ellis, 2004; Gül, et al., 2011; FAO, 2022).

Enables multifaceted utilisation of the soil

- Improves and develops the chemical, physical and biological properties of the soil
- Reduces soil erosion
- Corrects the microclimate, reduces air temperature and wind speed
- Reduces the risk of crop loss
- Reduces risks due to having two or more crop varieties.
- Increases total production quantity and quality
- Has a positive effect through tree shading
- Increases the farmer's crop variety and income
- Generates reserve capital
- Provides employment opportunities,
- Reduces total facility and maintenance costs
- Increases land value,
- Creates employment opportunities in rural areas and reduces migration

- Develops domestic and foreign trade
- Lowering agricultural production prices increases total net income and contributes appropriately to the national economy
- Conserves existing natural resources and prevents desertification
- Prevents floods and water overflows and extends the life of dams.

Challenges of Agroforestry Systems (Geray & Görcelioğlu, 1983; Young, 1986; Kang et al., 1990; Nair, 1993; Sefik, 1995, Peters, 2000; Ellis, 2004; Gül, et al., 2011; FAO, 2022).

- Competition between annual and perennial plants,
- The need for time to repeat the product,
- Additional maintenance and protection costs,
- Soil cultivation costs
- The need for financial support,
- The existence of courses, training and promotional expenses,
- The necessity of marketing the products,
- The existence of mechanism transfer costs,
- The existence of research costs to develop technological principles,
- Insufficiencies in the creation and implementation of land use policy.

3.3. Methods Used in Agroforestry

The plants to be cultivated in agroforestry systems are determined by considering the characteristics of the plants, soil, climate, topography, altitude, and socioeconomic factors. The applications of agroforestry systems can be divided into two separate groups (Turna 1992; Şefik, 1995; Dosskey, et al., 1997; Acar et al., 2002; Gül, et al., 2011).

(1) **Crop Rotation System**: It is based on the principle of temporary arrangement of crops. Annual agricultural crops and cash crops are grown together with trees. There are two types of rotation methods in this classification.

a) **Rotational Cultivation:** This is the oldest known agroforestry system. Agricultural crops are grown for 2-3 years to allow forest tree seedlings to be planted and to enable the nutrients stored in the forest biomass to be reclaimed. This is followed by 8-10 years of growing forest trees. The system thus continues in a rotational manner.

b- **Taungya System**: This is a low-cost approach for afforestation of open land. Agricultural crops are grown while the trees are young and before they begin to shade. Once the trees start to shade, agricultural crop production is stopped and transferred to another open area, where the same practices are repeated. There are two types of Taungya systems. In the first type, trees and agricultural products are grown in the same area for the first 3 years, then forest trees are planted from the 3rd to the 11th year. In this way, the forest is grown, and after the forest is cut down, the system continues in

the same way. In the second type, agricultural products are cultivated for the first 3 years, then trees and agricultural products are cultivated together between the 3rd and 6th years, and only forest trees are cultivated from the 6th to the 14th year, and this continues in a cyclical manner.

(2) **Intercropping System:** In this system, trees and agricultural products are cultivated simultaneously. These products are cultivated in such a way that they do not compete with each other at all; on the contrary, they support each other. Thus, the yield per hectare increases every year. There are three subsystems of this type.

a- Tree Planting Along Boundaries: In this system, trees are grown along the edges of fields as windbreaks, fences, and boundary markers. These functions complement services in protecting and improving fields through the use of green manure as organic fertilizer, producing animal feed for farm animals, and producing firewood. Trees are grown along the boundaries of fields, while agricultural products are grown in the inner parts, and in this way, trees also increase the productivity of agricultural products.

b-Changing Rows and Strips**:** This system is referred to as a two-sided tree-lined road, narrow road, and corridor. Cultivation is carried out in this manner. A strip consists of two or more rows, while a row consists of a single row. If this system is applied along contour lines or against the slope, it is more effective in terms of erosion control and improving sloping terrain. In the row method, trees are grown in one row and agricultural products in the next row, and this pattern is followed. In the strip system, trees are grown in two or more rows, followed by agricultural products in the next two or more rows, and this pattern is followed until the field is completed. The distance between rows can be 3-4-5-6 m.

c- Random Mixing: In this system, trees and agricultural products are arranged in a mixed pattern without any rules, so they do not compete with each other. Products are placed in their own specific ecological niches to coexist in the best possible way.

Agroforestry increases carbon storage in both vegetation and soil by integrating trees and shrubs into agricultural land. Minimum tillage reduces soil disturbance, thereby preserving soil organic carbon and improving soil structure, which sustainably increases soil fertility in the long term. Similarly, organic farming promotes soil biodiversity and increases carbon storage capacity by minimizing the use of synthetic inputs. Cover crops and crop rotation increase soil organic matter, raising the soil's carbon sequestration potential while also improving soil fertility and maintaining ecosystem balance. Integrated nutrient management increases agricultural production efficiency while minimizing environmental impacts, optimizing fertilizer use, reducing emissions, and promoting sustainable growth (Turna 1992; Şefik, 1995; Gül, 2022).

5. Conclusions and Recommendations

Climate change has brought new paradigms to the fore regarding plant and animal production or breeding methods and food resource management, which require a new economic, ecological, social, political and technical structure at the global level in order to mitigate its adverse effects and facilitate the adaptation process.

There is a need to develop innovative sustainable land management policies that target resilient ecosystems, one of the fundamental elements of the country's green transformation aimed at mitigating the adverse effects of climate change and facilitating the adaptation process.

Thus, the aim is to maximise the adaptation and mitigation potential of ecosystems in combating climate change. Climate change is an urgent situation that can only be prevented and its effects mitigated through a coordinated approach and actions at global, regional and local levels.

The carbon farming approach is a new farmer business model and sustainable land management that creates multi-faceted added value (e.g. promoting sustainable agricultural practices, enabling greater carbon sequestration and storage in soil and plants over a specific activity period, reducing greenhouse gas emissions into the atmosphere, supporting ecosystem conservation, improving soil health, strengthening local economies, creating employment, encouraging stakeholder participation, enabling healthy food production and water management, and others)

The carbon farming model is recognised as a multi-dimensional strategy that aims to establish a sustainable balance between the agriculture and forestry sectors and environmental management, thereby supporting the reduction of future climate change impacts, the protection of ecosystems, carbon sequestration, healthy food production, water management, increased social welfare, and economic sustainability.

Carbon farming encompasses agroforestry practices that aim to deliver environmental, economic and social benefits through sustainable agricultural practices in both rural and urban areas. This model will reduce carbon emissions from agricultural land while offering farmers the opportunity to earn additional income through carbon credits.

The primary objective of carbon farming focused on agroforestry systems is to increase the carbon storage capacity of land combined with trees, shrubs and herbaceous plants and to ensure the sustainable management of this land in the context of carbon crediting and certification. Agroforestry practices require a long period of time for trees to grow and reach full productivity. A management period of 15-25 years should be targeted for the rooting, growth and maximum carbon sequestration of trees.

In this context, the planning, implementation and management process of agroforestry-focused carbon farming must be comprehensively designed to suit the purpose, managed effectively and sustainably, with risks and threats predicted in advance, and be sustainable, measurable and traceable in accordance with national and international standards. Furthermore, it is crucial that carbon emissions trading is processed in line with real market conditions and that this process is guaranteed.

However, project implementation and management processes aimed at carbon emission reduction should be organised in a manner that contributes to the sustainability of natural resources and ecosystem services, rather than being based on market conditions for carbon trading.

Thanks and Information Note

The article complies with national and international research and publication ethics. All authors contributed equally to the article.

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Examination of the Current Spatial Status of Legally Protected Areas in Demre (Antalya) District

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Abstract

Urbanisation movements gaining momentum on a global scale, industrialisation, and anthropogenic pressures concentrated particularly in coastal regions pose a serious threat to the sustainability of natural and cultural heritage areas. This study aims to examine the spatial distribution and current status of legally protected areas in the Demre district of Antalya province, which hosts multi-layered protection statuses and sensitive ecosystems. Spatial analyses were conducted using Geographic Information System (GIS) technologies, based on the 1:100,000 scale Environmental Planning Data approved by the Ministry of Environment, Urbanisation and Climate Change of the Republic of Turkey. According to the findings, an area of 113.16 km², corresponding to 31.43% of the total area of Demre district, has legal protection status. These areas form a comprehensive, multi-layered structure consisting of archaeological sites such as the Kaş-Kekova Special Environmental Protection Area, Beymelek Lagoon and its surroundings, and Myra-Andriake. The study emphasised that, considering the district's world-renowned Lycian Way hiking route passing through its borders, as well as its Cittaslow and UNWTO Best Tourism Village titles, a holistic and sustainable area management strategy should be adopted instead of fragmented conservation decisions.

Keywords: Demre (Antalya), protected areas, spatial analysis, sustainability, geographic information systems

1. Introduction

Along with the increase in the world's population, industrialisation, anthropogenic pollution, oppressive human activities and urban development movements are increasing day by day. Protected areas are under pressure from these activities at both national and international levels. These areas, which contain both natural and cultural assets, offer an important perspective on both the past and the future with their multi-layered structure. Accelerating land use and land cover changes on a global scale, biodiversity loss, ecosystem fragmentation, and increased anthropogenic pressures on natural resources have led to protected areas playing a critical role in sustainability (Ellis & Ramankutty, 2008; Foley et al., 2005; Venter et al., 2016; Haddad et al., 2015; Maxwell et al., 2016; Edgar et al., 2014; Demirel et al., 2021; Gül & Metin, 2021). Kuvan (2005) describes protected areas as an indispensable element of nature conservation efforts. The International Union for the Conservation of Nature (IUCN, 1978) defines protected areas as geographical regions with legally defined boundaries that ensure the long-term sustainability of biological diversity as well as aesthetic and cultural values. Another definition by Dudley & Stolton (2008) states that protected areas

are land and/or marine areas managed by legal or other effective means, where not only biological diversity but also cultural values associated with natural resources are protected and sustained. Similarly, in line with Kuvan's (1991) emphasis on the need for protection in relation to natural resources, national and international efforts have been initiated in many countries to grant these assets 'protected area' status in order to prevent the misuse of natural and cultural assets and to achieve measurable, manageable and effective protection based on scientific and technical principles.

These definitions and the growing awareness of conservation are also reflected in concrete data. Over the years, the number of Protected and Conserved Areas (PCAs) has increased; today, 17% of terrestrial and inland water areas and approximately 10% of the world's oceans are under protection. In the last decade alone, the amount of protected land has reached seven times the size of India. These areas, which are fundamental to the conservation of biodiversity, are also recognised as one of the most important tools in combating climate change (mitigation) and adaptation processes, as well as in strengthening socio-economic and environmental benefits. (IUCN, n.d.). Indeed, protected areas around the world provide multifaceted services and contributions such as improving and enhancing the climate, protecting soil and water, increasing biodiversity, contributing positively to human health, increasing wildlife and plant species diversity, and contributing to tourism and recreation (Yıldırım & Erol, 2012; Gül & Metin, 2021; Gül et al., 2021; Demirel et al., 2021;).

The purpose of protected areas is to conserve biodiversity within the area (including species diversity, genetic diversity, habitat diversity, and ecological process diversity), conduct scientific research, improve environmental conditions, protect existing natural and cultural landscapes from negative impacts, and serve and contribute to tourism and recreational purposes. Protecting wildlife from negative impacts, improving the level of education, awareness, and consciousness of individuals and society, ensuring the sustainable use of natural resources, ensuring the protection and development of cultural values together with their natural environment, contributing to the social and economic development of the region, etc. (Gül, 2005; Gül & Metin, 2021; Gül et al., 2021).

This global sensitivity also applies to Türkiye which is a crossroads of civilisations with its underground and surface riches. Cultural and natural assets in Turkey are not static formations created at a single point in time, but rather dynamic formations that have emerged through a process of living and development over time and continue to accumulate today (Gürpınar, 2001). Inventory studies on protected areas in Türkiye are conducted by the relevant ministries according to the status of the area. When examining the 'Nature Conservation Status Report' published by the General Directorate of Nature Conservation and National Parks of the Ministry of Agriculture and Forestry of the Republic of Türkiye which contains current data as of 31 December 2024 reveals that the existing statistics are classified under two main headings according to management responsibilities: 'Protected Areas under the Ministry of Agriculture and Forestry' and 'Protected Areas under the Ministry of Environment, Urbanisation and Climate Change'. According to the report, there are a total of 5,891 protected areas across Turkey; 1,760 of these are under the Ministry of Agriculture and Forestry, while the majority, 4,131, are under the Ministry of Environment, Urbanisation and Climate Change. According to the latest calculations in the report, protected areas account for 7.86% of Turkey's land area and 5.96% of its marine area (Doğa Koruma Milli Parklar Genel Müdürlüğü, 2024). According to the Ministry of Culture and Tourism's end-of-year data for

2024, Turkey has a multi-layered protection network with a total of 26,128 registered archaeological sites. When examining the distribution of these areas, archaeological sites (25,353 sites, 97%) constitute the largest share, followed by 365 urban sites, 242 historical sites, 132 mixed sites, and 36 urban archaeological sites (Kültür Varlıkları ve Müzeler Genel Müdürlüğü,2024a). When examining the distribution of archaeological sites, which constitute the largest share of protected areas, it is seen that 'First Degree Archaeological Sites', where the highest level of protection measures are applied, form the largest group with 16,836 sites. These areas are followed by 'Third-Degree Archaeological Site Areas' (3,700 sites), where the balance between protection and use is maintained, 'Mixed-Degree Site Areas' (3,196 sites), and 'Second-Degree Archaeological Site Areas' (916 sites) (KVMGM, 2024b).

Within this scope, the district of Demre, located within the borders of Antalya Province, Türkiye stands out as one of the region's most sensitive ecosystems due to its different protection statuses, natural resources, and deep-rooted cultural heritage formations. According to the current Environmental Plan, an examination of the protection zones in the region reveals that the Beymelek Lagoon and its surroundings are designated as a 'Qualified Natural Protection Area', while the Mediterranean Fisheries Research, Production and Education Institute Directorate and its surroundings are designated as a 'Sustainable Protection and Controlled Use Area'. while the Üçağız-Kaleköy and Kekova regions are designated as 'Natural Sites' and are also located within the boundaries of the 'Kaş-Kekova Special Environmental Protection Area'. In addition, numerous 'Archaeological Site Areas', primarily the ancient cities of Myra and Andriake, are integrated into this multi-layered protection network throughout the district. Demre stands out for its high biodiversity potential. Within the district boundaries, there are three 'Important Natural Areas' designated according to IUCN criteria: Kale, Kekova, and Kıbrısçık (Batı Akdeniz Kalkınma Ajansı, 2021).

Demre District has natural beauties and a rich and deep-rooted historical and cultural heritage dating back from the Lycian civilization to the Ottoman Empire. It is the pearl of the Mediterranean, which fascinates with its mystical atmosphere and historical and cultural texture that bears the traces of various civilizations for thousands of years among the shores adorned with the vast blues of the Mediterranean (Gül & Erdoğan, 2024; Dündar et al., 2024).

The primary objective of this study is to determine the spatial distribution and spatial boundaries of protected areas in Demre district, which possesses rich natural and cultural assets and sensitive ecosystems, based on the data contained in the Isparta-Burdur Environmental Plan, sheets p23 and p24, published by the Ministry of Environment and Urbanisation. Antalya-Isparta-Burdur Environmental Planning Map, in accordance with the data contained in sheets p23 and p24. The aim is to analyse the level of protection of the region's natural and cultural heritage using quantitative data by establishing the proportional relationship between the district's total area and the protected areas, and to develop protection and protection-compatible use strategies.

2. Materials and Methods

The research area is the district of Demre, located in southwestern Turkey at 36°14'40.00"N latitude and 29°59'14.92"E longitude, approximately 147 km from the provincial centre of Antalya, and comprising a total of 17 neighbourhoods. An examination of the region's administrative history reveals that the settlement was first recorded in official records in 1904 as a village named 'Eynihal', that it became a municipality in 1968, and that it gained district

status under the name 'Kale' on 4 July 1987. The district adopted the name Demre, which is used today, in 2005 (BAKA, 2021).

In order to determine the boundaries of the study's legal protection status and district boundaries, sheets p23 and p24 of the current 1/100,000 scale Antalya-Isparta-Burdur Environmental Plan, approved by the Turkish Ministry of Environment, Urbanisation and Climate Change, were used as basic material.

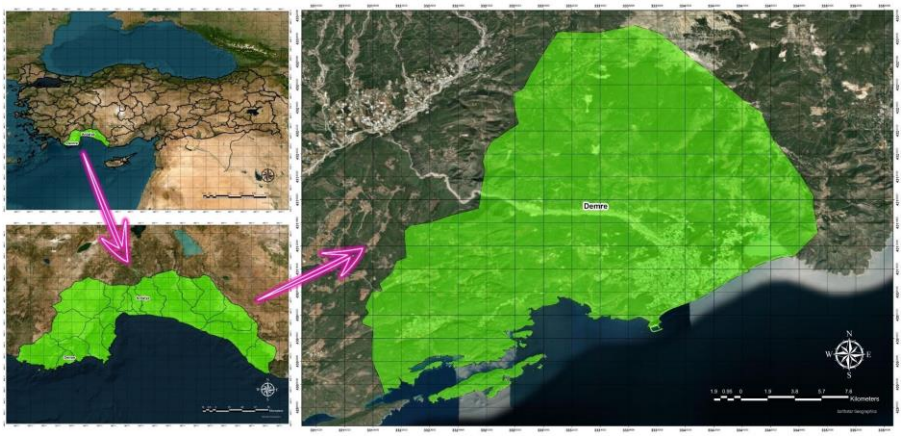


Figure 1. Research area location (From the authors' archive, 2025)

Within the scope of this study, Geographic Information Systems (GIS) technologies were utilised in the process of geographic referencing, production, processing and analysis of spatial data. In this regard, the 1:100,000 scale Environmental Planning Map Sheets (p23 and p24), which were determined as the basic base, and the current location data provided by the General Directorate of Mapping (HGM) Küre application were used. The p23 and p24 sheets belonging to the Antalya-Isparta-Burdur Environmental Planning Map were subjected to geographic referencing. The boundaries of Demre district and the boundaries of protected areas with different statuses on the raster data defined by the coordinate system were converted to vector data structure using the digitisation method on the ArcGIS Pro 3.5 software interface. The spatial dimensions of the obtained spatial data were calculated using geodetic measurement techniques, and the coordinate information was obtained using the same software infrastructure. The coordinate information and spatial dimensions of the current outputs were evaluated in relation to the district's total area and each other, and the results were interpreted.

3. Findings and Discussion

According to the Demre District Environmental Plan, the district boundaries cover an area of approximately 360 km² (land area). Although protected areas with conservation status have been identified under the Environmental Planning Scheme and the boundaries of natural and cultural protected areas have been specified, the distribution of protected areas within the boundaries of Demre District according to their types and spatial values has not been clearly established. This study clearly outlines the boundaries of the natural and cultural protected areas within the boundaries of Demre district, separates them according to status types and ratings, and calculates their spatial values. As a result of these assessments, the legally protected areas in Demre district cover a total area of 113.16 km². This value corresponds to 31.43% of Demre's land area.

The conservation statuses in Demre are: Kaş-Kekova Special Environmental Protection Area, Beymelek Lagoon and Surroundings Qualified Natural Protection Area, Mediterranean Fisheries Research, Production and Education Institute Directorate and Surroundings Sustainable Protection and Controlled Use Area, Within the Special Environmental Protection Area and on the Taşdibi Peninsula, it consists of Natural Site Areas and 1st, 2nd and 3rd degree Archaeological Site Areas located in the region, such as the Ancient City of Myra. The same area may simultaneously have multiple protection statuses. This demonstrates the multi-layered protection structure of Demre district and the high importance given to the protection of the region.

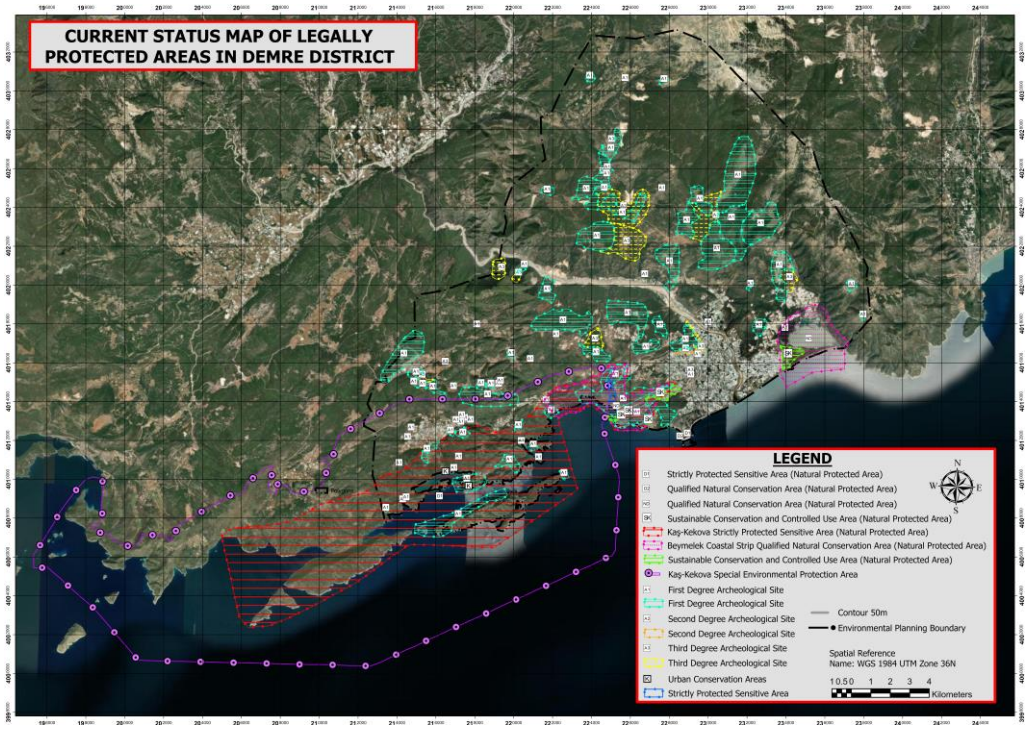


Figure 2. Current status map of legally protected areas in Demre District (From the authors' archive, 2025)

3.1. First Degree Archeological Sites in Demre

A total of 79 first-degree archaeological sites have been identified in the district of Demre. The distribution of these sites by neighbourhood is as follows: 1 in Alakent, 15 in Belören, 6 in Beymelek, 1 in Büyükkum, 3 in Çağman, 10 in Çevre, 4 in Davazlar, 4 in Gürses, 1 in Gökyazı, 9 in Kaleüçağız, 11 in Kapaklı, 3 in Karabucak, 3 in Köşkerler, and 8 in Yavu. The location and coordinates of the sites are provided in the study. Furthermore, the area values of the sites determined in accordance with the boundaries obtained as a result of the digitisation of the environmental plan are shown in hectares in the table (Table 1.). As some sites extend beyond the boundaries of more than one neighbourhood, the location information for the relevant areas has been preserved; however, data has been entered into the database under the name of the neighbourhood in which the site has the largest spatial distribution.

Table 1. First degree archeological sites in Demre Neighbourhood-location-coordinates-area size ınformation

No.	Neighbourhood	Locality	Longitude (E)	Latitude (N)	Area (ha)
1	Alakent	Karşı	029° 59' 20.87" E	36° 15' 14.89" N	Not available
2	Belören	Çayyurt	029° 57' 55.72" E	36° 19' 50.25" N	Not available
3	Belören	Yuvalca	029° 56' 2.22" E	36° 20' 22.47" N	89.95
4	Belören	Bağcaağız	029° 55' 57.36" E	36° 19' 47.79" N	24.39
5	Belören	Sartma Tepe (Hill)	029° 55' 20.14" E	36° 19' 45.02" N	143.62
6	Belören	Kocaağız Tepe (Hill)	029° 58' 48.92" E	36° 18' 58.19" N	119
7	Belören	Kuşyuvası Tepe (Hill)	029° 59' 14.69" E	36° 19' 34.44" N	90.74
8	Belören	Turanta Tepe (Hill)	030° 00' 21.21" E	36° 19' 4.97" N	271.22
9	Belören	Karadiş Tepe (Hill)	029° 59' 52.69" E	36° 18' 12.49" N	297.3
10	Belören	Alacahisar Tepe (Hill)	029° 53' 59.61" E	36° 19' 41.84" N	22.12
11	Belören	Yeniyer	029° 55' 45.0" E	36° 18' 27.31" N	223.55
12	Belören	Kuruluk Tepe (Hill)	030° 00' 31.6" E	36° 20' 16.19" N	488.09
13	Belören	Belkuyu	029° 56' 35.85" E	36° 19' 7.23" N	130.83
14	Belören	Çetirliyüz	029° 58' 16.14" E	36° 17' 48.62" N	170.41
15	Belören	Çatal Tepe (Hill)	029° 56' 1.22" E	36° 20' 11.75" N	89.95
16	Belören	Asarcık Tepe (Hill)	029° 56' 8.36" E	36° 20' 54.62" N	63.08
17	Beymelek	Koca Tepe (Hill)	030° 02' 18.34" E	36° 16' 3.31" N	Not available
18	Beymelek	Yılanbaşı	030° 01' 21.55" E	36° 18' 56.93" N	281.93
19	Beymelek	Örencik Damları	030° 02' 2.56" E	36° 17' 48.1" N	165.88
20	Beymelek	Mercimek Tepe (Hill)	030° 01' 24.52" E	36° 16' 6.96" N	44.9
21	Beymelek	Sakarcalı Tepe (Hill)	030° 04' 32.38" E	36° 17' 19.73" N	23.89
22	Beymelek	Kaklık	030° 04' 58.18" E	36° 16' 29.65" N	10.76
23	Büyükkum	Çayağzı	029° 57' 19.01" E	36° 13' 35.15" N	216.52
24	Çağman	Kazak Tepe (Hill)	029° 56' 32.88" E	36° 22' 51.78" N	Not available
25	Çağman	Mazı Sırtı	029° 57' 53.15" E	36° 22' 52.37" N	8.96
26	Çağman	Güceyman Tepe (Hill)	029° 55' 19.99" E	36° 22' 54.09" N	19.44
27	Çevreli	Kargabelen Tepe (Hill)	029° 49' 28.9" E	36° 12' 41.3" N	Not available
28	Çevreli	Kargabelen Tepe (Hill)	029° 49' 35.83" E	36° 12' 57.27" N	Not available
29	Çevreli	Zencirkurulacağı	029° 51' 37.34" E	36° 13' 13.42" N	Not available
30	Çevreli	Zencirkurulacağı	029° 51' 24.99" E	36° 13' 16.08" N	Not available
31	Çevreli	Zencirkurulacağı	029° 51' 18.80" E	36° 13' 20.73" N	Not available
32	Çevreli	Zencirkurulacağı	029° 51' 17.6" E	36° 13' 9.49" N	Not available
33	Çevreli	Zencirkurulacağı	029° 51' 7.52" E	36° 13' 12.42" N	Not available
34	Çevreli	Mucukbelen Tepe (Hill)	029° 50' 9.58" E	36° 12' 22.55" N	36.19
35	Çevreli	Asar Tepe (Hill)	029° 51' 22.44" E	36° 12' 51.97" N	26.25
36	Çevreli	Asar Tepe (Hill)	029° 50' 56.8" E	36° 12' 54.64" N	9.33
37	Davazlar	Kocakışla Tepe (Hill)	029° 51' 43.84" E	36° 15' 52.91" N	Not available
38	Davazlar	Çalbağlıkıtır Tepe (Hill)	029° 54' 41.0" E	36° 16' 4.63" N	266.3
39	Davazlar	Gavur Yolu	029° 54' 6.07" E	36° 16' 55.68" N	70.77
40	Davazlar	Payamlıöz	029° 53' 17.63" E	36° 17' 35.77" N	15.85
41	Gökyazı	Karakol Tepe (Hill)	029° 59' 7.43" E	36° 14' 40.46" N	Not available
42	Gürses	Deligözlek Tepe (Hill)	029° 55' 51.12" E	36° 15' 12.94" N	67.23
43	Gürses	Hüseyinhocalar Tepe (Hill)	029° 58' 0.63" E	36° 16' 2.08" N	46.5
44	Gürses	Akköristan Tepe (Hill)	029° 56' 53.77" E	36° 16' 20.26" N	242.81
45	Gürses	İnönü	029° 54' 27.15" E	36° 15' 40.74" N	Not available
46	Kaleüçağız	Mucukbelen Tepe (Hill)	029° 49' 13.14" E	36° 11' 57.57" N	Not available
47	Kaleüçağız	Alt Tepe (Hill)	029° 49' 23.26" E	36° 10' 57.01" N	Not available
48	Kaleüçağız	Alt Tepe (Hill)	029° 49' 30.24" E	36° 11' 0.55" N	Not available
49	Kaleüçağız	Çapaklık Tepe (Hill)	029° 51' 15.29" E	36° 12' 11.45" N	Not available
50	Kaleüçağız	Orunlu	029° 51' 6.26" E	36° 11' 52.15" N	Not available

51	Kaleüçağız	Geyikova Burnu	029° 54' 53.01" E	36° 11' 49.64" N	15.15
52	Kaleüçağız	Alan	029° 51' 33.71" E	36° 11' 34.84" N	122.91
53	Kaleüçağız	Kekova	029° 51' 18.31" E	36° 10' 35.43" N	280.68
54	Kaleüçağız	Bulamada	029° 48' 49.19" E	36° 10' 41.96" N	4.6
55	Kapaklı	Buzalık	029° 54' 11.38" E	36° 13' 50.04" N	Not available
56	Kapaklı	Buzalık	029° 54' 22.45" E	36° 13' 33.91" N	33.03
57	Kapaklı	İnlidere	029° 53' 15.89" E	36° 13' 7.1" N	16.24
58	Kapaklı	Aşırlı	029° 53' 23.2" E	36° 12' 40.92" N	Not available
59	Kapaklı	Aşırlı	029° 53' 48.04" E	36° 12' 36.08" N	13.68
60	Kapaklı	Kişneli	029° 53' 59.57" E	36° 12' 14.62" N	Not available
61	Kapaklı	Burç	029° 52' 59.93" E	36° 12' 9.33" N	58.22
62	Kapaklı	Sütkaklık Tepe (Hill)	029° 52' 10.56" E	36° 13' 56.61" N	208.59
63	Kapaklı	Sütkaklık Tepe (Hill)	029° 51' 56.5" E	36° 14' 15.28" N	7.81
64	Kapaklı	Sütkaklık Tepe (Hill)	029° 52' 17.08" E	36° 14' 14.99" N	8.97
65	Kapaklı	Üçtaş Tepe (Hill)	029° 52' 36.34" E	36° 14' 20.29" N	Not available
66	Karabucak	Kocayanık	029° 57' 33.26" E	36° 15' 24.58" N	64.02
67	Karabucak	Kule Tepe (Hill)	029° 58' 54.07" E	36° 15' 39.3" N	92.68
68	Karabucak	Karaemlik Çayı	029° 56' 32.11" E	36° 14' 37.03" N	60.74
69	Köşkerler	Kule	029° 57' 26.31" E	36° 17' 25.75" N	Not available
70	Köşkerler	Tepeardı	029° 59' 39.62" E	36° 16' 8.62" N	Not available
71	Köşkerler	Çatallar Tepe (Hill)	030° 01' 3.85" E	36° 17' 15.44" N	9.89
72	Yavu	İkizkilise Tepe (Hill)	029° 53' 36.25" E	36° 14' 58.11" N	Not available
73	Yavu	Mercimek Tepe (Hill)	029° 51' 0.12" E	36° 14' 8.52" N	Not available
74	Yavu	Asar Tepe (Hill)	029° 50' 17.88" E	36° 14' 6.92" N	59.72
75	Yavu	Asar Tepe (Hill)	029° 49' 38.19" E	36° 14' 14.05" N	59.72
76	Yavu	Bağcaklı Tepe (Hill)	029° 49' 41.95" E	36° 14' 30.37" N	26.02
77	Yavu	Asar Tepe (Hill)	029° 49' 56.35" E	36° 14' 10.94" N	59.72
78	Yavu	Asar	029° 49' 15.77" E	36° 15' 0.36" N	265.66
79	Yavu	Merdivenli Tepe (Hill)	029° 52' 56.63" E	36° 15' 7.1" N	11.48

3.2. Second Degree Archeological Sites in Demre

The area in the Karşı of Alakent Neighbourhood, where the chapel of the ancient city of Myra is located, has been designated as a second-degree archaeological site. Thanks to the thick alluvial layer, this structure, which has survived to the present day intact in terms of its static and decorative aspects, reflects the archaeological potential of the region (Akyürek, 2010). In the investigations carried out within the scope of the environmental plan, although it was difficult to distinguish the areas due to the density of the drawings and overlapping boundaries, it was seen that the only area that could be clearly identified as having second-degree site status within the scope of this study was the area in question. The coordinates of the area are 29° 59' 4.99" E and 36° 15' 24.92" N, with a total area of 24.69 hectares.

3.3.Third Degree Archeological Sites in Demre

A total of 14 third-degree archaeological sites have been identified in the district of Demre. The distribution of these sites by neighbourhood is as follows: 1 site in Alakent, 1 site in Beymelek, 4 sites in Belören, 1 site in Çağman, 2 sites in Davazlar, 1 site in Gürses, 1 site in Gökyazı, 1 site in Kapaklı, and 2 sites in Yavu. The locations and coordinate information of these archaeological sites are presented within the scope of this study. The sizes of the archaeological sites, determined in hectares based on the boundaries obtained from the digitisation of the environmental plan, are shown in Table 2.

Table 2. Third Degree Archeological Sites in Demre Neighbourhood-Location-Coordinates-Area Size Information

No.	Neighbourhood	Locality	Longitude (E)	Latitude (N)	Area (ha)
1	Alakent	Karşı	029° 59' 26.68" E	36° 15' 27.79" N	30.01
2	Beymelek	Göhsükızıl Damları	030° 02' 24.49" E	36° 17' 28.25" N	66.46
3	Belören	Yuvalca	029° 55' 53.22" E	36° 20' 15.46" N	Not available
4	Belören	Çaltıyanı	029° 56' 46.76" E	36° 18' 20.14" N	252.22
5	Belören	Yelkenağaç	029° 56' 38.26" E	36° 19' 18.22" N	357.56
6	Belören	Dereköy	029° 59' 49.04" E	36° 19' 7.86" N	186.13
7	Çağman	Eşekalan	029° 56' 8.61" E	36° 21' 9.44" N	Not available
8	Davazlar	Avcı Tepe (Hill)	029° 52' 30.99" E	36° 17' 29.68" N	62.41
9	Davazlar	Avcı Tepe (Hill)	029° 53' 6.46" E	36° 17' 21.63" N	15.1
10	Gürses	Lelelik Tepe (Hill)	029° 55' 47.76" E	36° 15' 35.52" N	64.92
11	Gökyazı	Karakol Tepe (Hill)	029° 59' 6.52" E	36° 14' 47.96" N	Not available
12	Kapaklı	Ferminde	029° 52' 32.93" E	36° 14' 15.24" N	Not available
13	Yavu	Kocaalan	029° 50' 41.29" E	36° 14' 49.0" N	Not available
14	Yavu	Asar Tepe (Hill)	029° 49' 54.86" E	36° 14' 25.94" N	16.16

3.4. Urban Conservation Areas (Kentsel Sit Alanı) in Demre

Both of the two urban archaeological sites identified in Demre district are located within the boundaries of Kaleüçağız Mahallesi. The first of these areas is Kaleköy, located at 029° 51' 37.72" E longitude and 36° 11' 26.41" N latitude, representing an important archaeological and cultural landscape that includes the ancient city of Simena. As there is no road access to the area, it can only be reached by sea; the Simena Necropolis, Kaleköy Mosque, royal tombs and other natural and cultural layers in the surrounding area can be observed. Within the neighbourhood boundaries, Kekova Island and the sunken city of Kekova located adjacent to it are also important elements that reinforce the natural and cultural integrity of the region.

The second urban site is located in the centre of Kaleüçağız Village, at 029° 50' 49.06" E longitude and 36° 11' 49.47" N latitude. The ancient settlement of Teimussa and rock tombs are located in the immediate vicinity of the village. As a result of efforts to protect and sustainably use its cultural and natural heritage, Kaleüçağız was awarded the United Nations World Tourism Organisation (UNWTO) 'Best Tourism Village 2025' award in 2025. Similarly, thanks to the sustainable living and tourism model implemented throughout the district, Demre was included in the international 'Cittaslow' network during the same period, documenting its participation in the Cittaslow network (Cittaslow Türkiye, 2025).

3.5. Kaş- Kekova Special Environmental Protection Area

According to the management plan data prepared by Ornat et al. (2013), the Kaş-Kekova Special Environmental Protection Area was declared by the Council of Ministers Decision No. 90/77 dated 18 January 1990 with the aim of comprehensively protecting its ecological and archaeological values. The region, with a total area of 258.30 km², includes the villages in the region (Kaleüçağız settlement, Çevreli, Kapaklı) and sensitive marine areas in its administrative structure. When examining the geographical boundaries of the region, it can be seen that it encompasses a rugged coastline stretching from Ulu Burun, west of the district of Kaş, to the Demre (Kale) Plain in the east, as well as a group of islands (Kekova, İç Ada, etc.) running parallel to this coastline. With its geomorphological structure exhibiting 'Dalmatian-

type' coastal features and settlements and sunken city remains belonging to the ancient Lycian civilisation, the region displays a unique structure where natural and cultural heritage are intertwined (T.C. Çevre Şehircilik ve İklim Değişikliği Bakanlığı, t.y.).

Within this general framework, as a result of the spatial analyses and boundary digitisation processes carried out on the 1/100,000 scale Environmental Planning Map sheets specific to this study, it was determined that 48.22% of the total protected area (approximately 124.56 km²) lies within the boundaries of Demre district. This spatial overlap demonstrates, with concrete data, the importance of monitoring the region's management plan decisions and conservation strategies at the Demre scale.

3.6. Beymelek Coastal Strip Natural Protected Area (Beymelek Kıyı Bandı Doğal Sit Alanı)

The Beymelek Coastal Strip Natural Site Area, located within Demre, was designated a 'First Degree Natural Site Area' in 1999 by decision of the Antalya Cultural and Natural Heritage Preservation Board due to its unique ecosystem and coastal morphology. Its boundaries were updated by the Preservation Board in 2010 (Maritime Journal, 2021). The status of the area has been reconsidered in light of changing legislation and current ecological assessments; and with the approval of the Ministry of Environment, Urbanisation and Climate Change dated 09.03.2021 and numbered E.469593, the area has been registered as a 'Qualified Natural Protection Area' and a 'Sustainable Controlled Use Area'. The boundary of the 'Strictly Protected Sensitive Area' within the area's boundaries was approved by Presidential Decree No. 3881 and entered into force upon its publication in the Official Gazette dated 22 April 2021 and numbered 31462 (T.C. Çevre Şehircilik ve İklim Değişikliği Bakanlığı, 2021).

These registered statuses do not constitute independent statuses (Qualified Natural Protection Area - Sustainable Protection and Controlled Use Area) as required by legislation and regulations, but represent the current subheadings of the 'Natural Site Area' status. As a result of digitising the boundaries of the Beymelek Lagoon and its surroundings as a Qualified Natural Protection Area in the environmental plan, the area was calculated to be 1014.12 ha. This Qualified Natural Protection Area also encompasses another status in the region, namely the Sustainable Protection and Controlled Use Area. In this context, the Sustainable Protection and Controlled Use Area within the whole covers 78.76 hectares, constituting 7.76% of the total area. Furthermore, the Mediterranean Fisheries Research, Production and Education Institute Directorate is located within the boundaries of the Sustainable Protection and Controlled Use Area.

The status definitions and classifications made in this area are based on a fundamental change in national legislation. The protection statuses previously referred to as First, Second and Third Degree Natural Protected Areas' have been updated by the 'Regulation on the Procedures and Principles for the Identification, Registration and Approval of Protected Areas' published in the Resmi Gazete dated 19.07.2012 and numbered 28358. With this regulation, natural site areas have been divided into three new categories according to their protection sensitivity: 'Strictly Protected Sensitive Areas', 'Qualified Natural Protection Areas' and 'Sustainable Protection and Controlled Use Areas'. The statuses determined for the Beymelek Lagoon have been established within the framework of the current protection and compatible use introduced by this regulation, legally guaranteeing the ecological sensitivity of the area and the sustainability of scientific research activities. (T.C. Çevre Şehircilik Bakanlığı, 2012).

3.7. Naturel Protected Areas (Doğal Sit Alanı) in Demre

When examining the protection statuses within the boundaries of Demre district, it is observed that, in addition to the 'Qualified Natural Protection' and 'Sustainable Protection and Controlled Use' areas, there are three more Natural Site areas on the current Environmental Planning Scheme. The largest of these areas in terms of surface area is located on Kekova Island within the Kaş-Kekova Special Environmental Protection Zone and covers a total of 99.16 km². As a result of the spatial analyses conducted, it was calculated that 60.60 km² of this natural site area lies within the boundaries of the Demre district, constituting 61.1% of the total area. The other two natural site areas identified are located on the Taşdibi Peninsula, in the Taşdibi Tepesi area. Following digitisation processes conducted using the current Environmental Planning Scheme maps, the spatial dimensions and coordinate information obtained for these three natural site areas are presented in Table 3.

Table 3. Naturel protected areas in Demre Neighbourhood-location-coordinates-area size ınformation

No.	Neighbourhood	Locality	Longitude (E)	Latitude (N)	Area (ha)
1	Kaleüçağız	Kekova	029° 50' 38.32" E	36° 11' 5.91" N	9919.67
2	Büyükkum	Taşdipi Tepe (Hill)	029° 59' 3.8" E	36° 13' 4.06" N	Not available
3	Büyükkum	Taşdipi Tepe (Hill)	029° 55' 53.22" E	36° 20' 15.46" N	Not available

3.8. Legally Protected Wetlands in Demre District

There are two legally protected wetlands in the district of Demre. These are the Beymelek Lagoon Wetland and the Demre Çayağzı Bird Sanctuary Wetland. Beymelek Lagoon is an important wetland located within the boundaries of Demre district, Antalya province, on the western coast of the Mediterranean Sea, and is the only natural lagoon lake in the region. Located at approximately 36°16′N – 30°03′E coordinates, the lagoon has an area of 4,561 hectares, including the legally designated wetland boundary. It is approximately 8 km from the centre of Demre district. The lagoon area has a triangular morphology, with water depths ranging from 0.5 to 2.6 metres and an average depth of approximately 1.6 metres. Beymelek Lagoon and its immediate surroundings have a multi-layered structure with different legal protection statuses, and First Degree Archaeological Site Areas are also located within the Beymelek Lagoon Wetland. The legal establishment date is stated as 19 September 2023. The lagoon area was previously operated by the Beymelek Aquaculture Production and Development Centre and is currently managed by the Mediterranean Aquaculture Research, Production and Education Institute. (DKMPM, n.d.). Upon examination of the 1/100,000 Antalya-Isparta-Burdur p24 Environmental Planning Map sheet published on the Ministry of Environment, Urbanisation and Climate Change website, the Beymelek Lagoon and its immediate surroundings are designated as a 'Qualified Natural Protection Area', the Mediterranean Fisheries Research, Production and Education Institute and its immediate surroundings are designated as a 'Sustainable Protection and Controlled Use Area', and the coastal strip stretching from the eastern part of Beymelek Lagoon to Finike is designated as a 'Strictly Protected Sensitive Area'. These findings are consistent with the decision approved by Presidential Decree No. 3881 dated 22 April 2021, published in the Resmi Gazete No. 31462 and entered into force.

Demre Çayağzı Bird Sanctuary Wetland is located in the western part of Demre district, Antalya province, in the Mediterranean Region, within the boundaries of Karabucak and Büyükkum neighbourhoods. The area covering the wetland was registered as a 'Natural Site-

Qualified Natural Protection Area' by the Ministry of Environment, Urbanisation and Climate Change on 02.09.2022 with the approval number E.4478260. Furthermore, a large part of the area falls under the status of a First-Degree Archaeological Site Area. The legal establishment date of the Demre Çayağzı Bird Paradise Wetland Area is stated as 19.09.2023. The area is located at approximately 36°14'/36°13' N and 29°58'/29°56' E coordinates and covers an area of 606 ha (DKMP, n.d.b). The 'Natural Site-Qualified Natural Protection Area' registered by the Ministry of Environment, Urbanisation and Climate Change covers 1008.35 hectares.

There are two significant stream in the region: the Karaemlik Stream and the Burguç Stream. When examined under the Protected Areas Management System Application of the General Directorate for the Protection of Natural Assets, the Karaemlik Stream is defined as a 'Sensitive Area Requiring Strict Protection'. Another protection status within the region is that of a Sustainable Protection and Controlled Use Area. This status covers part of the Çayağzı Yacht Harbour, the boat maintenance area located on the entrance route to the yacht harbour, the old industrial area recently demolished by the Demre Municipality, the immediate vicinity of the 'Nymphaion' structure where excavation work is being carried out, and the areas identified as newly developed according to satellite images in the Kumdağı Tepe area of the Büyükkum neighbourhood. These areas are closely related to the registered protection statuses within and around the boundaries of the Demre Çayağzı Bird Sanctuary Wetland (Figure 2.).

4. Conclusion and Recommendations

Protected areas are the insurance of natural systems, climate change, and biodiversity (Gül, Dinç & Gül, 2021). For the world to remain livable for all living beings, it is necessary not only to have legal regulations for the protection of natural and cultural values, but also to turn Ecopolitic (ecological policies) approaches to become state policy, effective governance organization, the development of individual and collective conservation awareness and organization, planning informed by scientific data, practices that involve expertise in the process, egalitarian and sharing approaches, sufficient financial capacity, and the development of collective wisdom (Gül & Metin, 2021).

Demre district is rich and diverse in terms of its existing natural and cultural resource values. Spatial analyses conducted within the scope of this study revealed that approximately one-third (31.43%) of the district's total area is under legal protection. The existence of 113.16 km² of protected areas proves the decisive role of the district in spatial planning processes. In particular, recent status changes in Beymelek Lagoon show that conservation approaches are not static but follow a dynamic process based on ecological requirements.

However, in addition to the existing protected areas, the region possesses numerous potential areas of value that could be granted protected status. A large part of the Demre Plain bears historical and archaeological traces, and it is estimated that most of these remains are currently buried underground as a result of the alluvial deposits brought by the Demre River in the past. Furthermore, the selection of the Lycian Way as the 'World's Most Beautiful Walking Route' in 2025, the fact that part of this route passes through the district boundaries, and Demre's Cittaslow designation necessitate the prioritisation of conservation policies.

In this context, due to the density of areas with existing potential protection status, planning and management policies for the district of Demre should be addressed with a holistic approach. The district should be planned and managed within the framework of the concept of

'Holistic Protection-Oriented Urban Planning' rather than the traditional 'Master Urban Plan' approach. The fundamental objective in designing strategic actions for the future is to implement holistic and sustainable tourism planning, taking into account absolute protection, compatible use values and unique identity.

Thanks and Information Note

The article complies with national and international research and publication ethics. Ethics Committee approval was not required for the study. All authors contributed equally to the article.

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Managing Conservation and Recreation Conflicts Under Wildfire Risk: The Case of the Dilek Peninsula National Park

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Abstract

National parks are crucial protected areas that ensure biodiversity conservation, ecosystem sustainability, and human–nature interaction. However, increasing recreational and tourism activities expose these areas to growing wildfire risks, creating a critical tension between conservation and use. Climate change—through rising temperatures, low humidity, and strong winds—further intensifies both the frequency and spread of wildfires. In the Mediterranean Basin, including Turkey, the predominance of human-induced fires makes national parks particularly vulnerable. Fire management has therefore become a priority for both ecological sustainability and visitor safety. Although Long-Term Development Plans and sub-plans such as ecotourism, forest management, and fire action programs aim to address this issue, practical deficiencies persist. Exceeding carrying capacity, uncontrolled fire use, and the lack of temporary closures during high-risk periods exacerbate the conservation–recreation conflict. The Dilek Peninsula–Büyük Menderes Delta National Park exemplifies this challenge, combining high biodiversity, fire-sensitive ecosystems, and increasing visitor pressure. It serves as both a critical national case and a representative example for other Mediterranean parks. Addressing such conflicts requires integrating carrying capacity management, risk-based access control, visitor education, and preventive as well as early-response strategies. The Dilek Peninsula case provides valuable insights for improving wildfire-oriented management in protected areas.

Keywords:, Conservation, national parks, recreation, wildfire risk

1. Introduction

Climate change is a global environmental problem that has emerged as a result of the increase in greenhouse gas emissions caused by human-induced processes such as fossil fuel consumption, industrialization, deforestation, and improper land use. These emissions lead to rising global average temperatures and significant alterations in the climate system (Sargıncı & Beyazyüz, 2022). This process particularly affects climatically sensitive regions such as the Mediterranean Basin, causing higher temperatures, irregular precipitation regimes, more frequent droughts, and the disruption of ecosystem balance (Öztürk et al., 2015; Noto et al., 2023). The decrease in precipitation and the increase in temperature create multidimensional impacts on both natural and human systems, increasing the frequency and severity of forest fires and thus intensifying ecological and economic losses (Vilà-Cabrera et al., 2018).

Although fire has been an integral component of ecosystem dynamics for millions of years, in the modern era it has evolved into a direct environmental threat due to the combined effects of climate change and human activities (Bowman et al., 2009; Duygu et al., 2012; Abatzoglou et al., 2014). Historically, fires have contributed to vegetation regeneration, species diversity, and the continuity of ecological cycles; however, today they often manifest as megafires, posing severe risks to human life, infrastructure, tourism, and natural resources (Flannigan et al., 2009; Flannigan et al., 2013; Güney, 2024; Tezcan & Eren, 2025). Toward the end of the 21st century, temperatures in the Mediterranean Basin are expected to rise while precipitation decreases, making the region one of the most vulnerable to global climate change (Legg, 2021). Indeed, in recent years, Mediterranean countries such as Turkey, Greece, Portugal, and Spain have

experienced large-scale forest fires driven by intense heatwaves, resulting in considerable ecological, economic, and social losses (Calda et al., 2020; Avcı & Korkmaz, 2021).

Turkey is among the countries highly sensitive to the impacts of climate change. Over the past four decades, the duration and intensity of heatwaves have increased, while summer droughts have deepened, particularly in the Mediterranean and Aegean regions (Avcı & Korkmaz, 2021; Çetin, 2019; Türkeş et al., 2011). This trend has elevated fire risks in forest ecosystems and extended the fire season. Although most fires are of human origin, climatic variables—temperature, humidity, wind, and drought—are known to play a decisive role in their spread and intensity (Balshi et al., 2009; Parisien et al., 2011; Flannigan et al., 2013; Calda et al., 2020). Moreover, increasing population, tourism, and urbanization pressures further fragment forest landscapes and diversify the spatial distribution of fire risk (Tezcan & Eren, 2025).

In Mediterranean ecosystems, forest fires are considered both a natural process and a historical factor shaping the cultural landscape. However, the growing intensity of human influence has disrupted natural fire regimes, leading to severe degradation even in protected areas. This disruption threatens ecological sustainability by reducing biodiversity, decreasing soil productivity, and weakening ecosystem services. Recent studies also reveal that protected areas are not necessarily safe from fire risk; on the contrary, factors such as fuel load, topography, access constraints, and management limitations may exacerbate fire severity within these areas (Baldi et al., 2017; de Dios et al., 2025).

Within this context, neglecting fire risk in protected area management generates significant vulnerabilities for both ecosystem integrity and visitor safety (Abrhám et al., 2025). Increasing recreational use—particularly in camping zones, picnic areas, and hiking trails—amplifies fire risk; the exceeding of carrying capacity, uncontrolled use of fire, and low visitor awareness further heighten this danger. Therefore, fire management in protected areas must be addressed not only from an ecological conservation perspective but also within the framework of visitor management and sustainable recreation planning.

According to Turkey's National Parks Law No. 2873, national parks are defined as natural areas possessing scientific, aesthetic, cultural, and recreational value. In these areas, Long-Term Development Plans (UDGP) and their subprograms—such as ecotourism, fire action, and visitor management plans—are prepared within an ecosystem-based planning approach to ensure a balance between conservation and utilization (Tunçer & Oktay, 2018). However, studies examining how fire risk spatially varies in relation to increasing recreational pressure remain quite limited.

The main objective of this study is to identify the spatial and managerial relationships between forest fire risk and recreational pressure in the case of the Dilek Peninsula–Büyük Menderes Delta National Park, to evaluate how effectively existing management plans address this interaction, and to develop recommendations accordingly. The study underscores the importance of addressing fire risk in an integrated manner within protected area management under increasing climatic and recreational pressures.

2. Materials and Methods

2.1. Study Area: Dilek Peninsula–Büyük Menderes Delta National Park is located within the boundaries of Aydın Province in the Aegean Region of Turkey. The park is accessible via the İzmir–Söke–Milas–Muğla highway and lies 16 km from Söke, 24 km from Kuşadası, 27 km from Didim, 87 km from Aydın, and 174 km from İzmir. The northern, western, and southern

borders of the park are surrounded by the Aegean Sea. The settlement of Güzelçamlı lies to the northeast of the Dilek Peninsula, Tuzburgazı to the southeast, and the island of Samos to the northwest. To the east of the Büyük Menderes Delta are the villages of Batıköy, Balat, and Akköy (Figure 1).

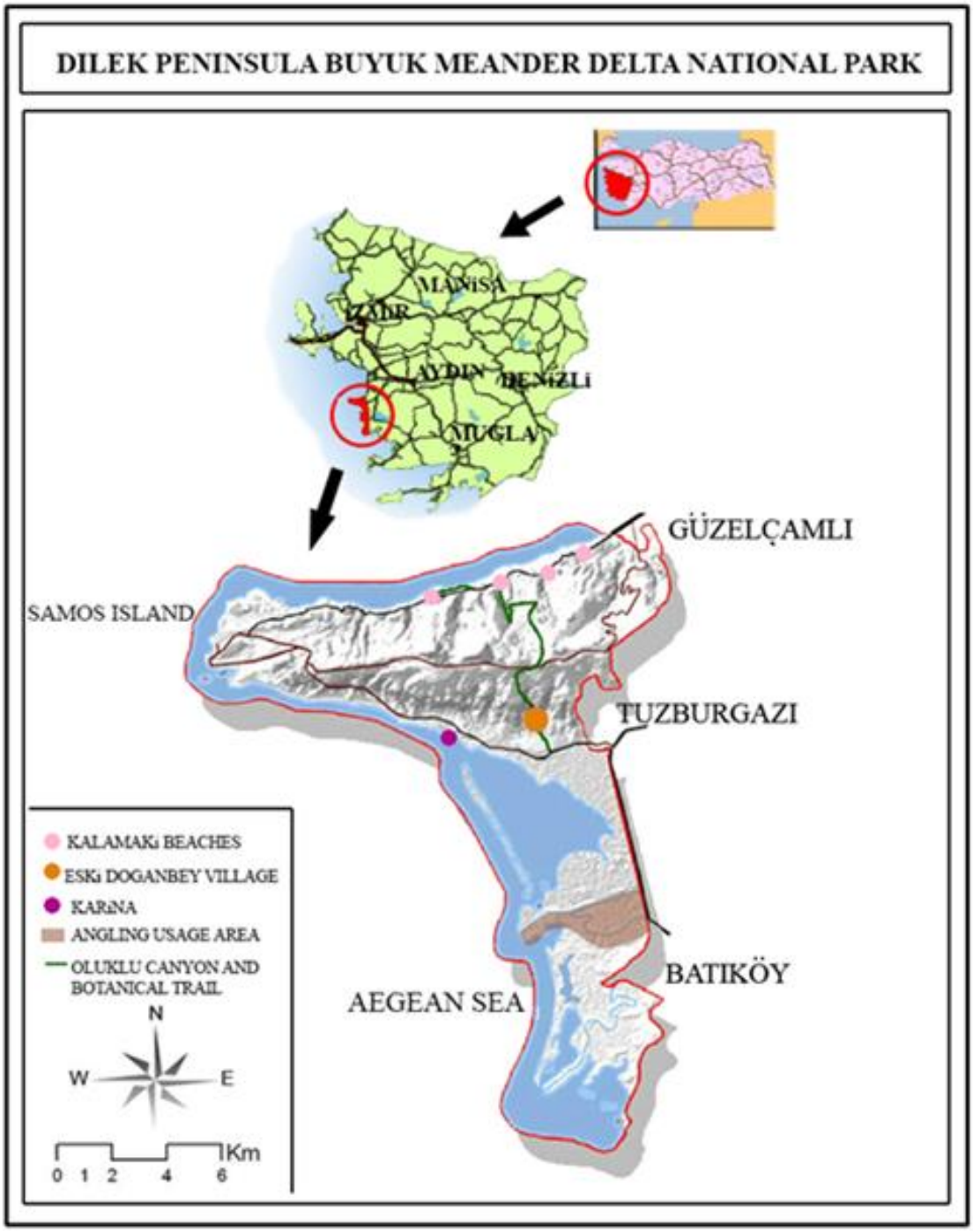


Figure 1. Location map (Created by author)

The national park encompasses two distinct natural units—Dilek Peninsula and the Büyük Menderes Delta—covering a total area of 27,675 hectares. Of this, 10,985 hectares correspond

to the Dilek Peninsula, designated as a national park in 1966, while 16,690 hectares were added in 1994 as part of the delta area. Morphologically, the park is highly diverse, featuring hills, valleys, canyons, and coves. Extending along an east–west axis, Mount Samsun (with Dilek Hill at 1,237 m) dominates the landscape. Toward the south, where the slope decreases, a deltaic system comprising lagoons, lakes, and wetlands has developed.

Dilek Peninsula–Büyük Menderes Delta National Park represents one of the most ecologically diverse and integrated landscapes in the Mediterranean Basin. Within its boundaries, nine distinct ecosystem types are found, including marine, lagoon, freshwater and brackish water systems, maquis shrubland, forest, agricultural, and settlement ecosystems. This ecological variety stems from the park's complex topography, climatic variability, and hydrological regime. The region is characterized by a typical Mediterranean climate with hot, dry summers and mild, rainy winters.

The vegetation cover exhibits substantial variation even across short distances. The park's flora includes 804 taxa from 95 families, 30 of which are endemic. Mediterranean and Eastern Mediterranean elements predominate. The Dilek Peninsula hosts some of Turkey's best-preserved maquis communities, while the lower slopes of Mount Samsun feature forest vegetation composed of Pinus brutia, Pinus nigra subsp. pallasiana, Castanea sativa, and Juniperus phoenicea. The park is also recognized as the last known western habitat of the Anatolian leopard (Panthera pardus tulliana) and provides shelter for the endangered Mediterranean monk seal (Monachus monachus).

The Büyük Menderes Delta was formed by alluvial deposits carried by the Büyük Menderes River, which drains a basin of approximately 25,000 km² and covers a wetland system of about 320 km². This area includes lagoons (Karine, Deringöl, and Kabahayıt), salt marshes, and mudflats. The delta is internationally protected under the Ramsar, Bern, Rio, and Barcelona conventions. Hosting around 250 bird species—including flamingos, Dalmatian pelicans, and pygmy cormorants—it is one of Turkey's most significant ornithological habitats.

The national park also offers diverse recreational opportunities. The northern coastline of the Dilek Peninsula features the Kalamaki Coves (İçmeler, Aydınlık, Kavaklıburun, and Karasu), designated for day-use recreation. Oluklu Canyon and the Botanical Trail are popular hiking routes. On the southern slopes, the historic village of Eski Doğanbey—protected as an urban conservation site—serves as a cultural heritage destination open to visitors. The Karina area is notable for gastronomy-based tourism, while birdwatching and recreational fishing are common activities across the delta.

2.2. Methodology: The research methodology consisted of two main stages. In the first stage, field observations were conducted throughout the Dilek Peninsula–Büyük Menderes Delta National Park. Recreational land uses, visitor densities, site arrangements, fire safety infrastructure, information signage, and control points were examined in situ. The degree of consistency between on-site practices and the strategies proposed in existing management plans was assessed.

In the second stage, a consistency analysis was performed between the Long-Term Development Plan (UDGP) and its subprograms—the Fire Action Sub-Program and the Visitor Management Sub-Program. The objectives, principles, strategies, and actions defined in these documents were compared in terms of ecological conservation, visitor management, fire prevention, infrastructure planning, and monitoring–control mechanisms. Based on the

findings, the study identified shortcomings in plan integration, deficiencies in implementation, and gaps in the overall management framework.

The evaluations ultimately led to the proposal of a new conceptual framework aimed at reducing fire risk and guiding recreational activities in a sustainable manner within protected area management. By analyzing existing management plans, this study develops practice-oriented discussions and contributes to defining strategic priorities that can strengthen the conservation–use balance in national park management**.**

3. Findings and Discussion

3.1. Land Use and Recreational Pressures: Field observations revealed a significant increase in visitor density during the summer months, particularly in Kavaklıburun, İçmeler, Aydınlık, and Karasu coves. In these areas, where recreational activities such as picnicking and swimming are concentrated, a substantial rise in vehicle numbers was noted in June, July, and August. In addition to the official parking lots, vehicles were observed parked along secondary roads in both directions, as well as within inner picnic zones (Figure 2).



Figure 2. Vehicle density

Visitor control at the Dilek Peninsula entrance gate is conducted by the gendarmerie after vehicles pass through the HGS (electronic toll) system. Long queues were observed at this checkpoint during peak hours (Figure 3).



Figure 3. Long queues

Although open fires are officially prohibited throughout the park, visitors are allowed to use barbecue facilities for a fee within the area allocated to the concession-operated facility. Furthermore, despite signs indicating a ban on smoking, there is no effective monitoring or penalty mechanism in place (Figure 4).

Visitors are not systematically informed—either verbally or in writing—about the need for fire precaution upon entry. While occasional verbal announcements are made during park opening hours, they are not consistent. The lack of fire safety information boards, particularly in picnic and beach areas, and the generally low awareness of visitors regarding fire prevention significantly hinder risk management (Figure 4).



Figure 4. Fire uses and safety information boards

No fire hydrants were found within the businesses operating inside the park. Along the main road, six fire cabinets have been installed: one in İçmeler, two in Aydınlık, two in Kavaklıburun, and one in Karasu cove. Each cabinet contains six fire extinguishers. Additionally, large red water barrels are placed approximately every 500 meters, and smaller first-response buckets are installed at about 100-meter intervals along the main road and access routes to the coves. One fire engine and two first-response vehicles are stationed along the main road (Figure 5).

Despite contractual obligations between the park administration and the private operator, six required lifeguards have not been employed, resulting in red flags being raised at lifeguard towers (Figure 5). Similarly, the number of cleaning staff is seven fewer than stipulated in the contract, and one biologist position has not been filled.

Field observations—particularly in Kalamaki Coves, Oluklu Canyon, Eski Doğanbey Village, and Karina—indicate that recreational pressure is high, whereas fire safety infrastructure, waste management, and visitor information remain insufficient. Uncontrolled parking, incomplete enforcement of fire bans, and a limited patrolling system reveal site-specific deficiencies in implementing management plans.



Figure 5. Red flags at lifeguard,first-response buckets, fire cabinets, first-response vehicles

3.2. Analysis of Management Plans: Dilek Peninsula–Büyük Menderes Delta National Park, with its diverse ecosystems, rich biodiversity, and recreational potential, requires an integrated management approach. The first version of the park's Long-Term Development Plan (UDGP) was completed in 1997, and a revised version was approved in 2019. The Fire Management Sub-Plan (2025) and Visitor Management Sub-Plan (2022), developed under this framework, are the principal instruments guiding the park's sustainable use. However, an examination of

their content, scope, and implementation reveals significant coordination gaps affecting site management.

Consistency Analysis between UDGP and the Fire Management Sub-Plan: The Long-Term Development Plan (UDGP) of Dilek Peninsula–Büyük Menderes Delta National Park was structured into thematic subprograms to safeguard the park's ecological integrity. One of these, Subprogram 4.7: Fire Action Program, addresses the fire risks inherent in the Mediterranean climate and defines prevention, response, and coordination strategies at a strategic level. This subprogram provides the guiding framework for the Fire Management Sub-Plan and Fire Evacuation Plan prepared in 2025.

The analysis indicates a strong degree of strategic alignment among these three plans; however, operational-level inconsistencies remain. While the UDGP's fire subprogram establishes strategic objectives and guiding principles, the subplans focus on operational tools and implementation procedures (Table 1).

Common and Consistent Elements: Both the UDGP and the Fire Management Sub-Plan emphasize vegetation sensitivity, unfavorable Mediterranean climatic conditions, and increasing visitor pressure as major fire risk factors. Shared principles include the prohibition of open fires, prevention of agricultural burning in forest–agriculture transition zones, and reinforcement of inter-institutional coordination. Additionally, the installation of hydrant systems along the main transportation corridor from the park entrance to Karasu Cove, the development of early warning systems, and post-fire recovery procedures show alignment between the UDGP and subplans.

Divergent and Missing Elements: Despite these parallels, the UDGP's focus on reducing human pressure, enhancing local community and NGO participation, and preventing the burning of natural vegetation is insufficiently reflected in the subplans. The Fire Management Sub-Plan prioritizes technical infrastructure, equipment, response chains, and institutional responsibilities, leaving socio-ecological dimensions underdeveloped.

Although the UDGP identifies agricultural stubble burning in adjacent rural areas as a significant external threat, the subplan's jurisdiction is limited strictly to park boundaries and therefore excludes these peripheral activities.

The Fire Evacuation Plan translates the UDGP's goal of ensuring the applicability of preventive and response measures into operational form by defining evacuation routes, assembly points, and chains of command. Nevertheless, field observations in high-traffic areas (particularly Kalamaki Coves and Oluklu Canyon) reveal physical inadequacies in evacuation routes, missing directional signage, and limited emergency communication infrastructure. These deficiencies demonstrate that the plan's implementation capacity does not fully align with the UDGP's objectives.

Table 1. Consistency analysis between UDGP Subprogram 4.7 "Fire Action" and related subplans (Fire Management Subplan and Fire Evacuation Plan)

Objective in UDGP Subprogram 4.7 (Fire Action)	Corresponding Measure in Fire Management Subplan	Corresponding Measure in Fire Evacuation Plan	Level of Consistency
Considering vegetation sensitivity to fire	Fire-prone species and fuel load analyses conducted; fire risk zones defined.	Evacuation scenarios prioritize high-risk forest and maquis areas.	**High**
Taking precautions in areas with intense visitor and vehicle traffic	Hydrant systems, watch points, and equipment stations established along the Entrance–Karasu corridor.	Same route designated as an evacuation corridor; assembly points identified.	**High**
Prevention and control of open fire use	Open fire bans, warning signs, and penalties defined in plan documents.	Prohibits carrying flammable equipment during evacuation; includes public warning announcements.	**High**
Reducing human pressure	No direct mechanism defined; lacks carrying capacity or zoning strategy.	Proposes alternative evacuation routes for high-use areas, but no specific strategy to reduce pressure.	**Low**
Preventing the burning of natural vegetation	Includes preventive measures, but lacks post-fire ecosystem restoration strategies.	No direct linkage established.	**Moderate**
Preventing stubble burning in agricultural lands	Areas outside park boundaries excluded from plan scope.	Not addressed.	**Low**
Ensuring institutional coordination	Clear responsibility chain defined among DKMP, OGM, AFAD, and firefighting units.	Specifies task distribution and communication flow during emergencies.	**High**
Ensuring plan implementation	Implementation schedule, responsible institutions, and monitoring mechanisms defined.	Includes operational flowchart and designated assembly areas.	**High**
Promoting local community and NGO participation	Includes training and volunteer proposals, but implementation mechanisms weak.	No provisions for local community involvement in evacuation training.	**Low**

Overall, the consistency between the UDGP's Fire Action Subprogram (4.7) and its subplans is approximately 70%. While strategic objectives, intervention principles, and institutional responsibilities are largely aligned, deficiencies persist in spatial prioritization, socio-ecological integration, community participation, and post-fire ecological restoration. The UDGP's objective of "reducing human pressure" has not been effectively integrated into subplans through visitor management, leading to a lack of holistic assessment between fire risk and recreational intensity.

In conclusion, although strategic coherence among the plans is relatively high, further improvements are needed in spatial data integration, community participation, and monitoring–evaluation mechanisms. In the specific case of Dilek Peninsula–Büyük Menderes Delta National Park, a sustainable fire management approach must combine technical preparedness

with visitor behavior management and participatory governance within an integrated framework..

3.3. Consistency Analysis between UDGP and the Visitor Management Plan: The increasing recreational pressure within Dilek Peninsula–Büyük Menderes Delta National Park underscores the growing importance of visitor management strategies. Within the Long-Term Development Plan (UDGP), Subprogram 4.5: Visitor Management serves as a key strategic document aiming to align visitor use with the area's ecological sensitivities. It includes zoning systems, carrying capacity analyses, visitor flow control, awareness and education activities, and institutional cooperation. The Visitor Management Plan (VMP), prepared in 2022 with reference to the UDGP's strategic framework, acknowledges these principles but fails to fully operationalize them.

Zoning Approach: The zoning system is defined only in the UDGP; the VMP does not introduce a new zoning scheme, merely referencing the existing framework. Ideally, the VMP should have developed sub-zones based on recreation type, intensity, seasonality, and accessibility. Such a sub-zoning structure would help balance visitor distribution and reduce pressure in ecologically sensitive areas. The absence of this refinement limits the plan's applicability to site-specific conditions.

Carrying Capacity Approach: The UDGP proposes calculating carrying capacity across multiple dimensions—physical, real, effective, social, and ecological—following international standards. In contrast, the VMP defines carrying capacity solely in terms of the number of vehicles that can park in designated and secondary parking areas. For Kalamaki Coves (İçmeler, Aydınlık, Kavaklıburun, and Karasu), the physical carrying capacity is estimated at 7,693 visitors and 1,505 vehicles. This method, implemented in 2025, reduces carrying capacity to a purely physical indicator, neglecting ecological and behavioral factors.

The park operator later objected to this limitation, and the General Directorate of Nature Conservation and National Parks (DKMP) ruled that even if the physical capacity was exceeded, visitors with reservations should still be admitted—undermining the plan's intent.

Thus, the VMP's approach, though operationally simple, lacks scientific rigor and weakens ecological sustainability, deviating from the UDGP's principle of sustainable use..

Visitor Flow Control and Management: The VMP defines visitor flow management primarily through parking arrangements, ticket control, directional signage, and one-way road systems. While these measures provide short-term control, they lack behavioral or experiential management dimensions. Unlike the UDGP, the VMP does not include spatial planning tools that optimize visitor distribution based on route-specific carrying capacities or controlled access areas. Digital monitoring and alert systems are mentioned but lack implementation mechanisms.

Information, Awareness, and Education: Visitor information strategies in the VMP are limited to the Visitor Information Center, signage, and printed materials. Although these align with the UDGP's awareness objectives, they fall short of promoting behavioral change or participatory education. As emphasized in the UDGP, effective visitor management in protected areas requires educational transformation and volunteer involvement—elements absent from the VMP's passive communication approach.

Institutional Coordination and Feasibility: While the VMP designates the General Directorate of Nature Conservation and National Parks (DKMP) as the lead authority and outlines field staff responsibilities, it fails to define roles for local governments, NGOs, or tourism operators, contradicting the UDGP's multi-actor governance model.

Moreover, several proposed strategies lack practical feasibility. For instance, alternative routes and transport schemes aimed at reducing congestion are not immediately implementable given the existing road infrastructure and topography. Similarly, although the proposed reservation and digital tracking systems are technologically sound, the necessary data and management infrastructure are not yet available.

Monitoring and Evaluation Mechanism: The UDGP identifies monitoring and feedback loops as key principles during implementation. However, the VMP lacks a defined set of indicators, performance metrics, or reporting protocols, making evaluation of its effectiveness nearly impossible.

Table 2. Consistency analysis between the UDGP Subprogram 4.5 "Visitor Management" and the implemented Visitor Management Program

Evaluation Criterion	Level of Consistency with UDGP	Explanation
Zoning Approach	Moderate	Refers to UDGP zoning, but no sub-zoning has been developed.
Carrying Capacity Methodology	Low	Not based on scientific criteria; relies solely on vehicle capacity.
Visitor Flow Management	Moderate	Physical arrangements exist, but behavioral guidance is lacking.
Information and Awareness	Moderate	Passive information provided; no active training or participation programs.
Institutional Coordination	Moderate–Low	DKMP's responsibility is defined, but no local stakeholder participation included.
Monitoring and Evaluation	Low	Lacks mechanisms for monitoring implementation outcomes and feedback loops.

The UDGP identifies monitoring and feedback loops as key principles during implementation. However, the VMP lacks a defined set of indicators, performance metrics, or reporting protocols, making evaluation of its effectiveness nearly impossible.

Overall, the strategic consistency between the UDGP's Visitor Management Subprogram (4.5) and the Visitor Management Plan is estimated at 60%. While the VMP formally references the UDGP's guiding principles, it fails to reflect them substantively in content and implementation. The main shortcomings include the absence of sub-zoning, unsystematic carrying capacity assessment, lack of monitoring mechanisms, and limited operational realism.

Nonetheless, the VMP's inclusion of modern tools such as visitor flow control, signage systems, and digital monitoring represents a positive step forward. However, these strategies remain constrained by the park's existing infrastructure, limited personnel, and inadequate data systems.

In conclusion, to operationalize the visionary framework of the UDGP, future revisions of the Visitor Management Plan should integrate sub-zoning–based spatial planning, scientifically grounded carrying capacity analyses, stakeholder participation, and systematic monitoring mechanisms.

3.4. Discussion on the Management Approach: The assessment conducted in the case of Dilek Peninsula–Büyük Menderes Delta National Park reveals that although the existing management plans have been prepared with a conservation-oriented vision, this vision has not been translated into a spatially and institutionally integrated approach. The plans address key components—such as fire management, visitor management, and ecosystem protection—as separate documents, resulting in weak interdisciplinary interaction and limited coordination among plans. Despite sharing common conservation objectives, fire management and visitor management plans are implemented independently, with differing operational tools, data sets, and spatial priorities. This structural disconnection undermines both fire risk reduction and visitor safety, thereby weakening the overall effectiveness of the management system.

Fire risk analyses identify Kalamaki Coves, Kavaklıburun, and İçmeler as areas with the highest probability of fire occurrence, consistent with the literature indicating that most forest fires are human-induced (Ünlü, 2025; Kolanek et al., 2021). However, instead of limiting visitor numbers in these high-risk areas, the planning documents propose the construction of alternative fire roads—a measure that creates a conflict between conservation and safety objectives. Such new roads may lead to ecosystem fragmentation, disruption of habitat integrity, and the spread of invasive species (Forman & Alexander, 1998). While these engineering-based solutions may temporarily reduce fire risk, they threaten long-term ecological sustainability.

Although the UDGP's Subprogram 4.5 Visitor Management aims to ensure that visitor activities do not compromise the park's resource values, the implemented Visitor Management Plan (VMP) restricts this principle to physical capacity criteria alone. In contrast, international carrying capacity models developed by Cifuentes (1992) and Manning et al. (2002) incorporate social, ecological, and psychological dimensions alongside physical parameters. The current implementation, however, defines capacity solely based on the number of vehicles. The limit of 1,505 vehicles was calculated without reference to international standards, thus failing to reflect the area's true ecological capacity. Field observations indicate that this density adversely affects both resource values and visitor safety. The underlying reason for this management approach lies in economic concerns—that restricting visitor numbers might reduce park revenues—illustrating the tension between conservation goals and income-oriented management.

Such excessive density also poses a potential crisis scenario during a wildfire. Given that Dilek Peninsula has a single entrance and exit route, fire events could immobilize vehicles and visitors, blocking escape routes and hindering emergency response. Although this risk is acknowledged in technical plans, human behavior–based scenarios have not been integrated into planning. Yet, factors such as panic, loss of orientation, and collective behavioral responses are critical determinants of disaster magnitude (Thapa et al., 2013; Labhiri et al., 2024).

Recent studies indicate that tourists' behavior during wildfires is influenced not only by physical conditions but also by socio-psychological factors such as risk perception, access to information, prior experience, and safety culture (Labhiri et al., 2024). Temporary visitors,

unfamiliar with the area and local safety protocols and often facing language barriers, represent a high-risk group. Therefore, effective fire plans should integrate behavioral aspects alongside infrastructure measures. In the Dilek Peninsula case, such considerations have not been incorporated into planning.

Although the Fire Evacuation Plan's approval in 2025 marks a significant step, the drill conducted on April 24, 2025, involved only institutional staff and the gendarmerie, limiting the plan's practical applicability. The literature emphasizes that the success of disaster management drills in protected areas is directly linked to public and civil society participation (Doherty et al., 2024). Drills that exclude community involvement remain procedural and prove ineffective under real crisis conditions. Community participation not only raises risk awareness but also enhances collective response capacity during emergencies. In the case of Dilek Peninsula, the lack of public involvement has resulted in drills remaining theoretical, overlooking behavioral dimensions of crisis response.

Overall, findings indicate a management system that is institutionally strong but operationally weak. Although management plans articulate visionary goals, they lack sufficient monitoring–evaluation mechanisms, adaptive management processes, and stakeholder participation. The adaptive management framework requires continuous updating of decisions based on changing environmental conditions (Holling, 1978; Walters, 1986), yet such feedback loops are absent in the current plans.

In conclusion, the Dilek Peninsula case clearly demonstrates that in protected areas where fire risk and recreational pressure coexist, management plans must be designed on shared spatial foundations and integrated objectives rather than as isolated documents. In such contexts—at the intersection of conservation, disaster management, and recreation—coordination must extend beyond planning documents to include monitoring, implementation, and participation processes. This approach points toward a holistic management model applicable to other protected areas in the Mediterranean Basin.

4. Conclusion and Recommendations

This study demonstrates that the existing management plans of Dilek Peninsula–Büyük Menderes Delta National Park, particularly the fire and visitor management subplans, have not been developed through an integrated approach. The findings reveal that while the documents articulate a strong conservation vision at the institutional level, they display critical deficiencies in integration, monitoring, and participatory management in practice. In particular, fire management plans focus on the biophysical characteristics of forest ecosystems while largely neglecting the behavioral dimensions of human-induced fire risks and visitor interactions.

The Visitor Management Program's determination of a maximum capacity of 1,505 vehicles is not based on internationally recognized multidimensional capacity models (physical, social, ecological, and psychological). Implementing this limit as a "maximum" threshold has created excessive density, traffic congestion, and potential evacuation chaos during fires—representing a significant planning weakness. Given that the area has a single entrance–exit corridor, any wildfire could critically jeopardize both visitor safety and emergency response. This highlights the urgent need to restrict visitor numbers and redesign emergency scenarios in high-risk areas such as the Kalamaki Coves.

The lack of integration between existing fire risk maps and visitor density data indicates a missing spatial linkage between management plans. Ensuring coordination between fire and

visitor management is not only a technical requirement but also a cornerstone of disaster risk reduction and sustainable tourism policy. Adopting an adaptive management framework will allow dynamic updates of plans in response to changing climatic conditions, increasing visitor pressure, and emerging risk scenarios.

Furthermore, limiting fire drills to institutional staff significantly reduces their practical value. The active participation of local residents, NGOs, and tourism operators in these drills would enhance risk awareness and behavioral coordination during emergencies. The literature underscores that community participation strengthens crisis response and resilience in disaster management (Paton & Tedim, 2012; McCaffrey et al., 2015). Therefore, in the case of Dilek Peninsula, fire evacuation planning should be restructured on a participatory basis.

I conclusion, the Dilek Peninsula–Büyük Menderes Delta National Park case illustrates that achieving a balance between conservation and use in protected area management requires not only robust planning documents but also the effective integration of implementation, monitoring, and participation processes. Strengthening interplan integration, updating spatial datasets, applying internationally accepted carrying capacity methodologies, and reassessing fire–visitor management interactions through a risk-based lens are essential steps toward sustainable site management.

Accordingly, the following recommendations are proposed:

- Integrate fire and visitor management plans using spatial data, restricting access and activities in high-risk zones.
- Recalculate carrying capacity to include not only physical but also social and ecological criteria.
- Consider the construction of alternative fire roads only when absolutely necessary, ensuring minimal disruption to ecosystem integrity.
- Conduct fire drills involving local communities, NGOs, and visitors, testing realistic emergency scenarios.
- Integrate digital monitoring systems (visitor density, early warning sensors, evacuation routes) into management operations.
- Design education and awareness programs targeting behavioral factors that contribute to fire risk reduction.
- Refine the zoning system based not only on protection levels but also on recreation types and usage intensity.

These recommendations contribute to developing an integrated, adaptive, and participatory management model not only for Dilek Peninsula but also for other fire-prone protected areas across the Mediterranean Basin. Ultimately, the Dilek Peninsula–Büyük Menderes Delta National Park case demonstrates that sustainable protected area management can only be achieved through the full integration of planning, implementation, participation, and monitoring processes—a model that may serve as a guiding framework for similar protected landscapes throughout the region.

Thanks and Information Note

The article complies with national and international research and publication ethics. Ethics Committee approval was not required for the study.

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Assessment of Tangible Cultural Heritage Elements of Çorum City from a Tourism Perspective

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Abstract

The concept of culture encompasses the tangible and intangible values created by societies throughout the processes of social development, distinguishing one community from another and being transmitted to future generations. This study examines the tangible cultural heritage in Çorum city, with a particular focus on significant Hittite-era sites, including Hattuşa Ancient City, Yazılıkaya Open-Air Sanctuary, Alaca Höyük, Şapinuva, and İncesu Canyon. Cultural heritage, encompassing both tangible and intangible elements, reflects the identity, traditions, and artistic accumulation of societies and its preservation is crucial for sustainability. Çorum city hosts 325 immovable cultural properties recognized by the Ministry of Culture and Tourism, including streets, administrative, military, religious, industrial, and civil structures, as well as archaeological remains. These sites are dispersed across the province, presenting both opportunities and challenges for tourism development. Hattuşa and Yazılıkaya are listed as UNESCO World Heritage sites, while Alaca Höyük and Şapinuva are less known. Recreational developments at İncesu Canyon, such as water sports and nature trails, have increased interest among local residents and visitors, indicating that site-specific improvements can enhance tourism potential in other areas as well. Observations revealed that some historical structures have suffered damage due to natural and human factors. The study emphasizes the need to improve infrastructure and services, promote Hittite civilization and local culture, inform local communities, and protect and monitor sites of cultural and natural significance. Implementing these strategies can strengthen Çorum's cultural tourism potential while ensuring that its heritage is preserved and transmitted to future generations.

Keywords: Cultural heritage, tangible cultural heritage elements, tourism, Çorum City

1. Introduction

The concept of culture refers to the material and spiritual values created by societies throughout their historical and social development processes, which distinguish one society from another and are transmitted to future generations (TDK, 2024; Kolaç, 2009; Yılmaz, 2020; Günden, 2021). Throughout history, every society has developed its own unique cultural characteristics. However, these characteristics, inherited from the past, have undergone transformation in the face of modernity and popular culture, leading to the gradual decline of traditional cultural forms and their influence (Diker, 2016). With advancing technology and changing social conditions, some of the most significant elements of

traditional culture that are beginning to disappear are those related to cultural heritage (Diker, 2016; Gümüşçü, 2018).

In this context, cultural heritage, which contributes to the identity, continuity, and development of societies, can be regarded as an invaluable legacy passed down from the past to the future. It encompasses both the natural and cultural environment, including historical and archaeological sites, biodiversity, cultural practices, rituals, norms, customs, and traditions that have persisted over time, as well as artistic expressions, aesthetic representations, and accumulated knowledge and experiences. Cultural heritage is broadly divided into tangible and intangible forms (ICOMOS, 1999; Pehlivan, 2015; Günden, 2021; Ministry of Culture and Tourism, 2024).

Tangible cultural heritage includes historical sites and monuments protected by international conventions and organizations, while intangible cultural heritage encompasses elements such as epics, legends, folktales, proverbs, fairy tales, humorous anecdotes, engagement and wedding ceremonies (Çeliker and Genç, 2019), as well as traditional crafts and practices such as weaving, the making of evil eye beads, filigree and copperwork, and vernacular architecture (Elçi and Kalkan, 2023).

By the 20th century, with rapid population growth and the increasing threat of cultural erosion, numerous countries began to define new frameworks for heritage protection to ensure the safeguarding and transmission of cultural heritage to future generations. In this regard, the Convention Concerning the Protection of the World Cultural and Natural Heritage adopted by UNESCO (1972) emphasizes the universal responsibility of nations in preserving cultural and natural assets of outstanding value (Güden, 2021). According to this convention, tangible cultural heritage includes:

- Monuments: Architectural works, monumental sculptures and paintings, archaeological elements or structures, inscriptions, caves, and combinations of features that possess outstanding universal value from the perspective of history, art, or science.
- Groups of buildings: Separate or combined ensembles of buildings that possess outstanding universal value in terms of their architecture, harmony, or relationship with the landscape.
- Sites: Areas that include works of human creativity or the combined works of nature and humankind, as well as archaeological sites of exceptional universal value from historical, aesthetic, ethnological, or anthropological perspectives.

Turkey became an official party to the Convention Concerning the Protection of the World Cultural and Natural Heritage on 16 March 1983, aiming to preserve and transmit the rich cultural heritage of Anatolia to future generations. Currently, Turkey has 78 cultural properties on the Tentative List and 18 properties inscribed on the World Heritage List (UNESCO, 1972; Yılmaz, 2020).

This study focuses on the tangible cultural heritage assets located in the province of Çorum, including the ancient city of Hattuşa, the Yazılıkaya Open-Air Temple, Alaca Höyük, the Şapinuva archaeological site, and the İncesu Canyon. These sites are examined through a comprehensive literature review with the aim of evaluating their significance from a tourism perspective and assessing their potential contribution to the cultural and economic development of the region.

2. Materials and Methods

The main material of this study consists of tangible cultural heritage sites located within the province of Çorum. To establish the conceptual framework, a comprehensive literature review was conducted. Within this scope, significant cultural heritage sites associated with the Hittite Empire were examined in order to assess the tourism potential of Çorum Province and to identify strategies for their sustainable preservation and promotion.

Çorum Province is situated in the inner section of the Central Black Sea Region of Turkey, positioned behind the North Anatolian Mountains, and lies within the transition zone between the Central Black Sea region and the Central Anatolian Plateau plains (Günay, 2007).

It is bordered by Amasya to the east, Yozgat to the south, Çankırı to the west, Sinop to the north, Samsun to the northeast, and Kırıkkale to the southwest. The province covers an area of 12,820 km². Geographically, Çorum is located between 34°04′28″ east longitude and 39°54′20″ north latitude. Due to its location, Çorum lies within a climatic transition zone between the Black Sea and Central Anatolian climate types.

The northern districts of Kargı, Osmancık, İskilip, Laçin, Dodurga, Oğuzlar, and Bayat are influenced by the Inner Black Sea transitional climate, while the central district of Çorum, along with Sungurlu, Alaca, Boğazkale, Ortaköy, Mecitözü, and Uğurludağ, exhibit the typical features of the Inner Anatolian steppe climate (URL-1, 2024).

Administratively, Çorum consists of 14 districts (including the central district), 38 townships, and 735 villages (Günay, 2007). The province has an average elevation of 801 meters above sea level (URL-1, 2024). The location map of the study area is presented in Figure 1.

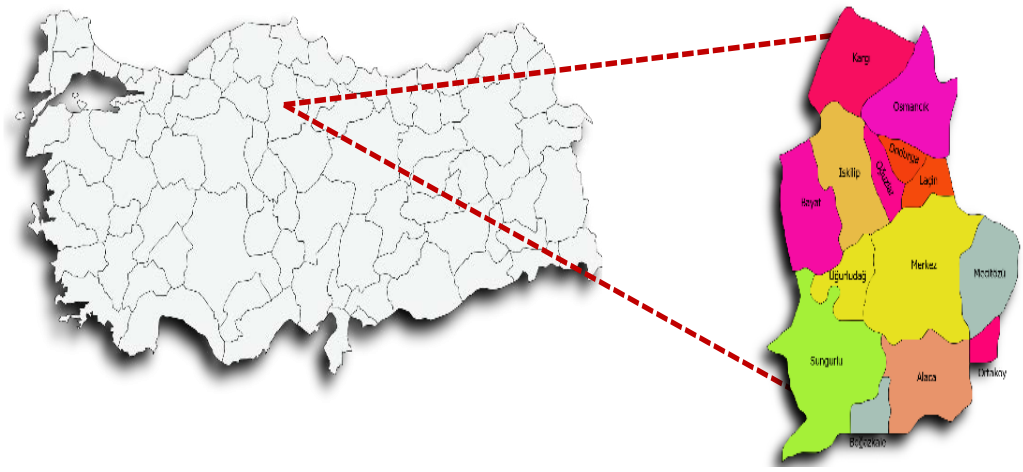


Figure 1. Study area boundaries

Although a number of stone tools indicating the existence of the Palaeolithic (Old Stone Age) and Neolithic (New Stone Age) periods have been discovered in Çorum Province and its surroundings, evidence suggests that permanent settlements in the true sense began and intensified during the Chalcolithic Age (URL-2, 2024; Bakır & Gökşen, 2019).

Archaeological findings indicate that Çorum's history dates back approximately 7,000 years, making it one of the significant centres of early Anatolian civilisation. Hattuşa, the first capital of the Hittite Empire, which is recognised as the first organised state in Anatolia, is also located within the province. The Hittite civilisation is considered to be as ancient and rich

as the Egyptian civilisation. Among the most remarkable discoveries in the region are the clay tablets of the Kadesh Treaty, concluded between the Hittites and the Egyptians, which were found in Boğazköy. Another prominent site, the Alacahöyük Archaeological Site, known in Hittite sources as Arinna, is regarded as one of the most important cult (religious) centres of the Hittite civilisation. The site contains notable examples of early Anatolian art and architecture, including the Royal Tombs, the Hatti Bronze Sun Disc, and the Sphinx Gate, all of which are significant components of Çorum's tangible cultural heritage. In addition to the remains of the Hittite period, Çorum also hosts numerous examples of Seljuk and Ottoman cultural heritage, such as mosques, bridges, and castles, which contribute to the city's multi-layered historical identity (URL-3, 2024).

The aim of this study is to examine the cultural heritage sites of Çorum Province within a conceptual framework of conservation and tourism, through a comprehensive literature review, and to evaluate the tourism potential of Çorum, which bears the enduring traces of the Hittite civilisation and subsequent historical periods.

3. Findings and Discussion

According to the Turkish Ministry of Culture and Tourism, a total of 325 immovable cultural assets have been identified as requiring protection within the province of Çorum. These assets represent a diverse range of cultural typologies and architectural functions that collectively reflect the province's rich historical and cultural heritage. Of these immovable cultural assets, 2 are classified as protected streets, 9 as administrative buildings, 74 as cultural buildings, 8 as military structures, 2 as industrial and commercial buildings, 84 as religious structures, 17 as cemeteries, 123 as examples of civil architecture, and 6 as ruins (Table 1) (URL-4, 2024; Şahin, 2021; İpek, 2014; Ortakcı, 2016).

Table 1. List of immovable cultural assets in the province of Çorum

Immovable Cultural Assets	Number
Protected Streets	2
Administrative Buildings	9
Cultural Structures	74
Military Structures	8
Industrial and Commercial Structures	2
Religious Buildings	84
Cemeteries	17
Civil Architecture Example	123
Remains	6
TOTAL	**325**

Hattuşa Ancient City: The Hattuşa World Heritage Site is located in the Boğazkale district of Çorum province and is a 167.69-hectare archaeological site and national park (URL-5, 2025; Ortakçı, 2016). Hattuşa, the capital of the Hittite Empire, was added to the UNESCO World Cultural Heritage List in 1986, and the cuneiform tablet archives excavated from the site were also included in UNESCO's Memory of the World Register in 2001 (URL-3, 2024; Şahin, 2021).

The ruins of the ancient city of Hattusa were first noticed during European travellers' expeditions to Anatolia, with the first exploratory trip organised by French architect Charles Texier in 1834. Texier identified surface remains, took notes, discovered a temple near Hattusa, and made drawings of the rock reliefs. Following this discovery, excavations were initiated in the area by the German Archaeological Institute in 1906. It served as the capital of the Hittites between 1650 and 1200 BC (Şahin, 2021; Akdoğan and Hiçyorulmaz, 2020).

The Hittites, Phrygians, Galatians, and Romans/Byzantines lived in Hattusa. Turkish rule began in the area after 1071 (Figure 2) (Alp, 1997; Adabalı, 2020).

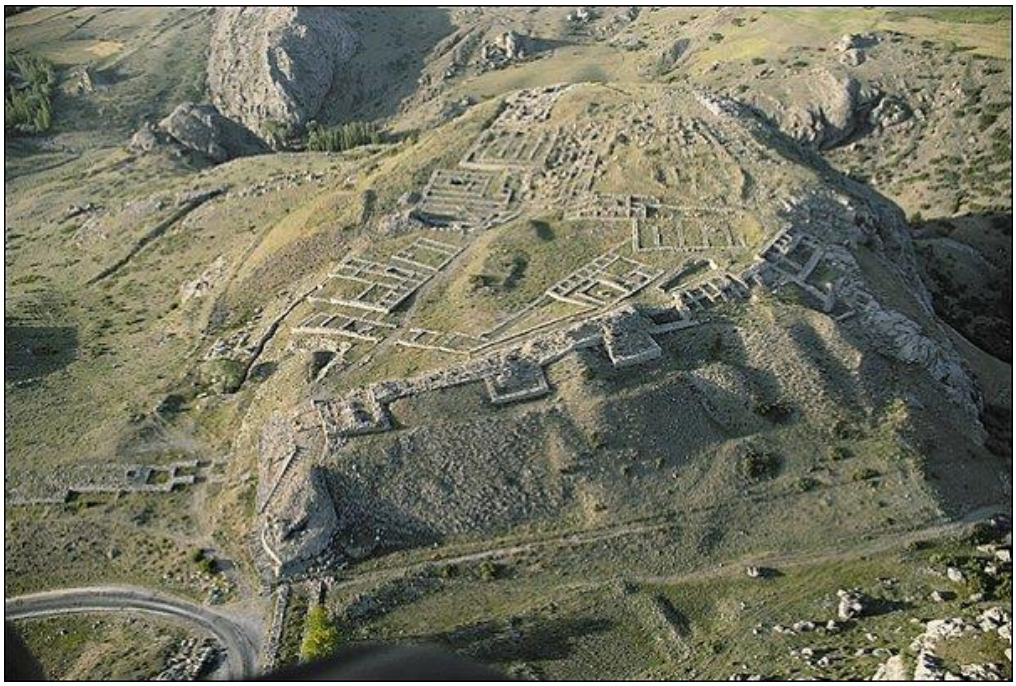


Figure 2. The ancient city of Hattuşa (URL-6, 2025)

Since excavations began at the Hattuşa archaeological site in 1906, a total of 31,519 cuneiform tablets have been found. These tablets contain information not only about Hittite culture but also about cultures in Anatolia and beyond. The tablets refer to Hattuşa as the "City of a Thousand Gods". Hattuşa has a total of four monumental gates: the Lion Gate, the Earth Gate, the Sphinx Gate, and the King's Gate (Figure 3).

In addition, the city walls and underground passages are unique monuments. During the 2nd and 1st millennia BC, Hattusa influenced the civilisations in Anatolia and northern Syria. As a centre of religious and political importance, its palace, temples, necropolis, and marketplace provide a comprehensive picture of the capital. Hattuşa has earned its place on the UNESCO World Heritage List due to the excellent preservation of its various buildings and architectural structures, such as temples, walls, and the palace (Figure 3) (UNESCO, 2021; Şahin, 2021).



Figure 3. Lion Gate, Ground Gate, King's Gate, Sphinx Gate (URL-7, 2025)

Alaca Höyük: Alaca Höyük is located in the Alaca district of Çorum province and was first discovered in 1885 by W. C. Hamilton, under its then name of İmat/Höyüğü. The Alacahöyük Archaeological Site features 13 Royal Tombs, the Hatti Bronze Sun Disc, and the Sphinx Gate (Figure 4) (Günay, 2007; Çınaroğlu, 2018).

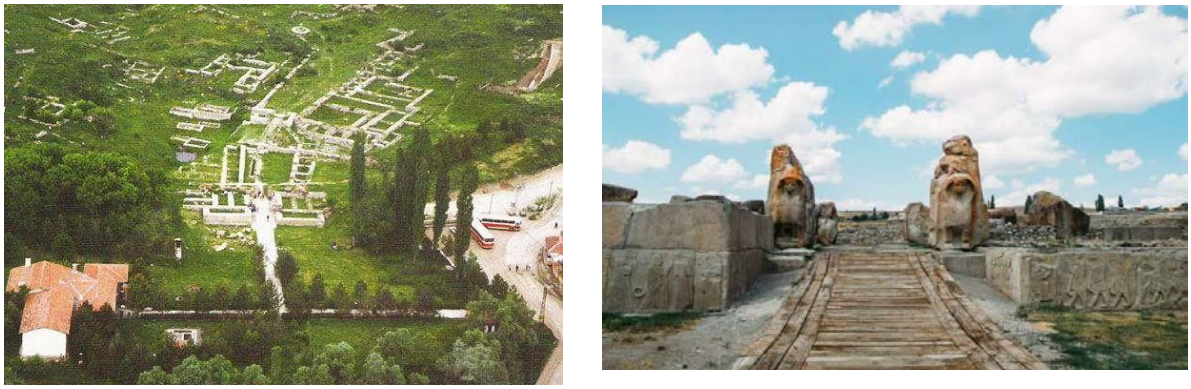


Figure 4. Aerial view of Alaca Höyük, Sphinx Gate (URL-8,2025)

Excavations at Alaca Höyük first began in 1907 and continued for a short time. Publications by researchers on the excavations caught the attention of Atatürk, who requested that excavations be carried out with money from his own account. The excavations, initiated on 22 August 1935 in the village square under the leadership of Remzi Oğuz Arık, uncovered three royal tombs and burial gifts, establishing Alaca Höyük as the first significant national excavation conducted by Turkish archaeologists (Figure 5) (Akurgal, 1995; Çınaroğlu and Çelik, 2010; Yılmaz, 2021).

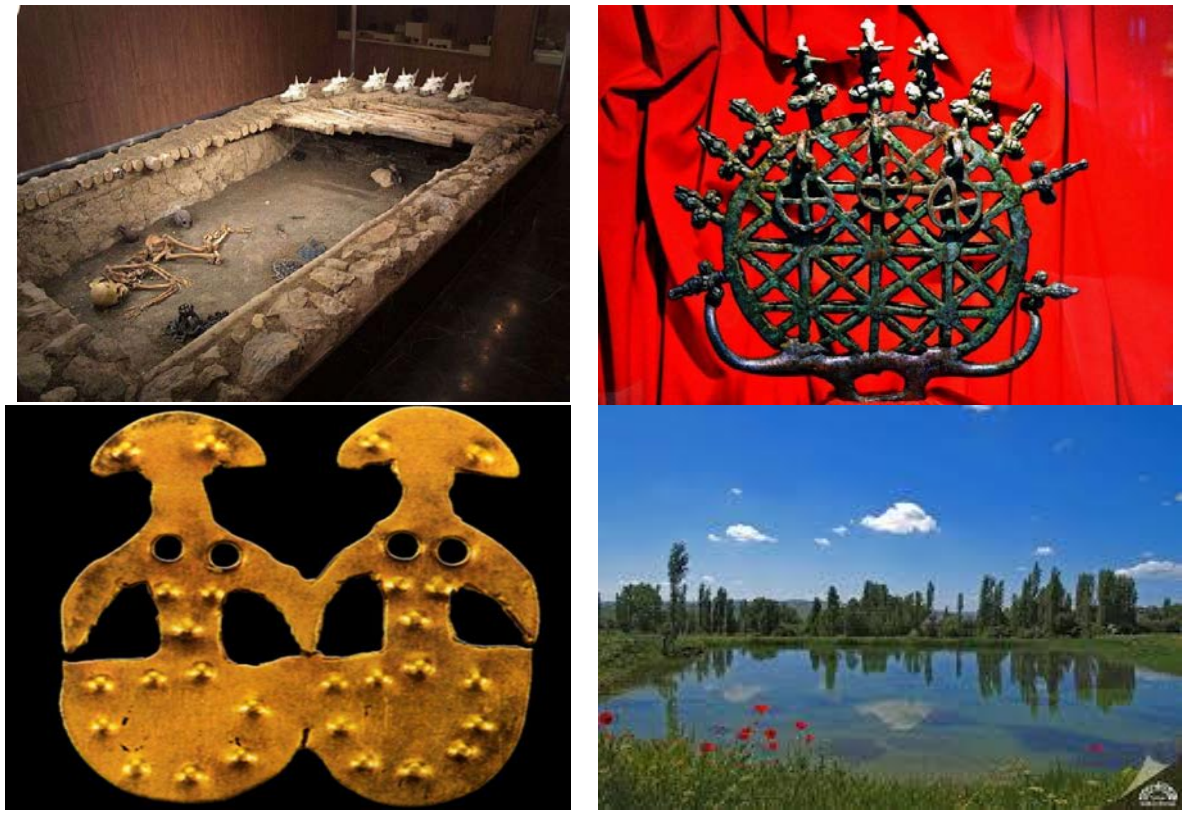


Figure 5. Royal tomb, Hittite sun, twin idols, Hittite dam (URL-8, 2025; URL-9, 2025)

Excavations at Alacahöyük, which was later identified as a very important religious ceremony and art centre during the Early Bronze Age and Hittite period, revealed four cultural layers dating from the Chalcolithic period to the present day. These layers, covering the Chalcolithic, Early Bronze, Hittite, and Phrygian periods, are divided into 15 separate architectural strata (Çorum Provincial Directorate of Culture and Tourism, 2021; Şahin, 2021).

Şapinuva Archaeological Site: One of the Hittites' major centres, Şapinuva is located in the Ortaköy district of Çorum province (URL-10,2025). Şapinuva, which is evaluated as an archaeological site and historical monument, is one of the largest historical monuments in Turkey. It was discovered during excavations carried out between 1987 and 1990 and has been protected as the Hittite capital under the Law on the Protection of Cultural and Natural Assets. (Süel, 2013; Weeden, 2013; Gülersoy and Gülersoy, 2016).

It is known that the excavation area covers approximately 10 square kilometres and that only 3% of the area has been uncovered so far; excavation work is still ongoing (Derinöz; 2021). After Hattuşa, known as the capital of the Hittite state, it served as the capital for a long

period and was an important centre in military, religious and political terms. After the Hittites, it was successively occupied by the Phrygians (750-546 BC), the Persians (559-330 BC), the Alexander Empire (336-323 BC), the Romans (509 BC-395 AD), the Byzantines (4th century AD-11th century AD), the Danismends (1075-1178), the Anatolian Seljuks (1178-1308), the Eretna Principality, the State of Qadi Burhaneddin Ahmed, and the Ottoman Empire (1324). (Gülersoy and Gülersoy, 2016). Şapinuva is an important religious centre where purification rituals, which were very special to the Hittite world, were recorded and performed. This aspect has given Şapinuva a sacred, important, and indispensable religious city identity (Figure 6).



Figure 6. Aerial view of the Şapinuva archaeological site (URL-12, 2025)

To date, excavation work has been carried out in two separate areas: Ağılönü and Tepelerarası. One of the richest archives of tablets from the Hittite period, consisting of approximately 3,500 cuneiform tablets and tablet fragments, was uncovered in Building 'A' in the Tepelerarası area. These tablets, believed to belong to the royal archives, are written in various languages such as Hittite, Hurrian, Hattic, and Akkadian, and cover various topics such as administration, religion, and divination (URL-12, 2025; Gülersoy and Gülersoy, 2016).

On the foundation walls of Building 'B', located on an area of 1200 m², 110 cm wide mudbrick walls rise, and 3-4 cm thick plaster is found on these mudbrick walls. Buildings C and D are important religious structures. Excavations are also continuing in areas E, F, and G in this region. A 75-metre section of the surrounding wall enclosing the area where these structures are located has been uncovered. In addition to architectural remains, the Ortaköy-Şapinuva excavations have yielded important and often rare small finds such as metal, ceramic, and stone objects. One of the most important features is the sacrificial pits found during the excavations, which contained various animal remains, such as bird beaks. These finds are considered proof that the rituals described on the tablets were actually performed (Figure 7).

In addition to architectural remains, the Ortaköy-Şapinuva excavations have yielded important and often rare small finds, including metal, ceramic, stone, and other artefacts (URL-12, 2025).



Figure 7. Sacrificial pits and pig skeleton found at Şapinuva, Hittite cuneiform tablet, gold diadem fragment (URL-12, 2025)

Yazılıkaya Open-Air Temple: It is located in the Boğazkale district of Çorum province, 2 kilometres from the Hattuşa archaeological site, on the slope of a mountain barrier among high cliffs (Figure 8).

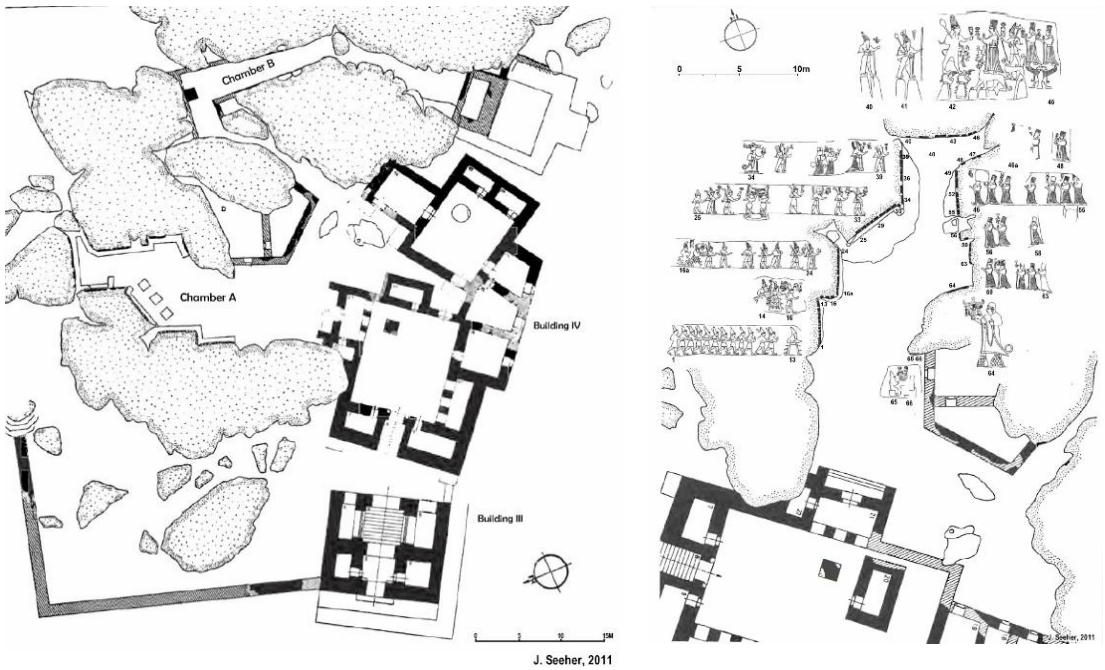


Figure 8. Plan of Yazılıkaya and description of Room A (Seeher, 2011; URL-13, 2025)

The walls of the temple, which has two rooms carved into the main rock, are covered with the richest examples of Hittite relief art, including figures of gods and goddesses and the Great Hittite King IV. Tuthaliya (UNESCO, 2021; Şahin, 2021). Over 90 goddesses, gods, animals, and imaginary 8 creatures are carved into the rock in the temple (Figure 9) (Çorum Provincial Directorate of Culture and Tourism, 2021; Şahin, 2021).



Figure 9. Reliefs belonging to the Yazılıkaya Open-Air Temple (URL-14, 2025)

It consists of two sections: the "Great Gallery" (A) and the "Small Gallery" (B). The western wall of the Great Gallery is decorated with reliefs of gods, while the eastern wall features reliefs of goddesses. Yazılıkaya, with its architectural plan resembling a naturally open cave, reflects the Hittite pantheon with its magnificent rock depictions. It is an important structure built as the home of Hatti's Storm God and the Sun Goddess of Arinna City (Figure 10) (Turkey Culture Portal, 2021; Şahin, 2021; Günay, 2007).



Figure 10. Reliefs belonging to the Yazılıkaya Open Reliefs belonging to the Yazılıkaya Open-Air Temple (URL-14, 2025)

İncesu Canyon: İncesu Canyon is located within the boundaries of Ortaköy District in the southeast of Çorum Province. The canyon is located approximately 5 km east of the Ortaköy District centre, near the village of İncesu. It stretches approximately 13 km from north to south, starting from the vicinity of İncesu (Çorum) in the north to the settlement of Kazankaya (Yozgat) in the south, and has a single entrance and exit. The width of the canyon varies between 40 and 60 metres (Figure 11) (Derinöz, 2021; URL-15, 2025).



Figure 11. İncesu Canyon (URL-15, 2025)

The ancient name of İncesu Canyon, which is among the historical and natural beauties of the region, is Scylax. On both sides of the canyon, which extends around the Çekerek River, there are wall remains and staircase-like water cisterns dating back to the Hellenistic period on the rising rocks. Discovered in 1985 by a citizen of İncesu village, the Cybele Rock Relief is the largest Cybele relief dating back to the Hellenistic period in Anatolia, and no other Cybele relief of this size is known to exist (Figure 12) (Gülersoy and Gülersoy, 2016; URL-16, 2025).



Figure 12. Kybele relief (URL-17, 2025)

The trail, designed as part of the Hittite road in the area envisaged as the İncesu Canyon Cultural Park, is known as Turkey's longest wooden walking platform, stretching 1,700 metres. Toilets, a children's playground, car park, and picnic areas are available for visitors.

Where history and nature meet in the same place, İncesu Canyon is an important centre for nature lovers, photographers, mountaineers, birdwatchers and history enthusiasts (Gülersoy, 1995; Ministry of Forestry and Water Affairs, 2015). The tangible cultural heritage assets examined in this study and located in the province of Çorum, namely the ancient city of Hattusa, the Yazılıkaya Open-Air Temple, Alaca Höyük, the Şapinuva archaeological site and the İncesu Canyon, bear important traces of the Hittite state and also have great tourism potential. However, various studies in the literature (Günay, 2007; Şahin, 2021; Akdoğan and Hiçyorulmaz, 2020; Gülersoy and Gülersoy, 2016; Doğruer, 2021; Derinöz, 2021; Bilgin, 2017; Yılmaz, 2021), this potential is not being utilised correctly, and the province of Çorum is not receiving the recognition it deserves in terms of tourism.

The main reason for selecting these areas examined in the study is that, as supported by other studies (Akdoğan and Hiçyorulmaz, 2016; Yılmaz, 2021). The fact that 55.84% of domestic tourists and 87.81% of foreign tourists who choose Çorum Province cite visiting sites from the Hittite Civilisation as their reason for coming to Çorum. Unfortunately, it is known that the vast majority of tourists who come to see the cultural heritage left behind by the Hittites, such as Hattuşa and Alaca Höyük, are day-trippers who move on to other tourist destinations without staying overnight or visiting the city centre (Yılmaz, 2021).

As Bilgin (2017) mentions in his study on the subject, the main reasons for the low level of accommodation in tourism activities are the lack of suitable places to stay around the district of Boğazkale and the fact that tourists prefer to stay in Cappadocia after visiting Çorum.

In addition, the main reasons for the underutilisation of Çorum's tourism potential are the lack of promotion of Çorum's tourist attractions, the lack of promotional content such as films and 11 documentaries about the Hittite civilisation, inadequate infrastructure and services, the lack of tourism knowledge among the local population, the lack of interest of local administrations in tourism activities, inadequate protection of tourist areas, lack of supervision, misuse, and lack of activities in tourist venues (Bilgin, 2017; Yılmaz, 2021; Derinöz, 2021; Gülersoy and Gülersoy, 2016).

4. Conclusion and Recommendations

Within the scope of this study, important cultural heritage sites belonging to the Hittite Empire were examined, and the tourism potential of the province of Çorum was evaluated in light of previous studies and findings on the tourism potential of the province.

The areas covered in the study, Hattuşa and Yazılıkaya Boğazkale, Şapinuva and İncesu Canyon Ortaköy, and Alaca Höyük, are located in the Alaca district of Çorum province. This also applies to other immovable cultural heritage assets located in Çorum province. There are 2 protected streets, 9 administrative buildings, 74 cultural buildings, 8 military buildings, 2 industrial or commercial buildings, 84 religious buildings, 17 cemeteries, 123 examples of civil architecture, and 6 ancient ruins. Many of these are located in different parts of the city, making it impossible to establish a single tourism centre. However, the fact that Çorum's cultural heritage, which can be considered as tourist resources, is spread over a wide area should be viewed as both an advantage and a disadvantage in terms of tourism activities.

Of the areas evaluated in terms of tourism, Hattuşa and Yazılıkaya are well known due to their inclusion on UNESCO's cultural heritage list, while Alaca Höyük, the first excavation site of the republican era, and Şapivuna, the capital of the Hittite civilisation and the religious centre of the Hittites after Hattuşa, are less well known. With the recent improvements made

by the Çorum Provincial Special Administration, the İncesu Canyon has begun to be recognised and visited by the local population and neighbouring provinces, offering various activities such as recreation, water sports and nature walks. This situation shows that the activities created and the arrangements made in the İncesu Canyon can contribute to other areas being preferred by tourists if various developments are made in accordance with the historical, cultural and natural structure of each area. Deficiencies were observed in all of the areas examined in terms of protection and management, and information such as appointment systems and contact numbers could not be accessed. It was observed that some of the historical structures in all of the areas, such as reliefs, walls, and columns, had been damaged due to natural conditions or human factors.

Finally, in order for the province of Çorum to develop in terms of tourism, the promotion of its existing natural and cultural beauties, urban culture and Hittite civilisation must be improved, infrastructure and services in tourist areas should be improved, the local population should be informed and encouraged to engage in tourism, local and central governments should support tourism through various initiatives, areas of cultural and natural importance should be protected and monitored to prevent their deterioration and destruction, and opportunities for various activities should be provided in these areas.

Thanks and Information Note

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Assessment of the Contributions of Immovable Cultural Heritage to Urban Tourism in Kocaeli City

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Abstract

Cultural heritage encompasses tangible and intangible values that reflect societies' identities, beliefs, traditions, and artistic accumulation, transmitted from the past to the present, and its preservation is vital for sustainability. Cultural heritage strengthens communities' connections with their past, promotes cultural diversity and social awareness, and revitalizes collective memory through historical links. Tangible cultural heritage, comprising historical buildings, monuments, and artifacts, provides valuable insights that encourage people to understand history and explore societal development. These assets hold significant importance for tourism and are preserved according to principles of sustainability and environmental protection to be passed on to future generations. Immovable cultural properties, reflecting architectural features, lifestyles, and historical processes of specific periods, carry traces of the past and play a crucial role in tourism. By ensuring a balanced conservation of both cultural and environmental elements, these assets contribute to the sustainability of cultural heritage tourism and strengthen cultural connections among communities. In this context, the study examines 1,134 immovable cultural heritage assets in Kocaeli city, identified by the Ministry of Culture and Tourism, focusing on 11 subcategories. Representative examples from each subcategory are analyzed to evaluate the characteristics and values of cultural heritage elements. Furthermore, the study provides recommendations regarding the preservation of cultural heritage and its impact on tourism development.

Keywords: Cultural heritage, immovable cultural heritage, urban tourism, Kocaeli City

1. Introduction

Cultural heritage represents a significant set of values that bear the traces of a society's historical past. It reflects collective identity, beliefs, traditions, and artistic expressions. These values are preserved and transmitted across generations to ensure their continuity and sustainability for the future. Cultural heritage strengthens societies' connections to their past, contributing to cultural diversity, social awareness, and collective memory (Kuscuoğlu & Taş, 2017; Aydoğdu Atasoy, 2019; Ede & Çelen Öztürk, 2024).

As a vital concept that embodies the accumulated knowledge and values of societies, cultural heritage functions as a bridge between the past and the present, ensuring cultural continuity and intergenerational connection (Okyay Bayazıt & Binan, 2017; Ede & Çelen Öztürk, 2024; Önculokur & Genç, 2024). It also provides individuals with historical and cultural insight, enabling them to better comprehend their roots and reinforce their historical identity. In this

context, cultural heritage revitalizes social memory and strengthens identity based on shared experiences. Moreover, it enhances solidarity and unity within society, fostering cohesion and a sense of belonging around shared values (Öksüz, Kuşcuoğlu & Taş, 2017; Gümüşçü, 2018; Rukancı, 2018; Çeliktaş Türkbay, 2021).

Elements of cultural heritage—such as historical buildings, monuments, and artefacts—are of great interest due to their historical and aesthetic value. These elements, representing both the past and the present, constitute the foundation of tangible cultural heritage. Tangible cultural heritage encompasses a wide range of visual and cultural assets, including both human-made and natural landscape components (Can, 2009; Mavus, 2021).

Such heritage elements provide valuable insights into past events, historical developments, and the cultural evolution of societies, while offering opportunities to experience unique natural and cultural features. For these reasons, tangible cultural heritage is an essential component of tourism development (Karapınar & Barakazı, 2017; Gümüşçü, 2018; Yaralı & Özçelik Baloğlu, 2023).

From the perspective of immovable cultural assets that require protection, cultural heritage tourism emerges as a key form of tourism encompassing natural, cultural, and historical elements that have retained their significance from the past to the present. It includes historical and archaeological sites, monumental structures, and other cultural properties that offer visitors cultural, historical, and aesthetic experiences (Çelik, 2001; Polat, 2021; Kökdaş, 2021).

Tangible cultural heritage enables individuals not only to witness their own cultural past but also to understand other cultures, discover regional distinctiveness, and appreciate diverse natural and cultural landscapes. Furthermore, cultural heritage tourism plays a crucial role in preserving these assets within the framework of sustainable tourism principles. It ensures the balanced protection of cultural and environmental resources while contributing to the transmission of this heritage to future generations (Behoo & Prentice, 1997; Kolaç, 2009; Öksüz, Kuşcuoğlu & Taş, 2017; Yücel, Batmaz & Biçici, 2021; Topçu, 2022).

Immovable cultural assets, in particular, are tangible entities that reflect the architectural characteristics, lifestyles, and developmental processes of specific historical periods (Yılmaz, 2019).

According to the *Law on the Protection of Cultural and Natural Assets and Amendments to Various Laws* (2004), these assets include above-ground, underground, and underwater structures that hold historical, cultural, religious, scientific, or artistic significance. Immovable cultural properties attract attention as they embody traces of past civilizations and reveal their social, cultural, and architectural identities (Aktuna, 2024). Examples include castles, bridges, city walls, caravanserais, covered bazaars, and madrasas (Demirtaş, 2009; Özverdi, 2023).

This study examines 11 of the 1,134 immovable cultural assets officially designated as protected by the Ministry of Culture and Tourism of the Republic of Türkiye in the province of Kocaeli. The primary aim is to evaluate their contribution to cultural and urban tourism and to highlight their potential role in enhancing the city’s cultural identity and sustainable tourism development.

2. Materials and Methods

The study area, the province of Kocaeli, is located in the Marmara Region of Türkiye, extending between east longitudes 29°22′–30°21′ and north latitudes 40°31′–41°13′ (Kocaeli Metropolitan Municipality, 2024). Bordered by the Black Sea to the north, the province lies south of Bursa, east of Sakarya, and west of Istanbul and Yalova. With a total area of 3,623 km², Kocaeli is the sixth smallest province in Türkiye (Ministry of Culture and Tourism of the Republic of Türkiye, 2024) (Figure 1).

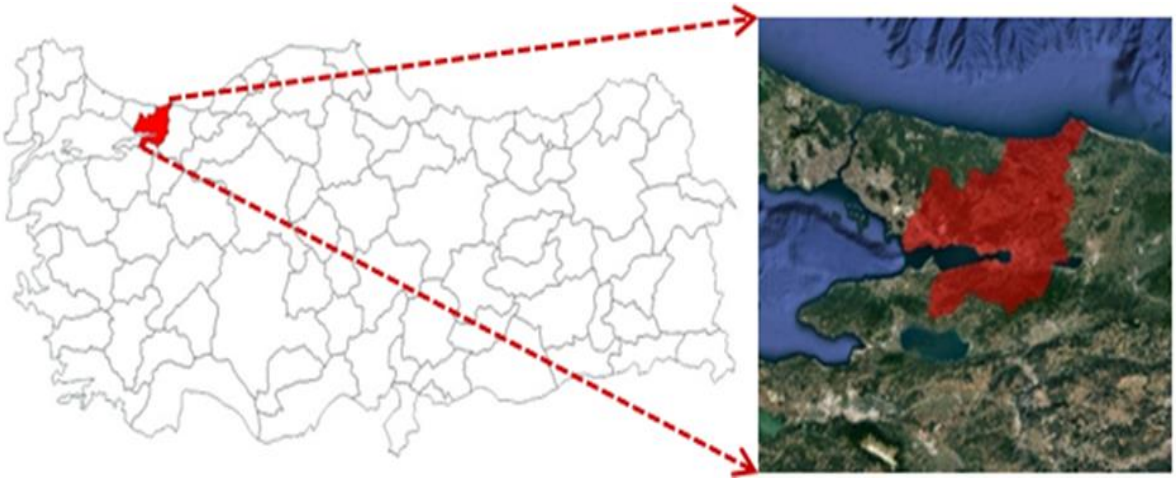


Figure 1. Study area boundaries

Kocaeli stands out as one of Türkiye's most industrially developed provinces and is also recognized as a "city of science" due to its strong research and innovation infrastructure. It hosts two universities, the Scientific and Technological Research Council of Türkiye (TÜBİTAK), the Turkish Institute for Industrial Management (TÜSSİDE), and several research and development centers (Kocaeli Governorate, 2024).

In addition to its industrial and scientific identity, Kocaeli possesses a rich historical and cultural background, with heritage dating back to the Bithynian Kingdom, Roman, Byzantine, Seljuk, and Ottoman periods (Küçükaydın, 2017).

Its geographical location, natural landscapes, and historical assets provide the city with considerable tourism potential throughout the year (Kocaeli Tourism Guide, 2023).

This study investigates the relationship between cultural heritage and tourism by focusing on 11 immovable cultural assets within the administrative boundaries of Kocaeli Province, officially designated as "protected cultural properties" by the Ministry of Culture and Tourism. A comprehensive literature review was conducted for each selected asset, followed by an evaluative analysis based on one representative example from each category. The assessment aimed to reveal the contributions of these immovable cultural heritage sites to urban tourism and their potential role in promoting sustainable cultural tourism in Kocaeli.

3. Findings and Discussion

Within the scope of the study, the findings were obtained through a comprehensive literature review (Table 1).

Table 1. The number of immovable cultural heritage assets in the province of Kocaeli

Kocaeli Province Immovable Cultural Properties	Number
Military buildings	35
Industrial and commercial buildings	66
Religious buildings	63
Cemeteries	80
Civil architecture examples	573
Ruins	83
Streets under protection	2
Monuments and memorials	5
Administrative buildings	52
Cultural buildings	174
Martyrdom Sites	1

3.1. Monuments and Memorials: Karamürsel Bey Monumental Tomb

Mürsel Alp, known as the Ottoman Empire's first naval commander to bear the title of admiral, was later honoured with the epithet *"Kara"*—meaning "bold" or "courageous"—for his bravery on the battlefield. Today, he is widely remembered as Karamürsel (Kocaeli Tourism Guide, 2023). During the early Ottoman period, in 1327, he became the first Turkish naval engineer to establish a shipyard and construct warships, marking the beginning of organized shipbuilding in the Ottoman Empire (Mustak & Şenyurt, 2016). Karamürsel Alp played a crucial role in the conquest of the southern shores of the Gulf of İzmit from the Byzantine Empire. Prior to his death, he expressed his final wish in a will, stating:

"Bury me in such a place that my back rests against the mountains, the sea lies in my lap, and I can always see my fleet."

In accordance with his wishes, he was buried on a hill overlooking the sea, behind the shipyard he had founded (Çoban, 2015; TUKAV, 2020; Cultural Inventory, 2022). Following the identification of Admiral Karamürsel Alp's grave in the Karamürsel district of Kocaeli, the construction of a monumental tomb began in 1949, during which the grave was covered with a marble sarcophagus. The initial memorial tomb project was designed by architect Ferit Hamdi Onan but was not implemented. Subsequently, in 1971, official discussions regarding the construction of the tomb were initiated under the municipal budget, with the involvement of the Naval Forces Command. Architect and engineer Hayri Güner prepared the project model; however, the Karamürsel Municipal Council later approved a revised design prepared by civil engineer Necmettin A. Pilge. The tender was held in 1972, and the project was completed in 1976, officially opening to the public on 4 July (Mustak & Şenyurt, 2016;

Kocaeli Encyclopedia, 2025). The completion and inauguration of the Karamürsel Alp Monumental Tomb hold great significance for the preservation and promotion of the region's historical and cultural heritage. The monument not only commemorates one of the foundational figures of Ottoman maritime history but also enhances cultural tourism in Kocaeli by increasing public awareness, visitor interest, and appreciation of local heritage.

3.2. Military Buildings: Eskihisar Castle

Located in Eskihisar Village within the Gebze district of Kocaeli Province, Eskihisar Castle stands at an elevation of approximately 35 metres above sea level. The structure is believed to have been built during the reign of the Komnenos dynasty (1081–1185) of the Byzantine Empire (Kocaeli Metropolitan Municipality, 2025).

Strategically positioned to protect the southern shores of the Gulf of İzmit, the castle was officially registered as a protected site in 1969. Although initial restoration works began soon after, they remained incomplete. Restoration activities resumed in 1989 and continued into 1998, including the construction of the main entrance and the establishment of a viewing terrace. Following the damage caused by the 1999 Marmara earthquake, the castle underwent another phase of restoration in 2001 (Bahar, 2013; Çomak, 2023).

Covering an area of 10,831.5 m², Eskihisar Castle consists of a rectangular inner fortress surrounded by an outer defensive wall that conforms to the topography of the site. The western and northern ramparts, together with the remains of a moat on the northern side, form an integral part of the castle's historical defence system (Bahar, 2021; Eskin, 2023).

Situated on the coast of the Sea of Marmara, the castle commands a panoramic view of the surrounding landscape, reflecting its strategic importance throughout history. Beyond its defensive function, Eskihisar Castle today holds significant cultural and recreational value. The site features an amphitheatre with a capacity of 1,025 seats, where theatre performances, concerts, and various cultural events are held year-round. These activities contribute not only to the preservation of the site but also to the enrichment of the city's cultural life and tourism economy (Uğurkan, 2019).

With its historical depth, architectural integrity, and continued cultural use, Eskihisar Castle stands as one of Kocaeli's most significant military heritage sites, symbolizing the integration of cultural preservation and contemporary tourism development.

3.3. Religious Buildings: The Çoban Mustafa Pasha Complex

Dating back to the reign of Sultan Suleiman the Magnificent, the Çoban Mustafa Pasha Complex is located in the Gebze district of Kocaeli (Kışlalı et al., 2018). Although many historical sources attribute its construction to the renowned Ottoman architect Mimar Sinan, the exact architect of the complex remains uncertain. The complex is named after Çoban Mustafa Pasha, a prominent statesman who held high-ranking administrative positions during the reigns of Yavuz Sultan Selim and Suleiman the Magnificent (Bayram, 2011). The origin of the epithet *"Çoban"* (meaning "shepherd") is unknown. Following his death in 1529, Çoban Mustafa Pasha was interred in the tomb located within the complex.

Occupying a central position in Gebze's town square, the complex stands out for its impressive scale, symmetrical composition, and refined architectural detailing. Constructed from various types of stone, it exemplifies the aesthetic sophistication characteristic of 16th-century Ottoman architecture, evident in both its exterior and interior design. The complex

comprises a diverse range of structures, including a mosque, madrasa, tabhane (guest rooms), zaviye (dervish lodge), caravanserai, guesthouse, library, imaret (public kitchen), hammam, and tomb (Öngen & Vardar, 2018).

This rich combination of architectural components demonstrates that the complex was not solely designed for religious purposes but also functioned as a multifunctional social and cultural center, serving the urban community of its time. Today, the Çoban Mustafa Pasha Complex continues to attract visitors with its architectural grandeur, historical significance, and representation of the social structure of the Ottoman period. Through its preservation and integration into local tourism routes, the complex contributes significantly to cultural tourism and the promotion of Kocaeli's historical identity.

3.4. Industrial and Commercial Buildings: SEKA Paper Factory

The foundation stone of the SEKA Paper Factory was laid by İsmet İnönü on 14 August 1934 in the İzmit district of Kocaeli, and the factory commenced production in 1936. Its establishment represented a major milestone in the industrialization and national production policies of the early Republican period, marking a significant step toward economic independence and modernization (Oral Aydın & Çömlekçioğlu Kartal, 2010; Oğuz et al., 2010). SEKA played a pioneering role in the development of Türkiye's domestic paper industry and became a symbol of industrial progress.

In parallel with the factory's foundation, various social infrastructures were established to improve workers' living standards and foster a sense of community. These included cooperatives, infirmaries, housing areas, cafeterias, cinemas, parks, and schools, which together reflected the social welfare-oriented industrial vision of the era. The publication of the *SEKA Postası* newspaper and the establishment of the SEKA Sports Club further strengthened the factory's influence on the city's social and cultural life, contributing to the economic and cultural transformation of İzmit and its surroundings (Ay et al., 2010).

However, as technological advances outpaced the factory's production capacity, SEKA ceased operations and was transferred to the Kocaeli Metropolitan Municipality in 2005. As part of the redevelopment process, conservation-oriented zoning plans and adaptive reuse strategies were introduced. The coastal section of the site was designated as a green and recreational area, transformed into a coastal park, while the former factory buildings were repurposed as a Paper Museum and Science Center (Güzel, 2010; Keleş Taylak, 2019; Yıldırım, 2020).

Functioning for decades as an industrial complex that embodied the social and structural values of its time, the SEKA Paper Factory holds not only historical and industrial significance but also scenic value due to its waterfront location. Its adaptive reuse has ensured the preservation of both the physical structure and the intangible social heritage associated with it. Within the framework of industrial heritage conservation, the transformation of SEKA represents a successful example of integrating heritage preservation with contemporary urban and tourism development.

Today, the SEKA Paper Museum and Science Center serve as vital cultural institutions that preserve and interpret the city's industrial past (Muskarà & Tuncelli, 2019). By enabling visitors to experience the industrial culture of the early Republican period, these institutions promote cultural continuity, public education, and tourism development. In this context, the

SEKA Paper Factory contributes not only to the economic and cultural vitality of Kocaeli but also to the preservation and reinterpretation of its historical identity.

3.5. Administrative Buildings: Kasr-i Humayun Palace

Built during the reign of Sultan Murad IV in the Izmit district of Kocaeli, Kasr-i Humayun Palace was among the most magnificent structures of the Ottoman Empire. However, it suffered severe damage and was destroyed in the 1766 earthquake. Reconstruction work began during the reign of Sultan Mahmud II and was completed within the same period. Later, during the reign of Sultan Abdulmecid, the palace was once again destroyed, this time by fire, leading to plans for a new structure. The current palace, rebuilt during the reign of Sultan Abdulaziz, represents the final architectural phase of this historic site (Kesikbasi & Erdogan, 2018; 2020).

Located on a hill overlooking the Gulf of Marmara, Kasr-i Humayun Palace served not only as a royal residence but also as a venue for hosting statesmen and foreign dignitaries during the Ottoman era. The palace played significant administrative, social, and cultural roles (Goktas Kaya & Çagil, 2018).

In the Republican period, the palace was converted into a museum and opened to the public. Today, it houses a variety of exhibits, including 19th-century furniture, steles, jewellery, decorative objects, and lamps. The palace gardens also display historical remains such as sculptures, gravestones, and archaeological artefacts (Golcuk, 2021).

Kasr-i Humayun is notable for being the first palace constructed outside Istanbul, reflecting both the architectural grandeur and political significance of the Ottoman period. Its transformation into a museum has reinforced its status as a valuable historical and cultural heritage site. With its commanding view, rich history, and high cultural value, the palace stands today as a prominent tourist attraction, contributing to the preservation and interpretation of cultural heritage in Kocaeli.

3.6. Ruins: Gültepe Necropolis

Located in the İzmit district of Kocaeli, the Gültepe Necropolis is a third-degree archaeological site that offers significant insights into the region’s ancient past. Excavations conducted in 1991 revealed numerous tombs dating back to the Hellenistic, Roman, and Byzantine periods. The site is distinguished by the diversity of its burial structures, including rectangular and brick-built tombs, sarcophagi, and inscribed votive stones (Çalık Ross, 2022). This variety reflects a rich and continuous funerary tradition spanning multiple historical eras.

In addition to the tombs, excavations in 1992 uncovered the remains of a Byzantine-period church with a cruciform plan. The surrounding structures are believed to have served as martyrdom sites, further emphasizing the area’s religious significance (Akyürek Şahin, 2011).

The Gültepe Necropolis holds great historical and archaeological value, as it encapsulates evidence of cultural and religious practices from successive civilizations. The diversity of architectural forms and artefacts found at the site provides valuable information on burial rituals, belief systems, and social organization in the ancient world (Çiftçi Gökkadar, 2018).

Today, the Gültepe Necropolis stands as an essential resource for archaeological research and heritage preservation. Its rich historical layers and religious associations make it an important site of discovery for both scholars and visitors interested in understanding the cultural evolution of the Kocaeli region.

3.7. Streets Under Protection: Kapanca Street

Located in the İzmit district of Kocaeli province, Kapanca Street is over a century old and has been officially designated as a *protected street*. It has largely retained its 19th-century architectural characteristics, serving as a living example of the city's historical urban fabric (Çelik Arısal, 2024). The street embodies significant structural and cultural heritage, having preserved its authentic atmosphere without the influence of modern architectural interventions.

As part of the municipality's ongoing "History Corridor" restoration project, efforts have been made to conserve the street's original structures and ensure their transmission to future generations. The houses on Kapanca Street exhibit diverse architectural details that provide valuable insights into the social life and living conditions of their era. In addition to traditional residences, the street also features historic elements such as fountains, cisterns, and schools (Özbayraktar, 2015).

Kapanca Street stands out for its ability to sustain its historical integrity and distinctive character over time. It is among the few residential areas that have successfully preserved the tangible traces of the past within a contemporary urban context. With its authentic architectural elements, spatial organization, and cultural continuity, Kapanca Street represents an exemplary case of urban heritage preservation (Ayyıldız & Ertürk, 2017).

The street's enduring historical structures reflect both the aesthetic sensibilities and functional needs of the period in which they were built. Thus, Kapanca Street is not only a residential area, but also a cultural heritage corridor that bridges the past and the present—playing a vital role in transmitting local architectural identity and collective memory across generations.

3.8. Cultural Buildings: Ereğli Houses

The Ereğli neighbourhood, once a small fishing village, is today a prominent residential area located in the Karamürsel district of Kocaeli. Over time, it has developed into a settlement that draws attention for its well-preserved cultural and architectural heritage. The historical buildings in the neighbourhood embody traces of local life and contribute to a strong sense of identity.

Initially, 18 buildings were designated for registration and protection; however, subsequent surveys identified an additional 102 buildings that also required preservation, revealing the broader cultural significance of the area. Most Ereğli Houses represent typical examples of traditional Turkish residential architecture, constructed primarily from stone and timber, and generally two to three storeys high. Although many of these structures have suffered deterioration over time due to natural factors and insufficient maintenance, restoration and conservation projects have been initiated to safeguard their historical integrity (Kuban, 2017).

To further enhance the preservation of the area's heritage, cultural events—such as festivals, exhibitions, and public gatherings—are organised to celebrate and promote Ereğli's architectural and social values. These activities encourage local residents to take ownership of their cultural assets and strengthen community engagement, while simultaneously supporting the regional economy.

The Ereğli Houses, with their distinctive aesthetic character and connection to traditional lifestyles, offer visitors a profound cultural heritage experience. The neighbourhood's proximity to the Sea of Marmara adds both historical and geographical significance. Ereğli's

enduring identity as a former fishing village continues to shape the spatial organization and daily life of its residents today (Çalışkan & Erdoğan, 2024). By combining architectural conservation with living cultural practices, Ereğli exemplifies a sustainable approach to heritage preservation. The neighbourhood's ongoing cultural events not only promote awareness of its unique historical character but also position Ereğli as an emerging destination for cultural tourism, where the past and present coexist in harmony.

3.9. Cemeteries: Degirmendere Cemetery

Located in the Gölcük district of Kocaeli, the Degirmendere Cemetery lies within a neighbourhood historically influenced by seafaring activities and potentially inhabited by Janissaries. Archival documents and gravestone inscriptions reveal the area's military heritage, highlighting the presence of past military communities. Gravestones bear nicknames such as *"Yazıcı," "Alemdar," "Beşe," "Çorbacı,"* and *"Karakullukçu,"* which correspond to historical military ranks, reflecting the local population's connection to its martial past (Tanik, 2016).

The cemetery exhibits a variety of grave types and markers, often segregated by gender, offering insights into the region's historical burial customs and social organization. Graves dating from the 18th century to the present demonstrate considerable diversity in form and design. While some are associated with soldiers, others reveal broader social and cultural practices. The separation of male and female graves, along with variations in gravestone design, highlights both the hierarchical and gendered aspects of past societies (Seçkin & Tanik, 2023).

Degirmendere Cemetery is therefore of significant cultural and historical importance, as it preserves the tangible traces of military and civilian life over several centuries. The variety of grave structures provides researchers and visitors with valuable insights into the region's historical social structure, belief systems, and local identity formation. As a protected site, the cemetery not only safeguards the region's heritage but also facilitates the study and understanding of Kocaeli's historical and cultural landscape.

3.10. Martyrdom Sites: Bagçeşme Prayer Ground Martyrdom Site

A namazgah is an outdoor prayer ground typically equipped with a qibla stone and a mihrab, often situated at an elevation to ensure visibility of the qibla for all worshippers. The Bagçeşme Namazgah, built in 1483 in the İzmit district of Kocaeli, gradually evolved into a cemetery over time. During the 1921 occupation of İzmit, 57 soldiers were martyred and interred at this site. A monument dedicated to Sırrı Paşa, the former governor of İzmit, also stands within the grounds, reinforcing the site's commemorative function (Akyüz, 2020).

The tradition of burying martyrs at the Bagçeşme Namazgah has persisted from historical times to the present day, making the site a living testament to the region's military and religious history. Beyond its historical significance, the cemetery contributes to cultural heritage preservation by illustrating past burial customs and fostering an understanding of the local historical context. Visitors to the Bagçeşme Namazgah Martyrdom Site gain valuable insights into the historical and cultural heritage of Kocaeli, while the site itself strengthens emotional and cultural connections to the past. In this way, the Bagçeşme Namazgah serves not only as a memorial site but also as a vital cultural resource, ensuring the transmission of historical memory and reinforcing the region's heritage identity.

3.11. Civil Architecture: The İzmit Clock Tower

The İzmit Clock Tower was constructed to commemorate the 25th anniversary of Sultan Abdülhamid II's accession to the throne. Located in the İzmit district of Kocaeli, the tower was commissioned by the provincial governor, Musa Kazım Bey (Bicici, 2016).

The structure consists of four tiers, with the widest section forming the base. It incorporates both aesthetic and functional elements, including fountains on three sides. Built from marble and travertine, the tower combines durability with architectural elegance, enhancing its visual prominence. Over time, the İzmit Clock Tower has become a symbol of the city, even featuring in the logo of the Kocaeli Metropolitan Municipality, reflecting the region's cultural identity (Vardar, 2016).

Its architectural form, historical significance, and detailed craftsmanship provide valuable insights into the city's past, making it an essential example of civil architectural heritage and an important asset for both residents and visitors.

4. Conclusion and Recommendations

Cultural heritage encompasses values that carry traces of the past into the present, allowing people to experience, understand, and connect with their history through both tangible and intangible elements. Tangible heritage includes historical structures and cultural artefacts, while intangible heritage encompasses social norms, traditions, and beliefs. Together, these elements form the foundation of a society's identity, shaping its social structures and cultural dynamics. Preserving this heritage is therefore crucial for both current and future generations, enabling them to understand their past, develop social identities, and strengthen collective memory. Cultural heritage fosters social cohesion by uniting communities around shared values, making its preservation a responsibility that transcends generations.

The examination of Kocaeli's cultural heritage across 11 categories demonstrates that, in addition to being an industrial and scientific hub, the city possesses rich historical and cultural resources. However, these cultural values and tourism potentials are often overlooked, and their significance is not always fully appreciated by either local residents or visitors. Moreover, deficiencies in preservation practices in certain areas pose serious risks to the sustainability of the city's heritage and its potential for tourism development.

To address these challenges, it is recommended that Kocaeli's cultural heritage values be preserved more effectively through comprehensive conservation strategies, restoration initiatives, and protective measures. Simultaneously, these assets should be communicated to wider audiences through targeted promotion, educational programs, and sustainable tourism projects, ensuring a balance between conservation and use. By doing so, Kocaeli's cultural heritage can be recognized not only as a protected resource but also as a driver of economic, social, and cultural development, contributing to the city's identity and tourism potential.

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Sculptures that Stand the Time: Durability and Sustainability in Outdoor Art

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Abstract

Sculptures installed outdoors are subject to more rapid deterioration than works installed indoors because they are directly affected by environmental conditions. Climatic factors (rain, freeze-thaw cycles, UV rays, humidity), as well as biological and chemical influences, threaten the permanence of these works. Throughout history, artists have created works using naturally available materials such as wood and marble; durable materials like marble have survived to the present day. In contrast, more fragile or prone to discoloration materials such as metal, wood, paint, or industrial polymers can deteriorate rapidly without the development of conservation strategies (Britannica, Metal Sculpture).

The purpose of this paper is to discuss sustainability-focused approaches that will enhance the longevity of sculptures produced specifically for outdoor use. First, the material selection process will emphasize the importance of choosing materials that are long-lasting, resistant to environmental impacts, and require low maintenance (Liu, 2018). Furthermore, periodic inspection, maintenance, and conservation planning (inspection and maintenance) should be systematically implemented, and physical, chemical, and biological deterioration should be mitigated through measures such as surface coatings and drainage solutions (Canadian Conservation Institute, 2020). Furthermore, it is recommended that the coatings and pigments used in painted outdoor sculptures be supported with sustainable conservation solutions, that conservator training be developed in accordance with international standards (ICOMOS, 1993), and that collaboration between artists, designers, and conservator be ensured during the production phase (Lowinger, 2024).

Ultimately, preserving the cultural continuity and aesthetic value of sculptures depends not only on the artist's choices during the production phase but also on the implementation of long-term conservation and maintenance programs. This paper will present recommendations for increasing the sustainability of outdoor sculptures, from material selection and maintenance planning to education and collaborative production models.

Keywords: Sustainability, conservation, outdoor sculptures, conservation strategies

1. Introduction

Throughout history, sculpture has been a form of cultural expression, creating one of the most enduring visual representations of collective memory. However, sculptures placed outdoors, in particular, are subject to direct environmental influences compared to indoor works, and are therefore subject to processes of deterioration and wear over time. Climatic variables, air pollution, biological organisms, and physical influences threaten both the aesthetic and structural integrity of these works.

New production technologies developed after the industrial revolution allowed artists to work with modern materials such as metal, concrete, fiberglass, plastic, and various polymers. However, the long-term durability and environmental reactions of these materials necessitated different conservation approaches compared to traditional materials. Today, not only the aesthetic or conceptual aspects of art production but also sustainability and conservation awareness are at the forefront.

In this context, researching sustainable conservation strategies designed to enhance the permanence of outdoor sculptures is crucial for both art history and contemporary

conservation science. This study explores material selection, conservation and care planning, interdisciplinary collaboration, and digital preservation technologies.

It discusses approaches to ensuring sustainability in outdoor sculptures across various dimensions, such as:

2. Materials And Methods

This study was conducted based on a literature review, international conservation standards, and contemporary art practices on the sustainability of sculptures installed outdoors. The study methodology is based on a descriptive-analytical qualitative research approach.

The primary materials for the research consisted of the following source types:

• Reports published by international conservation institutions (Canadian Conservation Institute, ICOMOS, Getty Conservation Institute);

• Scientific articles and experimental research on sculpture materials (e.g., Liu, 2018; Lowinger, 2024);

• Selected case studies of outdoor sculptures (metal, stone, and polymer-based works);

• Field observations and museum and park archive documents.

Methodologically, the sculptures' material properties, environmental impacts, types of deterioration, and conservation interventions were examined under four main headings. Under each heading, the chemical and physical behavior of the material, its interaction with the environment, and sustainable conservation methods were evaluated. Furthermore, the impact of the artist-designer-conservator collaboration on the production process was analyzed using qualitative data.

Because sculptures placed outdoors are directly exposed to environmental factors, they require special measures not only for aesthetics but also for conservation and sustainability. The artwork's location, material properties, environmental conditions, and maintenance practices are the primary factors determining its lifespan. Therefore, the concepts of material awareness and environmental durability should be prioritized in the sculpture production process.

a. Material Selection and Durability

Material selection is one of the most critical steps in ensuring the longevity of outdoor sculptures. Historically, materials such as stone, bronze, and marble have stood out for their durability, with examples from ancient times to the present day proving their durability (Figure 1). However, in the modern era, as artists prefer to work with industrial materials (steel, aluminum, fiber, concrete, resin, etc.), the environmental reactions of these new materials have become more complex (Figure 2). The physical and chemical stability of the material is as important as its aesthetic value; therefore, engineering and materials science are not the only factors influencing the sculpture's production (Sunara, 2018).

Materials such as wood, iron, and paint are sensitive to changes in humidity due to their hygroscopic properties. Surface deterioration such as cracking, rust, and fading are common in these materials. To reduce these risks, techniques such as applying protective coatings to sculpture surfaces, providing waterproofing, and cathodic protection at metal joints should be employed (Canadian Conservation Institute, 2020).



Figure 1. Ancient Period, Example of Sculpture Made with Durable Material, Marble Michelangelo, "David" 1501 – 1504



Figure 2. Modern Jeff Koons – "Balloon Dog" Series, Steel

b. Conservation, Maintenance, and Inspection Systems

While the deterioration process of outdoor sculptures is inevitable, it can be significantly slowed down through periodic maintenance and inspection systems. A systematic conservation approach includes regular inspection of the work, early repair of any damage, and long-term planning. The use of paints and varnishes resistant to UV rays and atmospheric pollution is an effective method for preventing surface deterioration.

Lowinger (2024) emphasizes the importance of a "preventive conservation" approach in the conservation of outdoor artworks. This approach aims not only to intervene after deterioration but also to develop proactive conservation strategies by identifying the causes of deterioration in advance. In this context, establishing drainage systems at the sculpture's base, preventing water accumulation, and preventing contact with plant roots should also be part of the conservation process.



Figure 3. An Example of a Statue Exposed to UV Rays

c. Sustainability and Education-Based Approaches

Sustainability in sculpture is not limited to material selection; it also includes reducing the environmental impact of production and maintenance processes. Therefore, the use of recyclable materials, low-energy production methods, and non-toxic dyes/pigments are important for sustainable art production. International conservation standards (ICOMOS, 1993) emphasize the need for multidisciplinary collaboration in the conservation of works of art. Models in which artists, designers, engineers, and conservators collaborate not only on aesthetic and technical quality but also on the creation of a work of art.

It also ensures permanence. Developing conservator training in accordance with these standards will contribute to the dissemination of sustainable conservation practices at the local level.



Figure 4. Şahin Bayram, Example of Sculpture Made with Waste Metal

d. Digital Technologies and Next-Generation Conservation Methods

In recent years, technologies such as digital scanning (3D scanning), laser surface analysis, and environmental data monitoring systems have offered new opportunities in sculpture conservation. These systems detect surface deformations of artifacts with millimeter precision, enabling early detection of deterioration. This allows for data-based conservation planning and optimized resource use (Ucakar et al., 2022).

3. Findings And Discussion

Research findings indicate that material selection, maintenance planning, and sustainable practices play a decisive role in the preservation of outdoor sculptures.

3.1.Material Durability

Studies have shown that traditional materials like marble, granite, and bronze are long-lasting, while wood, steel, and polymer-based sculptures experience more rapid discoloration, rust, deformation, and surface deterioration. This demonstrates that material selection should be evaluated not only based on aesthetic but also environmental suitability. Studies have shown that traditional materials like marble, granite, and bronze are long-lasting, while wood, steel, and polymer-based sculptures experience more rapid discoloration, rust, deformation, and surface deterioration. This demonstrates that material selection should be evaluated not only based on aesthetic but also environmental suitability.

3.2.Conservation Strategies:

Sculptures that receive regular maintenance, drainage systems, UV-protective coatings, and biological cleaning techniques have been observed to maintain their aesthetic integrity longer. This finding supports the effectiveness of preventative conservation (Lowinger, 2024).

3.3. Education and Collaboration:

In projects where conservators and artists work collaboratively, both structural durability and the authenticity of the artwork have been observed to be more successfully preserved. This demonstrates that the multidisciplinary approach recommended by ICOMOS (1993) has been validated in the field.

3.4. Sustainable Practices:

Choosing recyclable materials and low-toxicity coatings reduces both environmental impact and maintenance costs. Furthermore, digital scanning and sensor-based monitoring systems stand out as significant innovations in detecting deterioration at an early stage.

In light of these findings, a holistic sustainability model for the preservation of outdoor sculptures is proposed. The model consists of the following components: "material awareness, preventative protection, interdisciplinary collaboration, digitally assisted monitoring."

4. Conclusion and Recommendations

The preservation of outdoor sculptures is not simply a matter of physical maintenance; it is a multilayered process at the intersection of cultural continuity, art history, and environmental stewardship. The longevity of sculptures depends on holistic consideration of a range of factors, from material choices during production to display conditions and the sustainable implementation of maintenance programs.

Sustainability-focused approaches should encompass not only the physical preservation of works but also the ethical and ecological dimensions of their relationship with the environment. Therefore, artists and conservators must work collaboratively, local governments must support conservation programs, and academic institutions must develop conservation training in line with current international standards.

In conclusion, the preservation of outdoor sculptures is vital not only for their aesthetic value but also for the continuity of cultural heritage. This holistic approach, which combines materials science, artistic practice, and sustainability, forms the foundation of the artistic heritage that will be passed on to future generations.

Thanks and Information Note

The article complies with national and international research and publication ethics. Ethics Committee approval was not required for the study. All authors contributed equally to the article.

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Thermal Camera Analysis of the Potential of Herbaceous Plants Around Sidewalks to Influence Outdoor Thermal Comfort

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Abstract

With the acceleration of urbanization, increasing building density and decreasing green spaces intensify the urban heat island effect during summer, which negatively impacts the thermal comfort of city dwellers. This necessitates the development of sustainable urban design approaches. Previous studies indicate that vegetation along pedestrian routes can enhance thermal comfort, and that not only shade-providing trees but also herbaceous plants along sidewalks influence microclimatic conditions. In this context, the present study, conducted in July 2025 on the campus of Atatürk University in Erzurum, investigates the effects of herbaceous plants along sidewalks on thermal comfort. Measurements were taken in six different areas using a high-resolution thermal camera and Pro HD Lens. Sky View Factor (SVF) values were determined, and Physiological Equivalent Temperature (PET) values were calculated using the RayMan Pro 2.1 model. The study covered approximately 10,000 m² of pedestrian routes, including sidewalks with different plant densities and plant-free areas. Data were collected at various times of the day and analyzed in terms of thermal comfort. Findings reveal that areas with herbaceous vegetation were significantly cooler compared to those without plants. The cooling effect increased with plant density, and this effect was evident even under Erzurum's continental climate conditions. Average surface temperatures in plant-free areas were measured at 45–46 °C, while in vegetated areas the average was 30 °C. PET analyses further showed that vegetated areas provided greater thermal comfort. In conclusion, micro-scale green spaces play an important role in reducing the urban heat island effect and improving pedestrian comfort. The study emphasizes that urban design processes should consider not only large-scale green areas but also small-scale vegetation arrangements, such as sidewalk greenery.

Keywords: Urban heat ısland, microclimate, herbaceous plants, green space, thermal comfort, thermal camera

1. Introduction

Rapid urbanization, the expansion of impervious surfaces, and the reduction of green areas disrupt the microclimatic balance of cities and intensify the urban heat island (UHI) effect (Hashemi et al., 2023; Oke, 1982). This effect leads to increased surface and air temperatures, particularly in summer, thereby reducing thermal comfort (Wang et al., 2025).Key factors influencing urban microclimate include building density, surface characteristics, sky view factor (SVF), and vegetation (Dissanayake et al., 2021). Vegetation regulates microclimate through shading and evapotranspiration, helping to reduce temperatures (He et al., 2023). Recent studies have shown that even small-scale vegetation—such as herbaceous and shrub species along sidewalks—can provide localized cooling (Sun et al., 2024; Yan et al., 2023).In Türkiye, increasing urbanization pressure and arid climatic conditions intensify the UHI effect (Kuru & Okay, 2025). Research conducted in continental climates, such as Erzurum, has demonstrated that vegetation can reduce temperatures even during the summer period (Güller, 2024). However, studies focusing on micro-scale environments, particularly along pedestrian paths and sidewalk edges, remain limited.

In this context, the present research, conducted in June 2025 at the Western Campus of Atatürk University, investigates the effects of herbaceous vegetation along sidewalks on surface temperature and thermal comfort. Measurements using a thermal camera, SVF analysis, and the RayMan Pro model indicate that increasing vegetation density significantly lowers surface temperatures. The findings highlight that even small-scale green elements play an important role in mitigating the urban heat island effect.

2. Material and Method

Erzurum is located in the Upper Euphrates Section of the Eastern Anatolia Region, between 39°55′ N latitude and 41°16′ E longitude, at an elevation of approximately 1850 meters (Atalay, 2011). The study was conducted on the Atatürk University campus, situated west of the city center and covering an area of about 6.5 million m². With its academic buildings, administrative units, dormitories, and extensive green areas, the campus—particularly the Western Campus—offers suitable conditions for microclimate and urban heat island research due to its open spaces, walking paths, and plant diversity (MGM, 2020). The location of the study area is presented in Figure 1.

The Western Campus of Atatürk University was selected as the study area because of the intensive use of sidewalks, bicycle paths, and walking routes, as well as the opportunity to assess the influence of existing plant diversity. Within the scope of this research, six different site types were identified, and the effects of varying vegetation conditions were examined. The plant diversity influencing the microclimatic comfort of the study areas is illustrated in Figure 2.

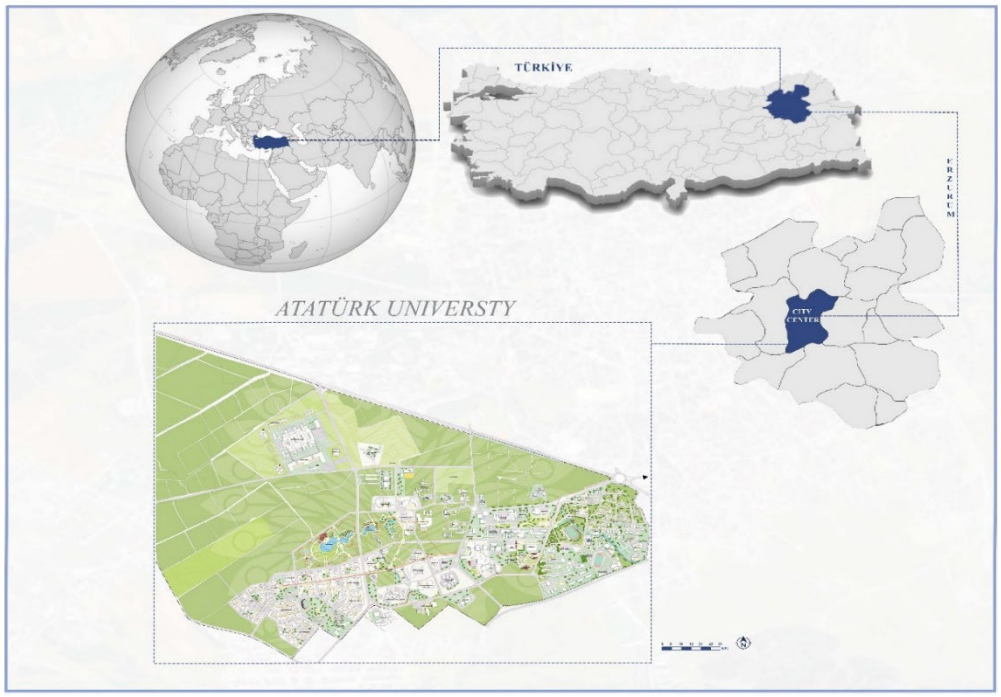


Figure 1. Location map of the study area (Created by the author).

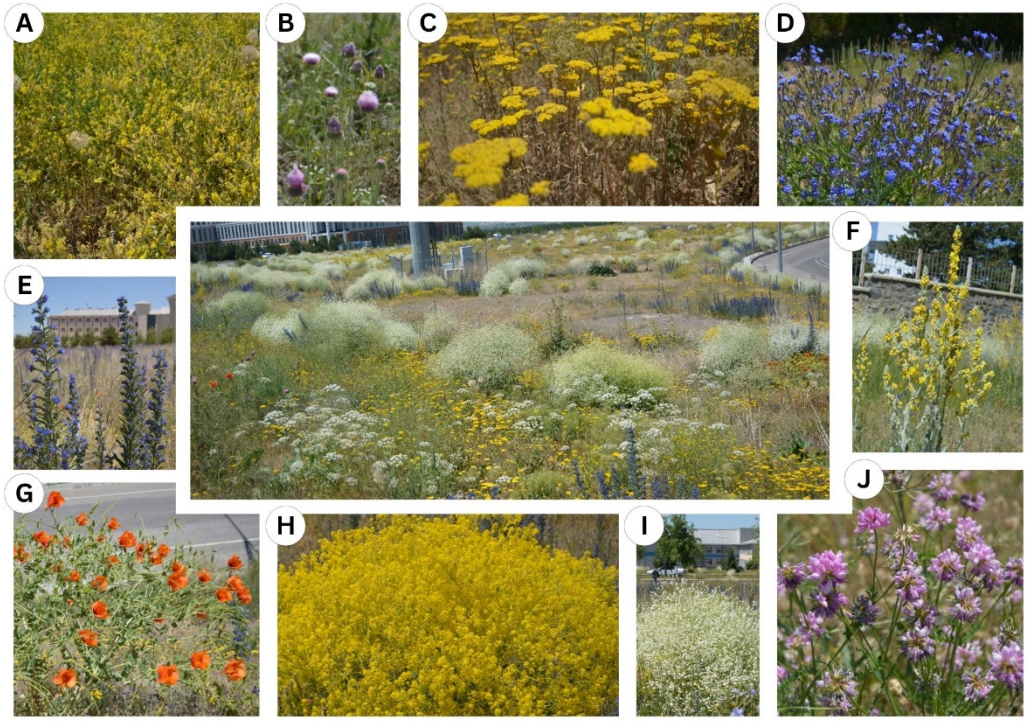


Figure 2. Plant diversity within the study area (Created by the author).

The herbaceous plant species found in the study area and their characteristics are listed below:

A–*Melilotus officinalis* (Yellow Sweet Clover)

Melilotus officinalis is a biennial herb belonging to the Fabaceae family. It typically grows 30–100 cm tall and is known for its fragrant yellow flowers that bloom in summer. It thrives in dry and calcareous soils.

B–*Tyrimnus leucographus* (White-veined Thistle)

This annual herb from the Asteraceae family grows in dry, rocky, and calcareous soils. It is commonly found along field margins, roadsides, and steppe areas. It prefers sunny, warm environments and is highly drought-tolerant.

C–*Achillea ageratum* (Sweet Yarrow)

A perennial herb of the Asteraceae family, typically growing in dry, sunny, and well-drained soils. Its drought tolerance allows it to thrive on rocky slopes, fields, and roadsides. It is commonly found both in natural landscapes and as an ornamental plant in gardens.

D–*Anchusa azurea* (Italian Bugloss)

A perennial herb belonging to the Boraginaceae family. It prefers sunny, dry, well-drained soils and is frequently found on rocky slopes, fields, and roadsides due to its drought resistance. It reproduces easily by seed and can spread naturally.

E–*Echium vulgare* (Viper's Bugloss)

A biennial herbaceous plant from the Boraginaceae family. It typically grows 30–100 cm tall with erect stems. The narrow, hairy, gray-green leaves accompany flowers that start pink and turn bright blue or violet as they mature.

F–*Verbascum pulverulentum* (Hoary Mullein)

A biennial herb from the Scrophulariaceae family. Native to Europe, it grows in dry, sunny, and rocky habitats. During the first year, it forms a rosette of hairy leaves; in the second year, it develops a flowering stalk reaching 1–1.5 meters. It is commonly found along roadsides, fields, and steppes and can tolerate drought and poor soils.

G–*Glaucium arabicum* (Arabia Horned Poppy)

A herbaceous species of the Papaveraceae family, typically growing in arid and semi-arid regions. It has gray-green, hairy, lobed leaves and yellow to orange flowers with four petals. It prefers sunny areas and is highly drought-tolerant.

H–*Isatis tinctoria* (Woad)

A biennial plant from the Brassicaceae family, usually reaching 30–120 cm in height. It produces yellow flowers in spring and early summer and grows well in sunny, well-drained soils.

I–*Gypsophil paniculata* (Baby's Breath/Bride's Flower)

A perennial species from the Caryophyllaceae family, known for its delicate branching stems and small white summer-blooming flowers. It is widely used as a filler plant in floral arrangements and thrives in light, calcareous, well-drained soils.

J-*Coronilla varia* (Crown Vetch)

A perennial herb belonging to the Fabaceae family. Native to Europe and Western Asia, this species is now widely used for erosion control and as an ornamental plant due to its spreading growth habit.

High-resolution thermal cameras and a Pro HD lens were used to conduct measurements in the study area. The Sky View Factor (SVF) was determined, and thermal comfort analyses were performed by calculating Physiological Equivalent Temperature (PET) values using the RayMan Pro 2.1 model. Photographs taken during the measurement process are presented in Figure 3.



Figure 3. Photographs taken during the study (Created by the author).

Thermal cameras are widely used to measure surface temperatures with high precision via infrared radiation and monitor environmental processes such as glacier melting, sea surface temperatures, and urban heat islands (NASA, 2022; ESA, 2023). They also play a crucial role in early detection of forest fires and assessing ecosystem health (Convergint, 2023). In this way, thermal imaging systems provide a fundamental tool for climate change analysis and sustainable environmental management (Satellite Vu, 2024).The Sky View Factor (SVF) represents the proportion of visible sky from a point and is a critical parameter in urban microclimate studies (Oke, 1967). Low SVF values limit radiative cooling, increasing surface temperatures and amplifying the urban heat island effect (Li et al., 2022). Studies have shown that increasing SVF through building design and vegetation can improve thermal comfort and energy efficiency (Zhao et al., 2023). Therefore, SVF analysis is an important component of sustainable urban planning (OneClickLCA, 2024).Measurements in the study were conducted in June, focusing on the microclimatic effects of vegetation on different sidewalk and road surfaces. Thermal images were captured on surfaces with vegetation on both sides, no vegetation, and vegetation on only one side. The collected data were transferred to the “Optris PI Connect” software for temperature analysis.

The temperature of each pixel in the images was recorded, the average temperature of the herbaceous plants was calculated, and the maximum and minimum temperatures at the marked points were determined. Thermal cameras and related measurement equipment were used during the analyses. These are shown in Figure 4.



Figure 4. Equipment used during the study (Created by the author).

A-Nikon D5200 Brand Camera- Pro Hd Lens

The Nikon D5200 is a mid-range DSLR with a 24.1 MP CMOS sensor and EXPEED 3 processor, offering Full HD 1080p video, a 39-point autofocus system, and a 3-inch articulating LCD screen. Equipped with a Pro HD Lens, it provides a wider aperture and sharp image quality. Its lightweight body and advanced focusing features make it ideal for amateur and semi-professional users.

B-Optris PI brand Thermal Camera

Optris PI series thermal cameras are high-resolution, non-contact temperature measurement devices designed for industrial and R&D applications. They measure temperatures from –20 °C to 1900 °C using long-wave (8–14 µm) or short-wave (~1 µm) models and are used in metal processing, plastics, lasers, and process control. Connected to a computer via PIX Connect software, they allow real-time analysis, recording, and alarms. Made in Germany, Optris PI cameras offer high accuracy, fast data transfer, and interchangeable lens options for reliable industrial temperature monitoring.

C-Anemometer (AM-4206M) Moisture Device

The AM-4206M anemometer is a versatile portable device for measuring air velocity, temperature, and humidity. Used in industrial, HVAC, and environmental monitoring, it features a precise vane sensor for airflow and an integrated moisture sensor for humidity. Its digital display and fast response make it practical and reliable for field measurements.

D-Anemometer (AM-4206M) Temperature Device

The AM-4206M anemometer is a portable device for measuring air velocity and temperature. Used in industrial, HVAC, and laboratory settings, it provides accurate airflow readings with a vane sensor and real-time temperature via an integrated thermometer. Its durable, digital design enables fast and reliable field measurements.

3. Findings and Discussion

The study was conducted at Atatürk University Western Campus in June during midday hours, when shading was minimal. Six different areas were selected, and the effects of herbaceous vegetation on surface temperature and microclimate were examined across three types of pedestrian paths: sidewalks with vegetation on both sides, sidewalks with vegetation on one side, and sidewalks without vegetation. Sky View Factor (SVF) images and thermal camera data were collected during the assessments.

The Western Campus was chosen due to the intensive use of sidewalks, bike paths, and pedestrian routes, allowing evaluation of the impact of existing plant diversity on microclimatic conditions.

1. Sidewalks with vegetation on one side and no vegetation on the other:

- Study Area 1: The average temperature of the non-vegetated surface was 47 °C, while the vegetated surface measured 27 °C. The overall average temperature of the area was 32,5 °C.
- Study Area 2: The non-vegetated surface averaged 51 °C, and the vegetated surface 28 °C. The area's overall average temperature was 38,4 °C.
- Study Area 4: Vegetated surface averaged 27 °C, and non-vegetated surface 52 °C, with an overall area average of 35,8 °C. Measurement results and images are presented in Figure 5.

2. Sidewalks with vegetation on both sides:

- Study Area 2: Vegetated surfaces averaged 35 °C.
- Study Area 5: Vegetated surfaces averaged 31 °C.
- Study Area 6: Vegetated surfaces averaged 27 °C. Measurement results and images are shown in Figure 6.

3. Sidewalks without vegetation on either side:

- Study Area 3: Non-vegetated surfaces averaged 48 °C. Measurement results and images are presented in Figure 7.

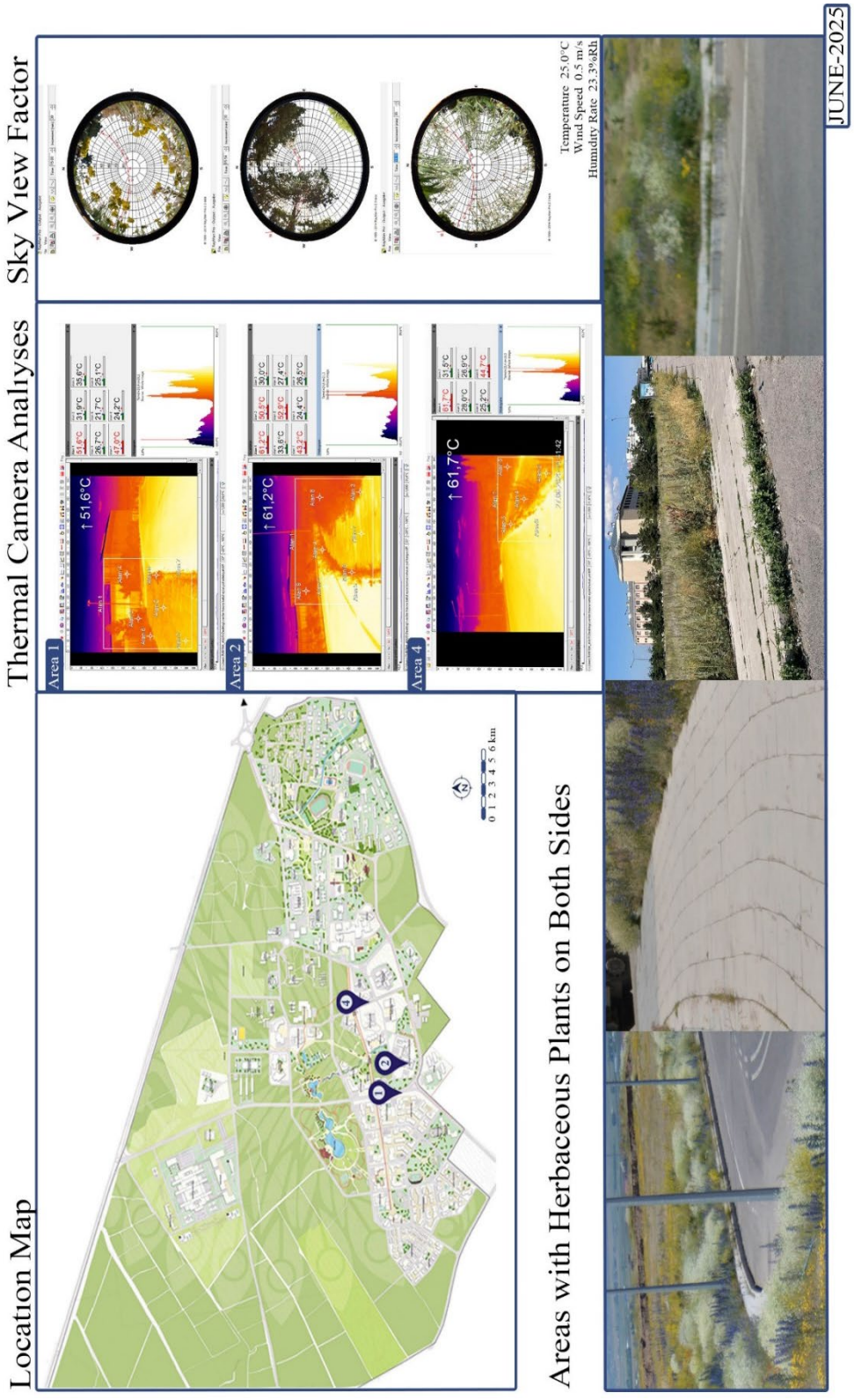


Figure 5. Thermal and microclimatic analysis images of areas with herbaceous plants on one side

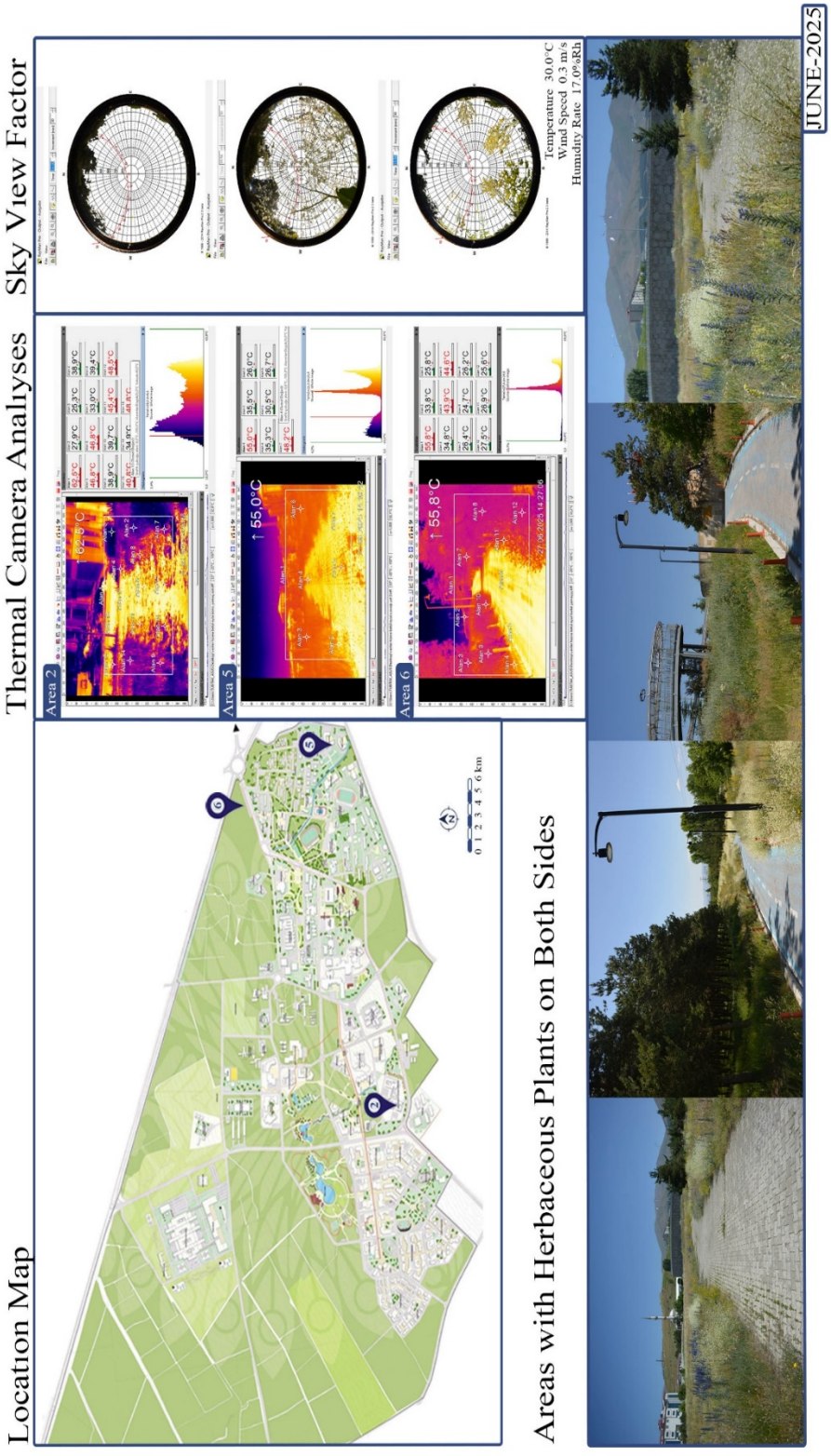


Figure 6. Thermal and microclimatic analysis images of areas with herbaceous plants on both sides

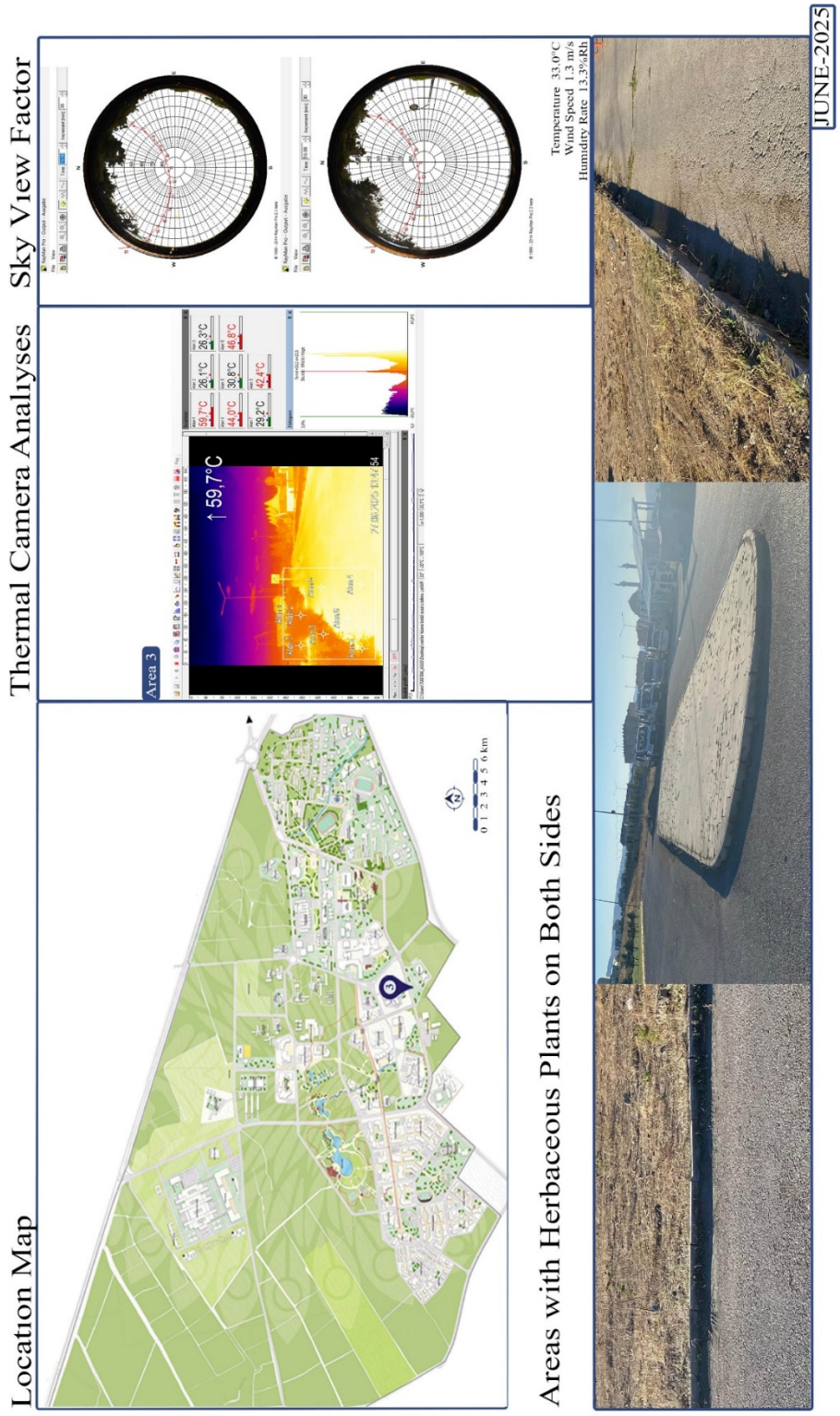


Figure 7. Thermal and microclimatic analysis images of areas without herbaceous plants

4. Conclusion and Suggestion

The measurements showed that the presence of vegetation on sidewalks significantly reduces surface temperatures. While non-vegetated surfaces recorded temperatures between 47–52 °C, surfaces covered with herbaceous plants ranged between 27–35 °C. These findings indicate that vegetation can lower surface temperatures by an average of 15–20 °C, positively influencing the urban microclimate. Therefore, plant elements, especially herbaceous species, play an important role in regulating temperatures in urban open spaces.

Increasing vegetation on urban hard surfaces is considered an important strategy for mitigating urban heat island effects, balancing surface temperatures, and enhancing urban quality of life.

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Thanks and Information Note

The article complies with national and international research and publication ethics. Ethics Committee approval was not required for the study. All authors contributed equally to the article. The authors declare no conflict of interest.

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A Thermal Imaging-Based Assessment of the Effect of Herbaceous Vegetation on Outdoor Thermal Comfort in Sloping Areas: The Case of Atatürk University

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Abstract

This study reveals the effects of herbaceous vegetation in sloping areas on outdoor thermal comfort through a thermal imaging–based assessment. Conducted in July 2025 at the Western Campus of Erzurum Atatürk University, the research was carried out on a 9,650 m² area. Within the scope of the study, six different sites were identified, and due to the limited formation of shade, particularly during midday hours, measurements were conducted using a Nikon 5200 Thermal Camera with a Pro HD lens. The obtained images were supported by the Sky View Factor (SVF) method, while surfaces with varying slope degrees were analyzed using the Optris PL Connect software. Additionally, wind and air temperature data were recorded with an anemometer to support the measurements. The findings indicate that herbaceous vegetation significantly reduces surface temperatures and enhances outdoor thermal comfort, particularly on south- and west-facing slopes. Moreover, the slope factor was found to reinforce the cooling function of vegetation by influencing its moisture retention capacity. The results show that slope plays a crucial role in surface temperature variation. In the area with a 15.8% slope, temperatures increased considerably, whereas in the area with a 5% slope, temperatures decreased by 14,5°C. Similarly, while the surface temperature was recorded as 43,1°C in the 4–5% slope area, it increased by 8,1°C in the 4.22% slope area. Overall, herbaceous vegetation has been identified as a critical component to be considered in sustainable landscape planning for sloping areas. In this context, the study provides valuable guidance based on the findings obtained from the Western Campus of Atatürk University.

Keywords: Herbaceous vegetation, sloping areas, thermal comfort, thermal imaging, Atatürk University campus.

1. Introduction

Global climate change and the consequent rise in temperature values make it increasingly difficult to maintain thermal comfort within urban ecosystems (Oke, 1987; Emmanuel, 2005). In regions where urbanization is rapidly expanding, the increase in impervious surfaces causes higher surface temperatures and leads to the emergence of the *Urban Heat Island* (UHI) effect (Santamouris, 2015; Li et al., 2023). In this context, the use of vegetation as a strategy to enhance outdoor thermal comfort has gained growing importance (Bowler et al., 2010; Yılmaz & Gölcü, 2023).

Vegetation regulates microclimatic conditions through mechanisms such as evapotranspiration, shading, and surface reflectivity, thereby reducing perceived heat in open spaces and improving thermal comfort (Shashua-Bar & Hoffman, 2000; Ziter et al., 2019). Herbaceous vegetation, in particular, plays a significant role due to its wide surface coverage and low height structure, which help retain soil moisture, enhance evaporation capacity, and reduce surface temperatures

(Wang et al., 2021). However, these effects vary on sloped surfaces, where the degree of inclination becomes a determining factor for solar radiation, water retention capacity, and surface temperature (Gao et al., 2022; Yılmaz et al., 2024). Surface slope is an important morphological factor that directly influences the cooling performance of vegetation. Sloped terrains create variations in solar exposure, shading, and radiation distribution, thereby altering the microclimatic performance of plant cover (He et al., 2023). Moreover, the (SVF) method, which measures the openness of a surface to the sky, is widely used to assess radiation balance and thermal exposure (Yoshida et al., 2020; Nassar et al., 2024). As SVF values decrease, a surface's radiative exchange with the sky diminishes, resulting in notable differences in surface temperature.

Recent studies have shown that combining vegetation parameters with SVF-based thermal analyses yields critical insights into outdoor thermal comfort (Aram et al., 2022; Gupta et al., 2023). In Turkey, current research has similarly emphasized that vegetative arrangements in continental climates—such as those in Erzurum—significantly reduce surface temperatures and improve microclimatic conditions (Yılmaz & Gölcü, 2023; Karakaya & Aydın, 2024).

Accordingly, the present study, conducted in July 2025 on the Western Campus of Atatürk University in Erzurum, aims to reveal the effects of herbaceous vegetation on outdoor thermal comfort in sloped areas through a thermal imaging–based assessment. Thermal images obtained using a Nikon 5200 Thermal Camera were analyzed in conjunction with the SVF method, while surfaces with varying slope degrees were evaluated using Optris PL Connect software. In addition, wind and air temperature data were recorded using an anemometer to support the field measurements. The findings indicate that herbaceous vegetation significantly reduces surface temperatures and improves outdoor thermal comfort, particularly on south- and west-facing slopes. Furthermore, slope inclination was found to enhance soil moisture retention, thereby strengthening the cooling function of vegetation. In this context, the inclusion of herbaceous vegetation in sloped areas is identified as a critical consideration for sustainable landscape planning (Gao et al., 2022; Yılmaz et al., 2024).

2. Material and Method

Erzurum is located in the Upper Euphrates section of the Eastern Anatolia Region, between 39°55′ north latitude and 41°16′ east longitude (Atalay, 2011). Situated at approximately 1,850 meters above sea level, the city is one of the highest and coldest settlements in Turkey. It is bordered by Kars and Ağrı to the east, Erzincan to the west, Artvin and Bayburt to the north, and Bingöl and Muş to the south. Erzurum experiences a harsh continental climate, with long, snowy winters and hot, dry summers (MGM, 2020), offering significant potential for winter tourism.

The research area is the Western Campus of Atatürk University, located about 6 km west of the city center. The campus stretches in an east–west direction and covers an area of approximately 6.5 million m². The campus features a coherent spatial organization, including academic buildings, administrative offices, dormitories, recreational areas, green spaces, and walking paths. Its wide open spaces and high plant diversity make the Western Campus a suitable environment for microclimate and urban heat island studies. A location map of the campus is also included in the study (MGM, 2020).

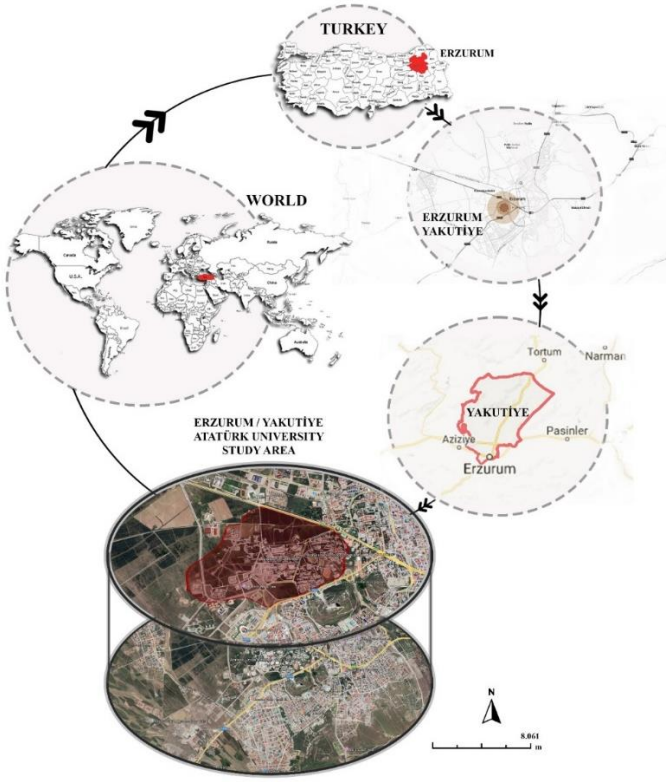


Figure 1. Western Campus Work Area of Erzurum Atatürk University (Created by the author).

The Western Campus of Atatürk University was chosen for its high plant diversity and presence of all target species: *Gypsophila paniculata*, *Papaver rhoeas*, *Salvia verticillata var. amplexicaulis*, *Coronilla varia*, *Achillea millefolium*, *Isatis tinctoria*, and *Melilotus officinalis*. Surface temperatures were measured using a manual-focus Optris® thermal camera with the "Optris PI Connect" software. SVF values were obtained from fisheye photographs taken with a Nikon D5200 and calculated using RayMan Pro 3.1.2.199.



Figure 2. Field study in the Western Campus of Atatürk University (Created by the authors)



Figure 3. Inventory of materials used for the study (Created by the author)

1: Optris PI brand thermal camera

2: Digital Anemometer (AM-4206M), moisture device

3: Nikon D5200 brand camera

4: Digital Anemometer (AM-4206M), moisture device

5: Asus computer ENVI-MET simulation program

The concept of SVF (Sky View Factor) was introduced by Oke (1988) to study urban heat islands and represents the portion of the sky visible from a point, with values ranging from 0 to 1 (Oke, 1988; Matzarakis et al., 2010). SVF can be calculated analytically from urban canyon geometry or using a modified manual Steyn method on digitized fisheye photographs (Chapman et al., 2001, 2007). Values near 1 indicate high sky visibility, while values near 0 indicate low visibility (Algeciras et al., 2016; Middel et al., 2017; Li et al., 2020; Gomes & Giannotti, 2024).

Measurements were conducted in June to examine the microclimatic effects of herbaceous plants on slopes of varying steepness. Thermal images were processed using “Optris PI Connect,” recording the temperature of each pixel to create a large dataset. Average temperatures for the plants were calculated, and multiple points were analyzed for maximum and minimum values. SVF data from RayMan Pro 3.1.2.199 were used to assess sky visibility beneath the plants and its directional variation.

3. Findings and Discussion

Thermal imaging of herbaceous plants in six areas of Atatürk University's Western Campus was performed from the north between 12:00 and 15:00, the hottest hours of the day. Details of each plant, including appearance, location, slope percentage, and orientation, were recorded. SVF images and surface temperature data from the thermal camera were also collected. Measurements were conducted in June under clear, sunny conditions to assess surface temperatures and microclimatic effects. These data provided a basis for evaluating the influence of slope, vegetation cover, and solar exposure on the thermal behavior of the plants (Table 1).

Table 1. List of Herbaceous Plant Diversity in the Study Area (Created by the author).

Herbaceous Plant Diversity

code	name	product image	Latin name	the slope gradient (%) of the area
GYPA	Cipso / Bride's Flower		*Gypsophila paniculata*	Average Slope: 3.2% Maximum Slope: 4%
PAPRH	Poppy		*Papaver rhoeas*	Average Slope: %4.06 Maximum Slope: %4-5
ISATI	Woad		*Isatis tinctoria*	Average Slope: %4.06 Maximum Slope: %4-5
COVA2	Crown Vetch		*Coronilla varia*	Average Slope: %4.29 Maximum Slope: %5
SAVE5	Whorled Clary / Purple Sage		*Salvia verticillata var. amplexicaulis*	Average Slope: %4.06 Maximum Slope: %4.22
VESP	Showy Mullein		*Verbascum speciosum*	Average Slope: %4.06 Maximum Slope: %15.8
ANAZ	Perennial herb		*Anchusa azurea*	Average Slope: %4.06 Maximum Slope: %4.22
ACMI2	Yarrow (Achillea millefolium – Yellow Variety)		*Achillea millefolium*	Average Slope: %3.15 Maximum Slope: %4-4.5

Herbal Plants In Near-Flat Areas

In nearly flat areas with an average slope of ~4%, solar-exposed surfaces can exceed 50°C, while shaded or vegetated areas remain around 25–28°C, showing that topography strongly affects microclimatic thermal comfort (Figure 4).

Herbaceaus Plants On Very Sloped Areas

Thermal variation increases with slope, but vegetation moderates this effect. On south-facing slopes up to 15%, vegetated surfaces are 15–25°C cooler than bare hard surfaces. Afternoon sun on non-vegetated areas can reach 55–62°C, whereas vegetated slopes remain 25–30°C, highlighting the cooling role of vegetation in surface energy balance (Figure 5).

Herbal Plants In Medıum Slope Area

In areas with ~4.5% slope (e.g., Area 1), surface temperatures reach ~48°C, higher than surrounding 20–30°C areas. This difference reflects solar exposure duration, slope orientation, and surface characteristics (Figure 6).

Herbal Plants In A Low Slopıng Area

Gently sloping areas (~4% slope; Areas 7–10) show surface temperatures of 25–30°C, lower than the 43.1°C maximum in Area 1. Denser, moisture-rich vegetation reduces heat accumulation, creating a thermally balanced microclimate where seasonally active herbaceous species dominate (Figure 7).

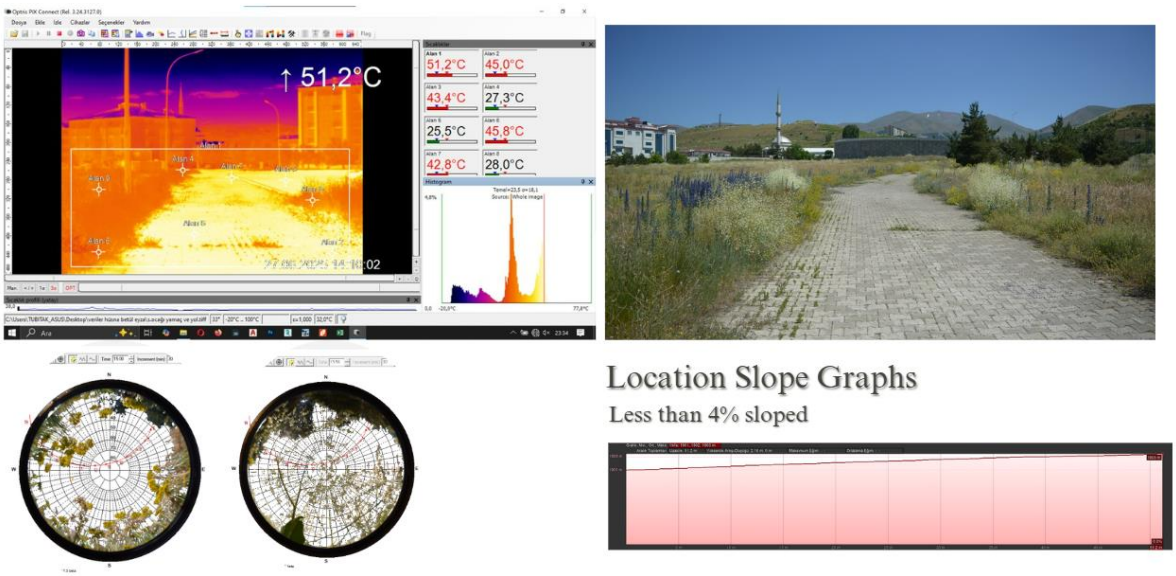


Figure 4. Herbal Plants In Near-Flat Areas (Created by the author).

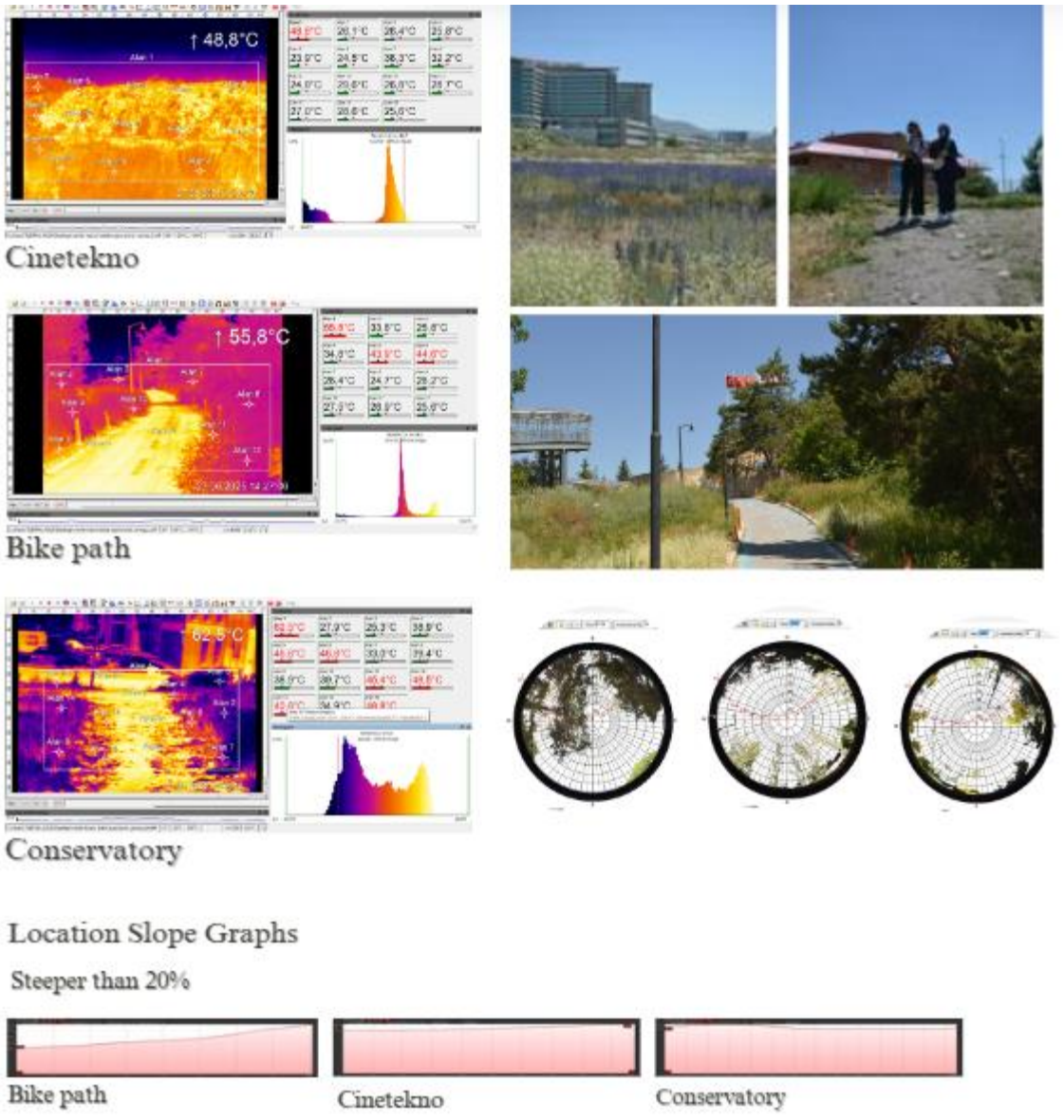


Figure 5. Herbaceaus Plants On Very Sloped Areas (Created by the author).

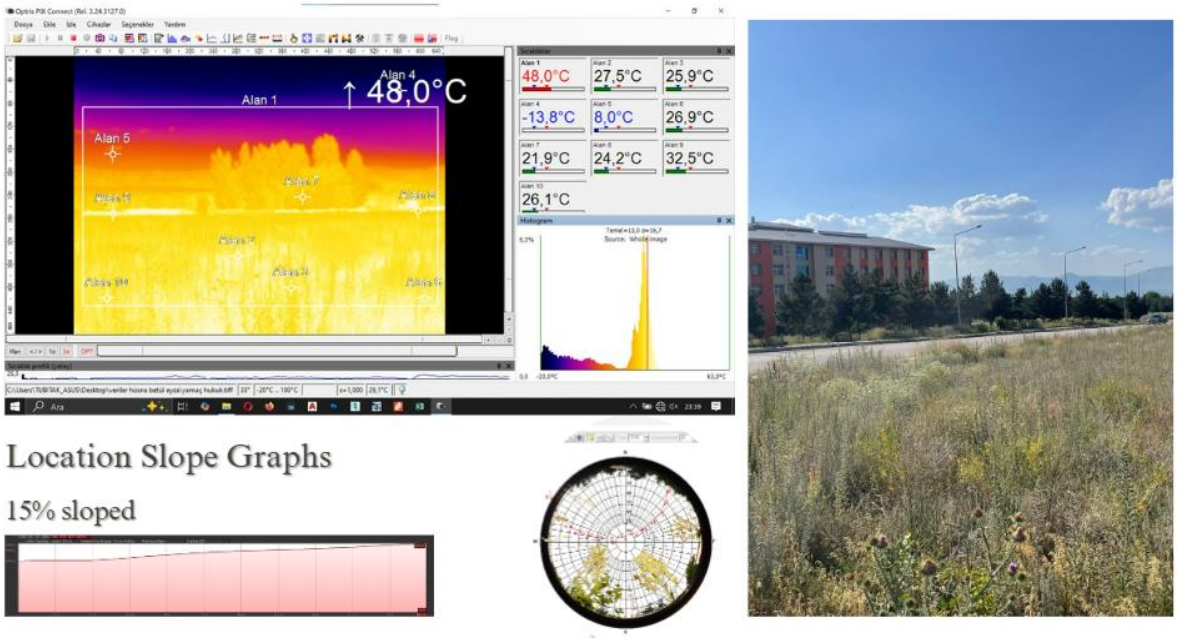


Figure 6. Herbal Plants In Medıum Slope Area (Created by the author).

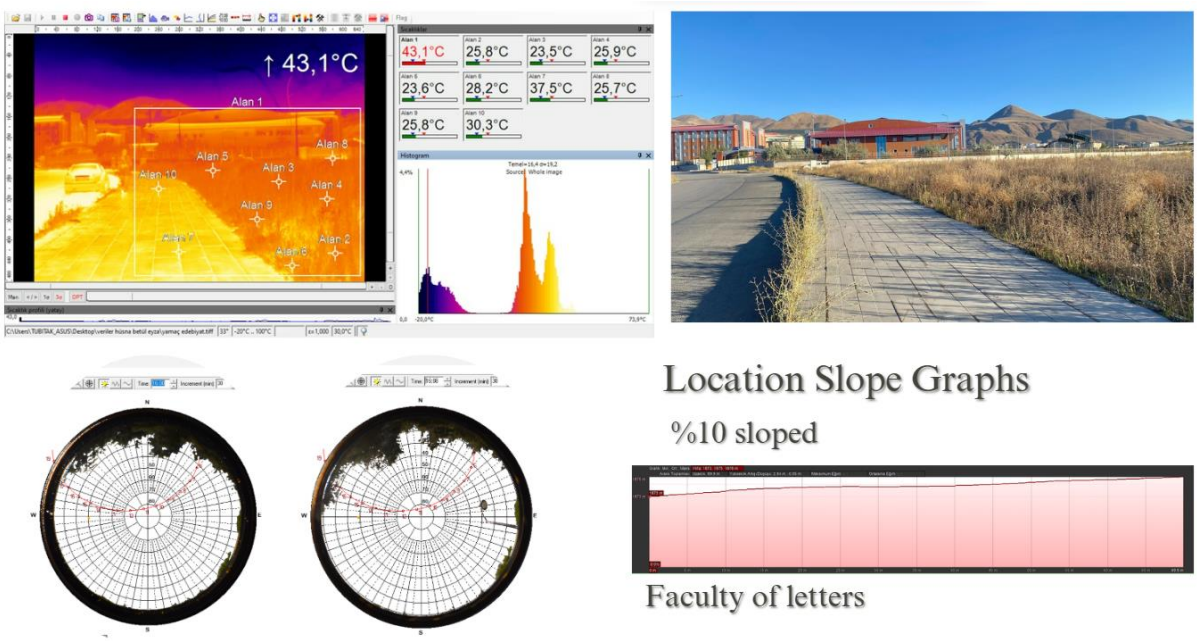


Figure 7. Herbal Plants In A Low Slopıng Area (Created by the author).

4. Conclusion and Suggestion

The results indicate that slope strongly influences surface temperatures and microclimate. Flat areas show 25–50°C, while vegetated slopes of 15.8% are 15–25°C cooler than bare surfaces. South-facing slopes can reach 55–62°C, but vegetation reduces heat and provides cooling. Therefore, vegetation density and slope together control thermal balance, highlighting the importance of increasing plant cover, conserving soil moisture, and slope-sensitive landscape planning.

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Thanks and Information Note

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Thermal Camera Analysis of the Effect of Different Flower Colors of Ground-Covering Herbaceous Natural Plants on Outdoor Temperature: Atatürk University Campus

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Abstract

In order to promote the use of herbaceous plants, the microclimatic conditions of the area were analyzed. In this context, the effects of different flower colors of natural groundcover herbaceous plants on outdoor temperature were examined with the aid of a thermal camera. The study was conducted in June 2025 at Atatürk University's Western Campus in Erzurum, covering a total area of 9,650 m². Six different zones were selected, the plants were classified according to their flower colors, and the data obtained with the thermal camera were analyzed using Optris PL Connect software. In addition, photographs taken with a Nikon D5200 camera and ProHD lens were evaluated to determine sky view, and analyses were carried out using Sky View Factor (SVF) data corresponding to midday hours when shading was minimal. The results revealed that sky view is an important parameter in the evaluation of microclimatic conditions. Thermal camera measurements were also performed during midday hours with minimal shading, while instantaneous wind speed and air temperature values were recorded. According to the analysis, plant colors were found to have a significant effect on surface temperature. Higher temperature values were recorded in darker-colored plants, while lighter-colored plants reflected more light and exhibited lower temperatures. As the flower color shifted from darker tones such as purple and red to lighter tones such as yellow and white, surface temperatures decreased, with differences sometimes reaching 8.0–20.0 °C. This finding demonstrates a direct relationship between plant color and surface temperature. In conclusion, the cooling effect of natural herbaceous vegetation was confirmed, and it was determined that considering plant colors together with sky view can contribute to improving thermal comfort in urban.

Keywords: Thermal camera analysis, flower color, microclimatic conditions, Sky View Factor (SVF), herbaceous plants

1. Introduction

Urbanization is one of the defining global transformations of the 20th and 21st centuries, reshaping land use patterns, altering ecological structures, and significantly affecting surface energy dynamics within cities (Oke et al., 2017). As urban areas expand and natural surfaces are replaced by impervious materials such as asphalt, concrete, and buildings, the thermal behavior of the urban environment undergoes substantial changes. One of the most prominent outcomes of these transformations is the Urban Heat Island (UHI) effect, characterized by higher temperatures in urban areas relative to their rural surroundings (Yang et al., 2024). The strengthening of UHIs has become a critical concern, especially in recent years when heat waves—intensified by global climate change—interact with UHI effects to produce prolonged periods of extreme heat (He et al., 2021). These combined impacts increase health risks, energy demands, and environmental stress in cities worldwide.

Globally, cities continue to face challenges resulting from rapid population growth, increased energy consumption, and climate change-induced extreme weather events such as heat waves, droughts, and irregular precipitation patterns (Ji et al., 2022). As urban populations rise, the demand for more comfortable living environments also increases, leading to greater energy use for cooling, which in turn contributes further to anthropogenic heat emissions. Since most human activities occur within the urban microclimate, understanding microclimatic processes and their interaction with urban form has become essential for sustainable planning and design (Bherwani, Singh & Kumar, 2020).

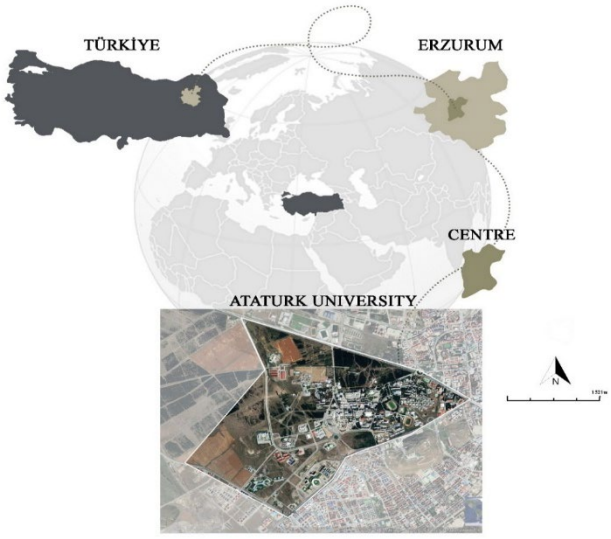
Urbanization increases the proportion of impervious surfaces, which absorb and store solar radiation more efficiently than natural surfaces. This change disrupts the city's surface energy balance, elevating surface and air temperatures and reinforcing UHI formation (Oke, Mills, Christen & Voogt, 2017). The UHI effect—first recognized as early as 1818—remains a central subject in urban climate studies, demonstrating that densely built environments exhibit elevated temperatures compared to rural landscapes due to reduced evapotranspiration, altered wind patterns, and increased heat storage (Howard, 1818; Voogt & Oke, 2003). These elevated temperatures affect air quality, human health, energy consumption, and overall urban livability (Luck & Wu, 2002; Buscail et al., 2012). Moreover, global assessments show that heat waves have become more frequent, more intense, and longer lasting in many regions since the early 2000s (IPCC, 2023). These escalating trends underscore the necessity of effective climate adaptation strategies in urban areas.

Urban green spaces serve as critical components for enhancing urban resilience and improving environmental quality. Vegetation differs fundamentally from impervious surface materials due to its moisture content, aerodynamic properties, and thermal behavior. These characteristics allow plants to lower temperatures through evapotranspiration and shading**,** which convert solar radiation into latent heat and reduce surface heating (Oke, 1989; Givoni, 1991; Taha et al., 1988; Grimmond & Oke, 1991). Numerous studies have demonstrated that green and blue infrastructures are more effective at moderating urban temperatures compared to gray infrastructure alternatives. In many cities, green areas have been found to be 1–2 °C—and in some cases as much as 4–7 °C—cooler than their surroundings (O'Malley et al., 2015; Pramanik & Punia, 2019; Li et al., 2022). These cooling effects are influenced by vegetation type, canopy characteristics, plant color, density, local climatic conditions, and spatial configuration (Şentürk & Mert, 2022).Urban morphology also plays a critical role in shaping microclimatic conditions. The SVF—a dimensionless variable representing the proportion of visible sky from a given point—serves as a key indicator of how urban form influences heat accumulation and radiative cooling (Steemers, Ramos & Sinou, 2004). Areas with low SVF values, such as narrow streets or shaded zones, tend to retain less heat during the day but also release heat more slowly at night. Conversely, high-SVF areas are more exposed to solar radiation and therefore often experience higher daytime temperatures. Understanding the interaction between vegetation and SVF is therefore essential for developing climate-sensitive urban design strategies.Within this context, herbaceous plants have gained increasing attention as functional landscape elements capable of contributing to urban cooling, particularly in semi-arid and continental climates. However, research exploring the microclimatic impacts of herbaceous plant species especially in relation to plant color, structural characteristics, and spatial context remains relatively limited compared to studies focusing on trees and shrubs.This study aims to address this gap by investigating the influence

of herbaceous plant species on surface temperature and microclimatic dynamics in an urban setting. The research was conducted on June 27, 2025, in the Western Campus of Atatürk University in Erzurum, covering an area of approximately 9,650 m². Thermal imaging techniques were used to measure the surface temperatures of herbaceous plants with different flower colors, including purple, red, yellow, and white species. In addition, SVF data were analyzed to determine how sky visibility interacts with plant characteristics to shape microclimatic conditions.By integrating thermal analysis with SVF assessment, this study aims to provide new insights into how herbaceous vegetation contributes to the mitigation of urban heat and enhancement of thermal comfort. The findings are expected to offer practical guidelines for urban planners, landscape architects, and environmental designers seeking to create cooler, healthier, and more sustainable urban open spaces**.** Ultimately, the research contributes to the broader understanding of vegetation-based climate adaptation strategies and supports the development of environmentally sensitive urban design approaches.

2. Material and Method

The study was carried out within the boundaries of the Western Campus. Atatürk University is located in the Yakutiye district of Erzurum Province, in the Eastern Anatolia Region of Türkiye, and covers an area of approximately 8 km² (6.5 million m² of open space and 1 million m² of built-up area). The university campus is situated on the eastern side of Erzurum city center, at 39.9089° north latitude and 41.2706° east longitude. Covering a large part of the Erzurum Plain, the campus is the second largest in Türkiye and is recognized as the first planned university campus in the country. Erzurum Province is located in the northeastern part of the Eastern Anatolia Region and has a surface area of 25,066 km². The city borders Bayburt to the north, Erzincan to the west, Bingöl and Muş to the south, and Ağrı and Kars to the east. Erzurum generally exhibits continental climate characteristics, with long, cold, and snowy winters, and short, hot, and dry summers (MGM, 2020). The location map of the study



area is presented in Figure 1.

Figure 1. Western Campus Work Area of Erzurum Atatürk University (Created by authors)

The study was carried out in two main phases**:** fieldwork and office-based analysis. During the fieldwork, six sampling areas with dense and homogeneously distributed herbaceous vegetation were identified within the Western Campus of Atatürk University. Site selection prioritized locations suitable for consistent thermal and microclimatic measurements. Each site was visited sequentially, and measurements were conducted around midday to minimize shading effects (Figure 2).Surface temperatures of herbaceous plants were recorded using a manually focused Optris® thermal camera, positioned 1.20 meters above ground and placed at equal distances from each plant. Complementary microclimatic data—including humidity and wind speed—were also collected. The study focused on four flower color groups (purple, red, yellow, and white) to enable comparative evaluation of plant color and its influence on microclimate and surface temperature.The herbaceous plant species examined included Gypsophila paniculata**,** Papaver rhoeas**,** Salvia verticillata var. amplexicaulis**,** Coronilla varia**,** Achillea millefolium (yellow variety), Isatis tinctoria**,** and Melilotus officinalis. Thermal measurements were processed using the "Optris PI Connect" software, which extracted temperature values for each pixel, producing a detailed dataset. Average, maximum, and minimum surface temperatures were derived by marking multiple points within each thermal image.For the SVF assessment, a Nikon D5200 camera equipped with a 0.25X ProHD fisheye lens was used to capture hemispherical photographs. SVF values were calculated in RayMan Pro 3.1.2.199**.** SVF, ranging between 0 and 1, represents the proportion of visible sky and serves as an important indicator in studies related to urban heat island formation (Oke, 1988; Matzarakis et al., 2010; Algeciras et al., 2016; Middel et al., 2017; Li et al., 2020; Gomes & Giannotti, 2024).All measurements were conducted in June. Thermal and SVF images were analyzed to evaluate the relationship between plant color, surface temperature, and sky visibility. The results facilitated a comparative assessment of yellow, purple, white, and red herbaceous plants in terms of their microclimatic performance. Photographs from the field survey conducted in the Western Campus are provided in Figure 2.



Figure 2. Field study in the Western Campus of Atatürk University (Created by the authors)

3. Findings and Discussion

This study was conducted in six different areas identified within the Atatürk University campus. The fieldwork was carried out in June, during midday hours when shading was minimal. In the research, herbaceous plants with four different flower colors (yellow, red,

white, and purple) were used. These plants were selected to allow for a comparative analysis of their effects on surface temperature and microclimate. Images of the plants used in the study are presented in Table 2.Sky View Factor images were also captured from each area, and these analyses were performed with reference to the north direction. During the measurements, the ambient air temperature was recorded as 26.4°C, wind speed as 1.03 m/s, and wind direction as north-northwest.The equipment used in the field studies included a thermal camera, computer, Canon digital camera, fisheye lens, and an anemometer. The technical specifications of the devices used are presented in Table1.In this study, the general appearance of herbaceous plant species with four different colors, as well as the morphological characteristics (stem circumference, close-up views, branches, and leaves) of ten different herbaceous species, their locations, SVF images and values, along with thermal camera images and measurement results, were evaluated in detail.

Table 1. Inventory of materials used for the study (Created by authors)

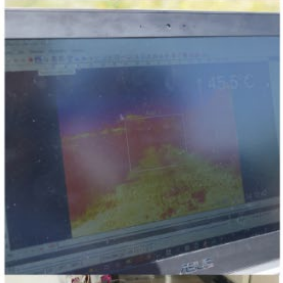
	Asus computer ENVI-MET simulation program
	Anemometer (AM-4206M)
	Asus computer ENVI-MET simulation program
	Anemometer (AM-4206M)

Table 2. List of Herbaceous Plant Diversity in the Study Area (Created by authors)

Papaver rhoeas		*Salvia verticillata var. amplexicaulis*	
Isatis tinctoria		*Verbascum speciosum*	
Coronilla varia		*Anchusa azurea*	

Thermal and Microclimatic Analysis of Purple-Colored Herbaceous Plants

Purple-colored herbaceous plants were found to be densely distributed in six areas, including species such as Salvia verticillata var. amplexicaulis, Anchusa azurea, Coronilla varia, and Carduus hamulosus. Thermal analyses showed their surface temperatures ranged between 37.8°C and 57.5°C, while soil temperature averaged 24.9°C. The higher surface temperatures were attributed to greater solar radiation absorption by purple plant surfaces. SVF analyses indicated open surroundings, suggesting that increased solar exposure further contributed to the elevated surface temperatures and microclimatic variations.

Thermal and Microclimatic Analysis of Red-Colored Herbaceous Plants

Red-colored herbaceous plants, including Salvia verticillata var. and Papaver rhoeas, were densely distributed in six areas of the study site. Their surface temperatures ranged from 26.3°C to 34.0°C, with a maximum of 50.8°C recorded near the Atatürk University Conservatory. This increase was linked to higher solar radiation absorption, leaf surface characteristics, and open site conditions. Soil temperature averaged 24.9°C, showing that plant color strongly affects surface temperature. SVF analyses confirmed open surroundings that prolonged solar exposure, contributing to higher temperatures. Overall, red-colored plants significantly influenced microclimatic variation by accumulating heat and altering local thermal conditions.

Thermal and Microclimatic Analysis of White-Colored Herbaceous Plants

White-colored herbaceous plants, mainly Gypsophila paniculata, were densely distributed across five areas of the study site. Due to their high reflectivity, these plants showed significant differences in surface temperature compared to other color groups, ranging from 27.5°C to 42.2°C, with some areas dropping to 27.7°C. Soil temperatures were 24.0°C, while adjacent asphalt reached 55.5°C, highlighting the cooling effect of vegetation through evapotranspiration and reduced heat accumulation. Sky View Factor (SVF) analyses indicated open surroundings, increasing solar exposure and influencing surface temperatures. Overall, white-colored plants effectively reduce surface heat, mitigate microclimatic variations, and enhance thermal comfort in sun-exposed areas like the Atatürk University campus, making them valuable for sustainable landscape and urban planning.

Thermal and Microclimatic Analysis of Yellow-Colored Herbaceous Plants

Yellow-colored herbaceous plants, including Melilotus officinalis, Isatis tinctoria, Achillea millefolium, and locally adapted Verbascum species, were densely distributed across six areas of the study site. These plants reflect a high proportion of solar radiation, helping to moderate surface temperatures, which ranged from 31.3°C to 46.1°C, with some areas dropping to 27.7°C. Compared to white-colored plants, yellow plants more effectively retain heat and balance surface temperatures, providing more controlled and gradual cooling. Soil temperatures were 24.0°C, while adjacent asphalt reached 55.5°C, highlighting the cooling effect of vegetation through evapotranspiration and reflectivity. SVF analyses indicated open surroundings, increasing solar exposure and influencing surface temperatures. Overall, yellow-colored herbaceous plants play an important role in reducing surface heat, moderating microclimatic variations, and enhancing thermal comfort in open, sun-exposed areas like the Atatürk University campus

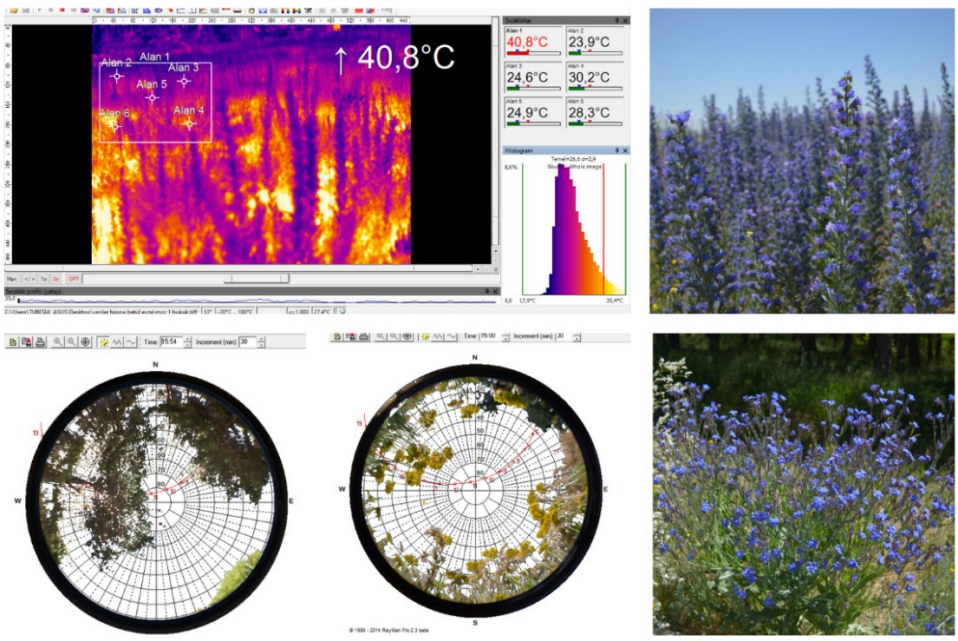


Figure 3. Purple-colored herbaceous plants (Created by authors)

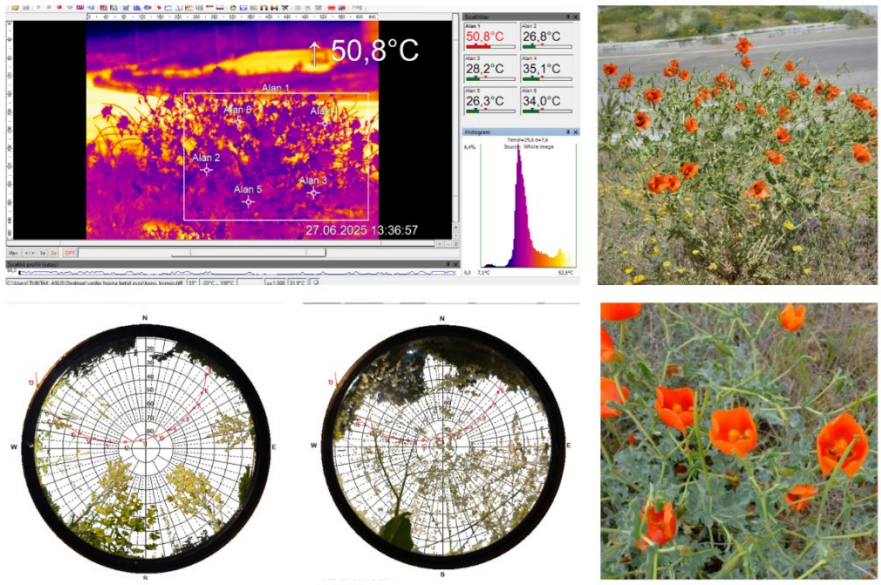


Figure 4. Red-colored herbaceous plants (Created by authors)

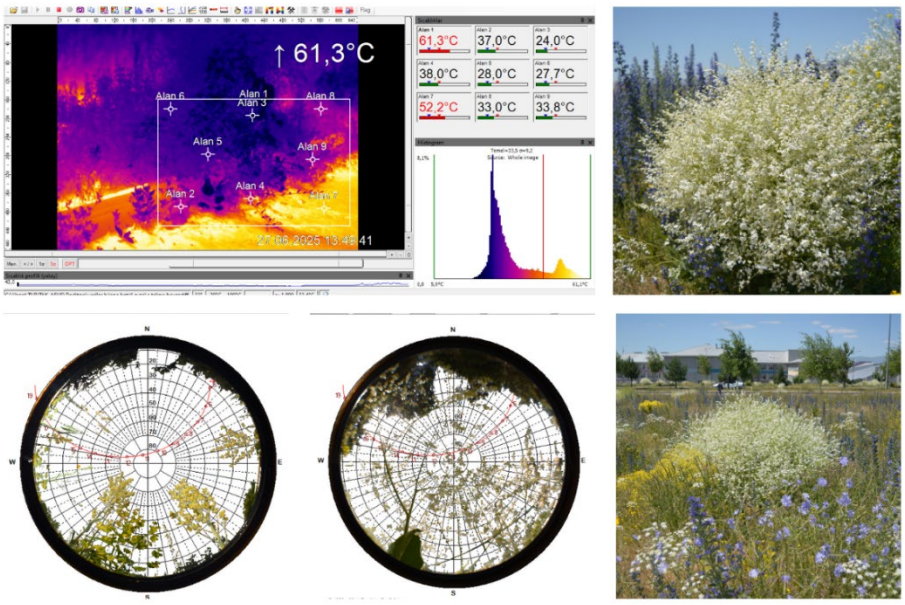


Figure 5. White-colored herbaceous plants (Created by authors)

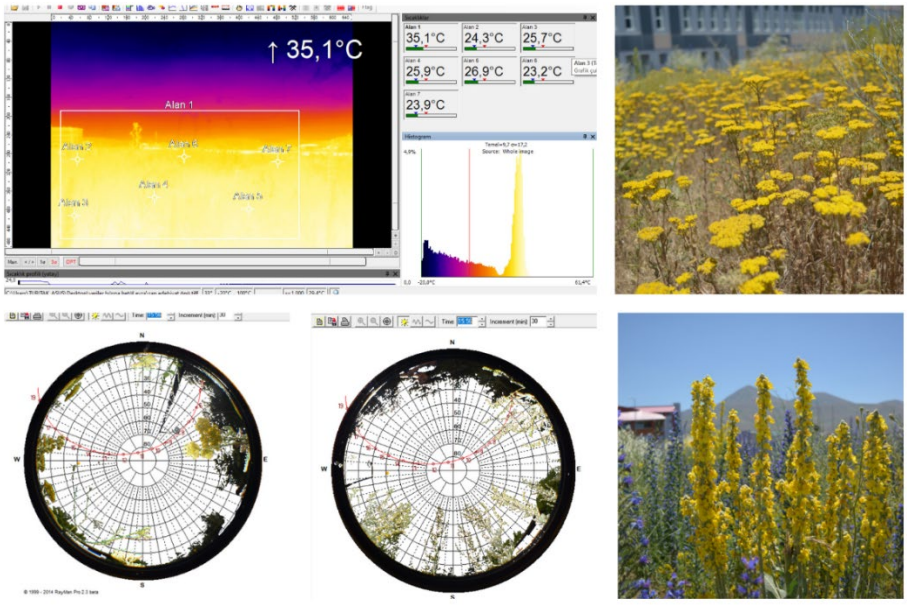


Figure 6 Yellow-colored herbaceous plants (Created by authors)

4. Conclusion and Suggestion

In the study area, herbaceous plants with yellow, white, red, and purple flowers were concentrated in six regions. Thermal measurements showed that plant color significantly affected surface temperatures. Yellow (Melilotus officinalis, Isatis tinctoria, Achillea millefolium, Verbascum spp.) and white (Gypsophila paniculata) plants reflected sunlight effectively, maintaining more balanced surface temperatures (yellow: 35.1–68.3°C, avg. 27.7°C; white: 27.5–76.0°C) and contributing to cooling. In contrast, red (Salvia verticillata var. amplexicaulis, Anchusa azurea, Coronilla varia, Carduus hamulosus) and purple plants absorbed more solar radiation, resulting in higher surface temperatures (red: up to 50.8°C; purple: 37.8–57.5°C) and localized heat accumulation. Soil temperatures ranged 24.0–24.9°C, while nearby asphalt reached 55.5°C. SVF analyses indicated open surroundings, increasing solar exposure and surface heating. Overall, yellow and white plants improve microclimatic conditions by reflecting sunlight and stabilizing surface temperatures, whereas red and purple plants increase local heat accumulation. These findings highlight the role of plant color and surface properties in urban landscape planning, suggesting yellow and white plants are particularly valuable for enhancing thermal comfort in sun-exposed areas.

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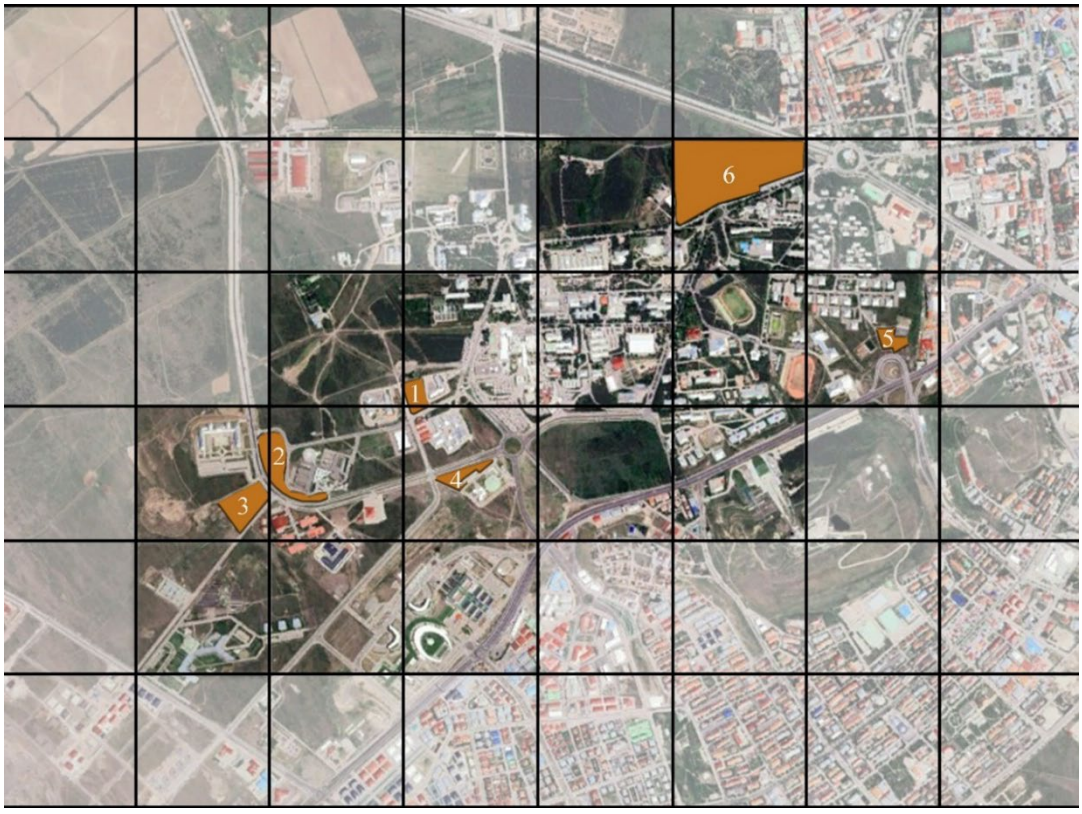


Figure 7 Map Of Selected Regions In The University

1. The right side of the Faculty of Law (East direction)
2. The left side of the Faculty of Architecture (West direction)
3. The front side of the Faculty of Letters (South direction)
4. The front-left side of Cinetekno (Southwest direction)
5. The right side of the Health Center (East direction)
6. The upper-left part of the Bicycle Path (Northwest direction)

Thanks and Information Note

The article complies with national and international research and publication ethics. Ethics Committee approval was not required for the study. All authors contributed equally to the article. There is no conflict of interest.

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Thermal Camera Analysis of The Effect of Natural Herbaceous Plants Along Sidewalks on Outdoor Thermal Comfort in Relation to Orientation: A Case Study of Atatürk University Western Campus

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Abstract

A large proportion of the world's population resides in urban areas, and this proportion is increasing rapidly. However, as a result of efforts to meet the growing demand for housing, the reduction of open-green spaces has led to increased air pollution, the expansion of impervious surfaces causing the Urban Heat Island (UHI) effect, and, combined with the adverse impacts of global warming, has highlighted the importance of the efficient use of water resources. The selection of natural and drought-tolerant plants in urban green spaces not only contributes to water conservation but also enables the development of ecologically compatible landscape areas. In this context, the effects of naturally occurring herbaceous plants of different colors located along sidewalks on outdoor thermal comfort were analyzed within the Western Campus of Atatürk University in Erzurum. Surface temperatures were recorded using an Optris PIX Connect Thermal Camera. From 27 recordings taken under clear sky conditions in July 2025 (between 13:00–17:00), 10 were selected. For each point, Sky View Factor (SVF) analysis was conducted simultaneously using a Nikon D5200 camera with a fisheye lens positioned at ground level, along with measurements of temperature, humidity, and wind. In determining the measurement stations, both the herbaceous plants on either side of the sidewalks and the color and density of those along a single side were considered. The measurements and evaluations revealed that the presence of natural herbaceous plants along sidewalks contributed to lower temperature conditions compared to existing surface values, thereby helping to maintain a cooler environment. The temperature difference between the sidewalks and the adjacent herbaceous plants ranged from 10 to 20 °C, indicating that these plants helped to moderate ambient temperatures. The findings underscore the significance of using natural herbaceous plants in enhancing thermal comfort along sidewalks and emphasize their contribution to the efficient management of water resources

Keywords: Thermal camera, outdoor thermal comfort, natural herbaceous plant, micro-climate

1. Introduction

Against the backdrop of global climate change, the urban heat island (UHI) effect—further exacerbated by rapid urbanization—has become increasingly pronounced. The UHI phenomenon not only has the potential to raise the average temperature of future cities by more than 4–5 °C, but also poses a significant overheating risk across most residential areas worldwide (Mughal et al., 2021; Santamouris, 2020). The combustion of fossil fuels, including coal, oil, and gasoline, releases large quantities of CO_2 and other greenhouse gases into the atmosphere. These gases absorb infrared radiation emitted by the Earth, leading to the trapping of heat and consequently the warming of the planet. According to data from the

Climate Change Research Group at the University of East Anglia, the global average temperature has increased by 0.6 °C over the past century, representing the most significant warming observed in the last millennium (Roy et al., 2025).

The aim of this study is to determine how naturally occurring herbaceous plants of different colors, located along sidewalks within the Western Campus of Atatürk University in Erzurum, affect outdoor thermal comfort. In this context, thermal camera imagery was utilized to analyze the impact of these natural herbaceous plants on the urban heat island effect, microclimate, and outdoor thermal comfort. The study emphasizes the importance of promoting energy-efficient and sustainable approaches to the use of clean water resources and highlights the necessity of incorporating natural herbaceous vegetation in new urban settlement areas to enhance thermally comfortable outdoor environments for human use.

2. Materials and Methods

The research material consists of the Western Campus of Atatürk University, located in the city of Erzurum. Erzurum is situated in the northeastern part of the Eastern Anatolia Region and covers an area of 25,066 km². The location map of the study area, indicating the position of Atatürk University's Western Campus, is presented in Figure 1.

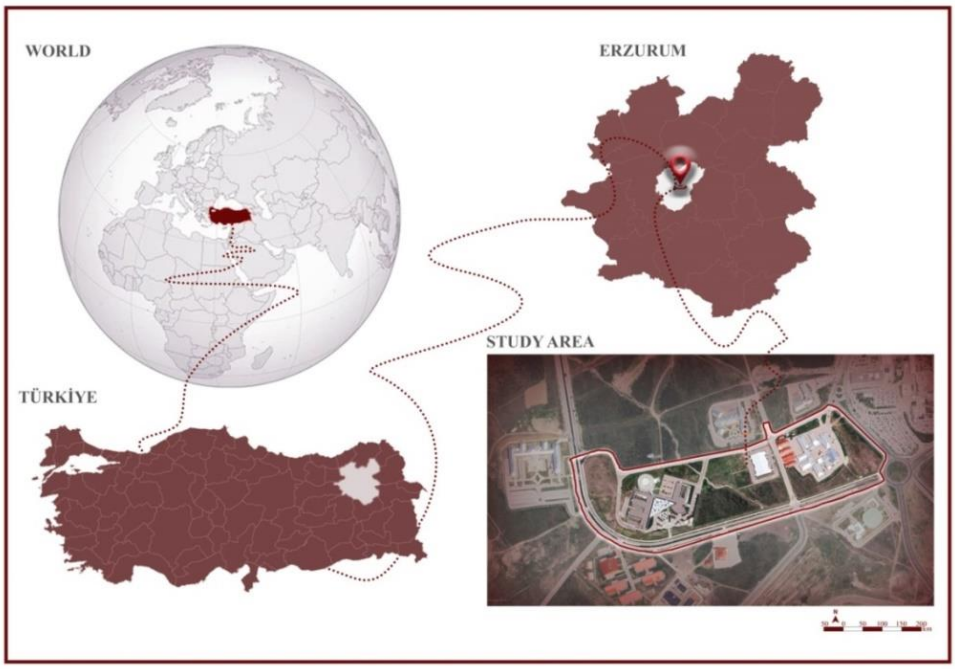


Figure 1. Location map of the study area (Created by authors).

Within the Western Campus of Atatürk University in Erzurum, ten stations were selected from a total of 27 recordings taken along sidewalks containing naturally growing herbaceous plants of different colors. These recordings were obtained in July 2025, during clear weather conditions between 13:00 and 17:00 hours, as illustrated in Figure 2.

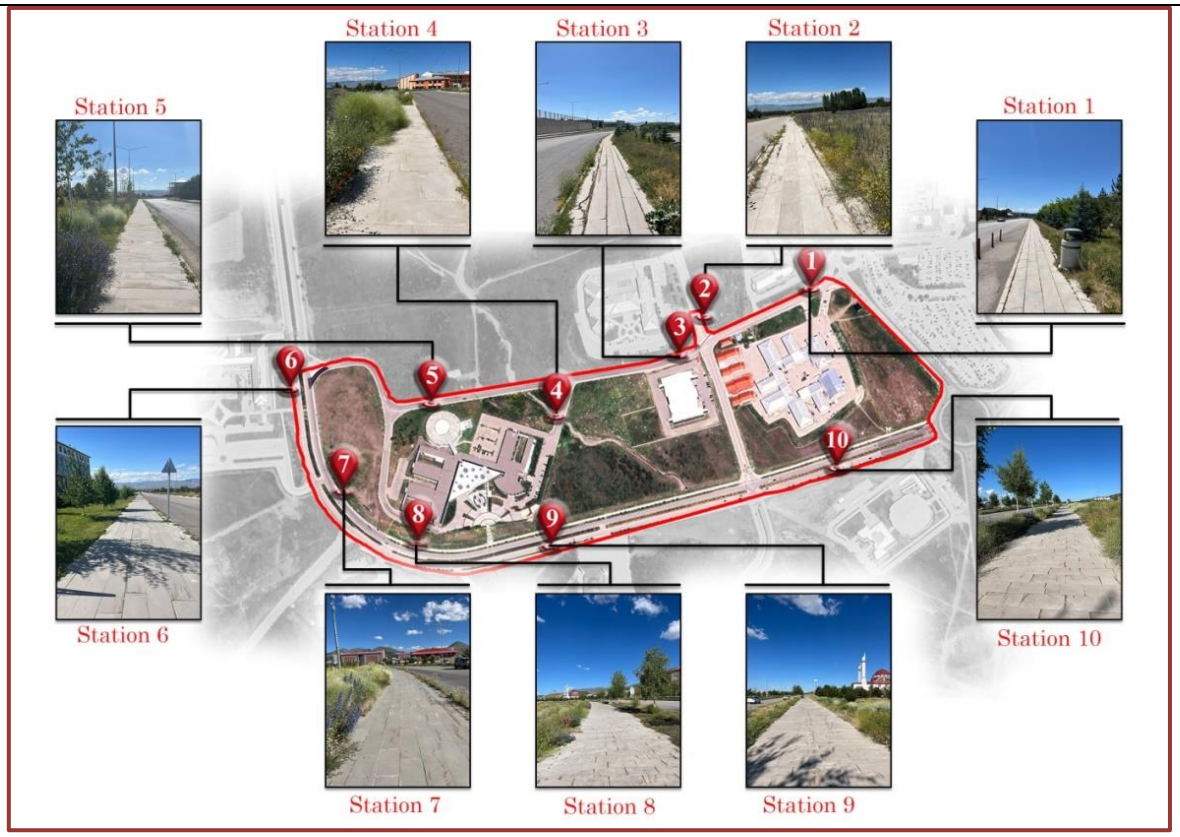


Figure 2. Location map of the stations analyzed using a thermal camera (Created by authors).

For each point, an Optris® PI-450 thermal camera (Optris, Berlin, Germany) with a spectral range of 7.5–13 μm, a resolution of 382 × 288 pixels, an accuracy of ±2 °C, and a sensitivity of 0.1 °C was used, and the measurement methodology is presented in Figure 3. In addition, air temperature, humidity, and wind data were measured using an anemometer to compare atmospheric conditions with surface temperatures (Figure 3). Hourly temperature and wind measurements were also recorded alongside the thermal camera observations.

Sky View Factor (SVF) analysis was conducted using a Nikon D5200 camera equipped with a fisheye lens, positioned at ground level (Figure 3). The lens used had the specifications "52 mm 0.25X ProHD FishEye + 12.5 Diopter Macro." SVF values were calculated from the obtained images using RayMan Pro 2.1 software.

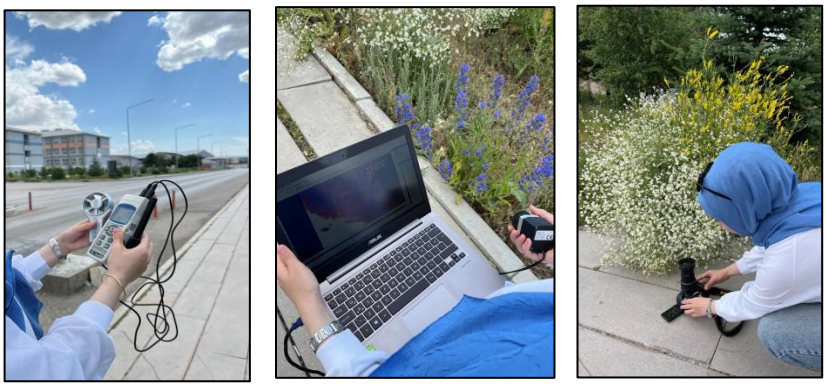


Figure 3. Images showing the use of the instruments (Created by authors).

Measurements were conducted in July, one of the hottest months of the year. Thermal images were captured from a height of approximately 150 cm above the ground for each sidewalk. The obtained images were analyzed using the "Optris PI Connect" software, which allowed temperature data to be extracted from nearly every point in the image. Consequently, the software recorded the overall average temperature for the sidewalks, adjacent herbaceous vegetation, and different surface types, as well as the maximum and minimum temperature values at specific points.

Table 1. Instruments used in the study and their specifications (Created by authors).

Device Name	Model / Brand	Purpose of Use	Measurement Unit	Measurement Height	Measurement Range / Accuracy	Measurement Period
Anemometer (Wind Sensor)	AM-4247SD (Lutron)	Wind Speed Measurement	m/s	1.6 m	±0.1 m/s	July 2025
Anemometer (Temperature Sensor)	AM-4247SD (Lutron)	Air Temperature Measurement	°C	1.6 m	±0.8 °C	July 2025
Anemometer (Humidity Sensor)	AM-4247SD (Lutron)	Relative Humidity Measurement	%	1.6 m	±3% RH	July 2025
Camera	Nikon D5200	Fisheye Photography for Sky View Factor (SVF) Analysis	–	0.0 m (yer düzeyi)	–	July 2025
Thermal Camera	Optris PI	Surface Temperature Measurement	°C	1.5 m	0.1°C	July 2025

3. Findings and Discussion

Surface temperatures of the ten stations analyzed with the thermal camera, along with SVF analyses for each station, were recorded.

Station 1: As shown in Figure 4, the asphalt surface exhibits the maximum temperature, while the herbaceous plants influence the average temperature, resulting in a reduction of the mean temperature value.

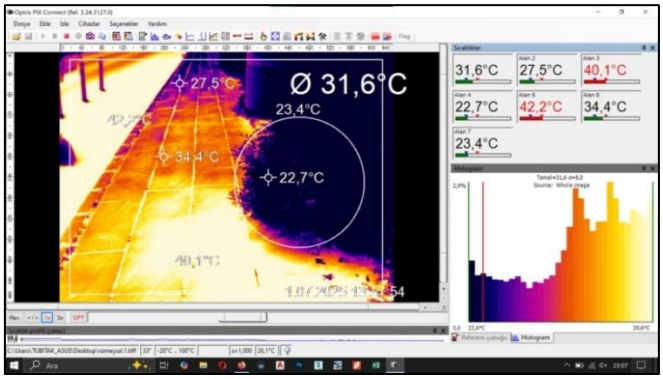


Figure 4. Thermal camera image of Station 1(Created by authors).

Station 2: As shown in Figure 5, the andesite-paved sidewalk exhibits the highest ambient temperature, while the herbaceous plants along the sidewalk reduce the surrounding temperature.

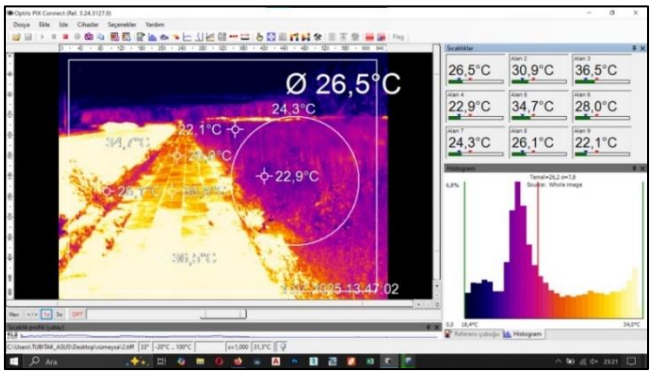


Figure 5. Thermal camera image of Station 2(Created by authors).

Station 3: As shown in Figure 6, the temperatures of the asphalt and andesite-paved sidewalks are similar. On both sides, the presence of herbaceous plants appears to mitigate these high temperatures, resulting in a reduction of the surrounding ambient temperature.

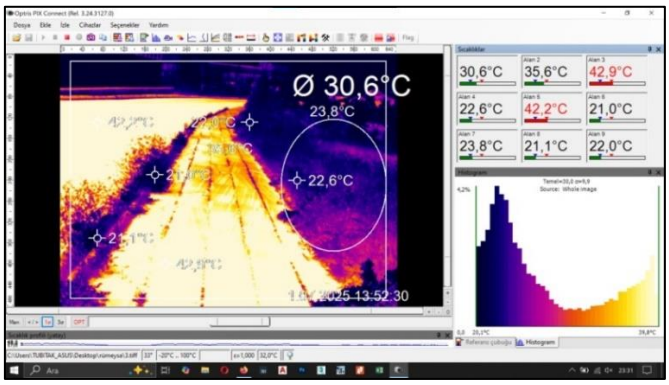


Figure 6. Thermal camera image of Station 3(Created by authors).

Station 4: The thermal camera image in Figure 7 indicates the presence of the maximum average temperature at the station, and it has been observed that the herbaceous plants effectively reduce this temperature.

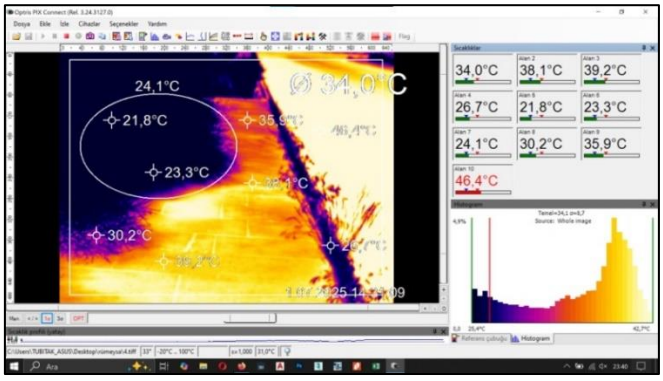


Figure 7. Thermal camera image of Station 4(Created by authors).

Station 5: As shown in Figure 8, the hard surfaces, namely the andesite-paved sidewalk and asphalt road, exhibit the highest temperatures, while the natural herbaceous plants reduce these temperatures, creating a cooler environment.

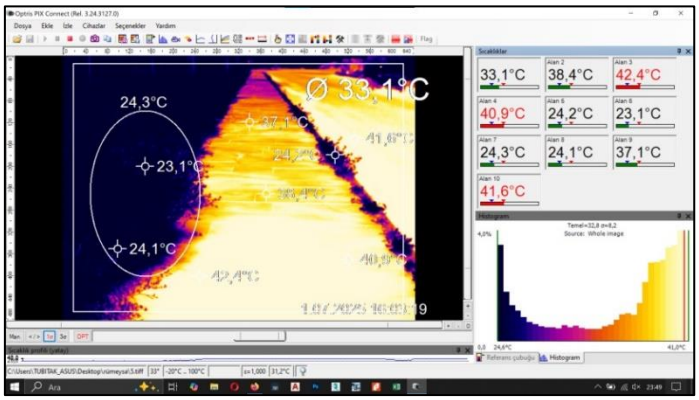


Figure 8. Thermal camera image of Station 5(Created by authors).

Station 6: As shown in Figure 9, the asphalt road exhibits the highest temperature. The limited presence of herbaceous plants resulted in minimal temperature reduction.

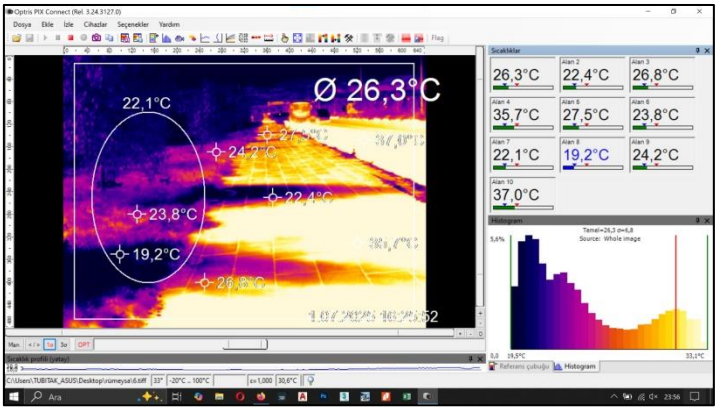


Figure 9. Thermal camera image of Station 6(Created by authors).

Station 7: As shown in Figure 10, the andesite-paved sidewalk exhibits the highest temperature, and the dense presence of herbaceous plants of different colors at this station appears to influence the temperature variation.

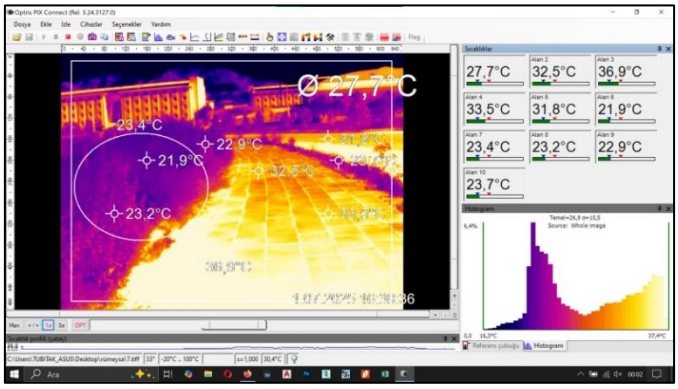


Figure 10. Thermal camera image of Station 7(Created by authors).

Station 8: As shown in Figure 11, the dense herbaceous vegetation on one side of the sidewalk reduces the high surface temperature, thereby lowering the average temperature.

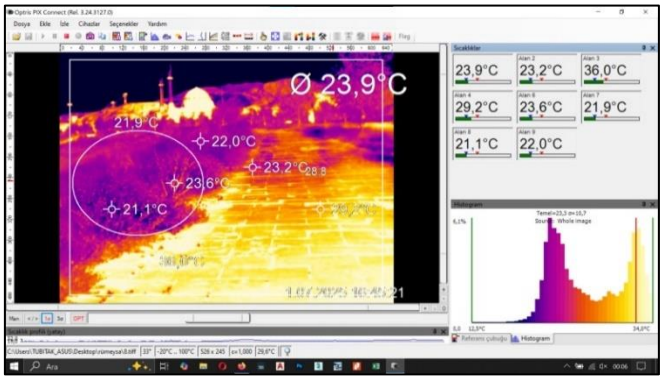


Figure 11. Thermal camera image of Station 8(Created by authors).

Station 9: As seen in Figure 12, although the asphalt surface exhibits high temperatures that increase the surrounding heat, the presence of herbaceous plants reduces the ambient average temperature.

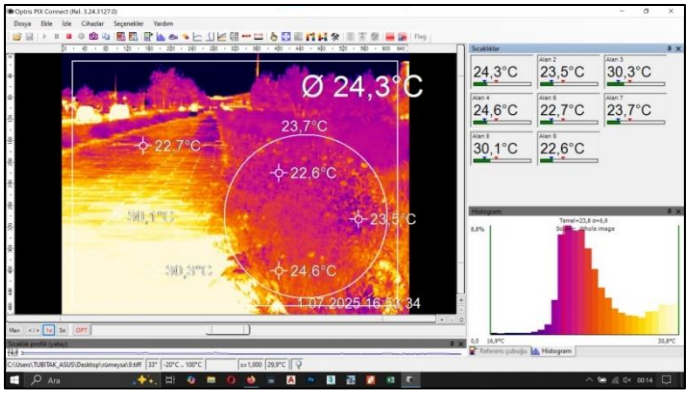


Figure 12. Thermal camera image of Station 9(Created by authors).

Station 10: As shown in Figure 13, the thermal image of this station records the minimum average temperature, and the dense natural herbaceous vegetation contributes to the formation of this low temperature.

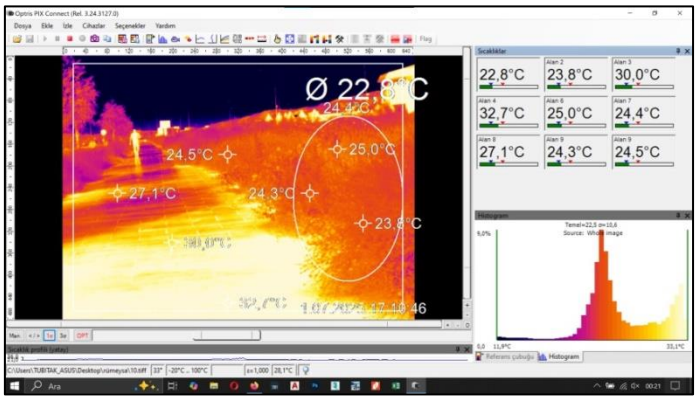


Figure 13. Thermal camera image of Station 10(Created by authors).

The Sky View Factor (SVF) represents the visibility of the sky within a hemisphere and ranges from 0 to 1. Values approaching 1 indicate high sky visibility, whereas values closer to 0 indicate reduced visibility (Algeciras et al., 2016; Middel et al., 2017; Li et al., 2020; Gomes and Giannotti, 2024). In this study, SVF values were calculated using RayMan Pro 2.1 software (Matzarakis et al., 2010). SVF values for each station were obtained as illustrated in Figure 14.

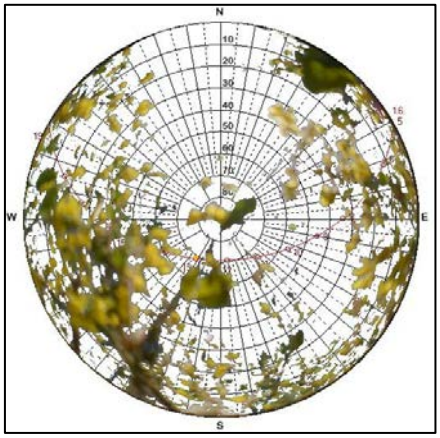


Figure 14. SVF analysis image.

4. Conclusion and Recommendations

In this study, thermal camera images and Sky View Factor (SVF) analyses were conducted for ten selected stations to evaluate the impact of naturally occurring herbaceous plants along sidewalks on outdoor thermal comfort within the Western Campus of Atatürk University in Erzurum. The results indicate that, in contrast to hard surfaces such as asphalt, andesite-paved sidewalks, and concrete—which tend to increase ambient temperatures—the presence of natural herbaceous vegetation contributes to cooler conditions, with temperature reductions ranging from approximately 3 to 18 °C. In areas with the highest average temperatures, the asphalt surfaces exhibited maximum temperature levels, whereas areas with the lowest average temperatures corresponded to locations where herbaceous plants were densely present on both sides of the sidewalk. At the micro scale, the effects of hard surfaces such as asphalt and andesite on local temperatures significantly influence the surrounding environment, thereby amplifying the urban heat island effect.

Thanks and Information Note

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Thermal Imaging Analysis of the Effect of Flower Color in Herbaceous Plants on Outdoor Thermal Comfort: A Case Study of Atatürk University Western Campus

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Abstract

With the effects of climate change in urban areas, enhancing thermal comfort in open spaces has become increasingly important. In this context, the morphological and physiological characteristics of plants influence microclimatic conditions. In particular, flower color can alter the capacity for light reflection and absorption, leading to differences in surface temperatures. In this study, conducted in July 2025 between 13:00 and 17:00 at the Western Campus of Atatürk University, the effects of different flower colors on thermal comfort in natural herbaceous plants were examined. Measurements were performed at a distance of 50 cm from the plants using an Optris PIX Connect Thermal Camera, and temperature and humidity values were simultaneously recorded with an Anemometer AM-4247SD device. In the study, seven different flower color groups were identified, and data were collected from various points. The findings revealed that light-colored flowers exhibited surface temperatures 3–7°C lower, while dark-colored flowers showed an increase of 0.5–2°C due to light absorption. As a result, flower color was determined to be a design element that should be considered for improving thermal comfort in urban landscapes. This highlights the importance of color diversity among herbaceous plants in sustainable and climate-sensitive landscape planning.

Keywords: Herbaceous Plants, Micro-Climate, Thermal Comfort, Thermal Camera, Flower Color, Sky View Factor (SVF)

1. Introduction

The urban heat island (UHI) effect is defined as the phenomenon whereby city centers exhibit higher temperatures compared to their surrounding areas. This effect arises from high building density, limited air circulation, anthropogenic heat production, and the high heat retention capacity of materials such as concrete and asphalt. The lack of green spaces and water surfaces exacerbates this effect, leading to increased temperatures during summer, higher energy consumption, and adverse impacts on human health and urban infrastructure (IPCC, 2023).

The rapid increase in urbanization has led to a reduction of open and green spaces in cities, limiting areas available to meet individuals' recreational needs. Therefore, efforts by local authorities to expand green spaces in urban planning are of great importance. Instead of traditionally used seasonal plants, the use of natural herbaceous species should be considered a sustainable and economical approach. While seasonal plants incur high costs due to frequent replacement, intensive maintenance, and irrigation requirements, natural herbaceous plants

contribute to environmental sustainability through their adaptability and low maintenance needs (Zengin, Yılmaz, & Mutlu, 2019).

This study aims to provide scientific data for urban landscape design by examining the effects of flower color on thermal comfort in natural herbaceous plants at Atatürk University's West Campus. The findings indicate that plant colors play a determining role in microclimatic conditions and thermal comfort. The research highlights the importance of considering the color diversity of natural herbaceous plants in climate-sensitive landscape planning, contributing to sustainable urban planning and climate change adaptation strategies.

2. Materials and Methods

The materials for this study consist of Atatürk University's West Campus in Erzurum and the naturally occurring herbaceous plants within this area. Erzurum, with a population of 749,993, is the third largest city in the Eastern Anatolia Region and ranks among Turkey's highest-altitude and coldest cities. The city experiences a harsh continental climate, characterized by long, cold, and snowy winters and hot, dry summers (URL-1). Established in 1957, Atatürk University hosts one of the largest campus areas in the country (URL-2). A location map illustrating the study area and measurement stations was prepared (Figure 1).

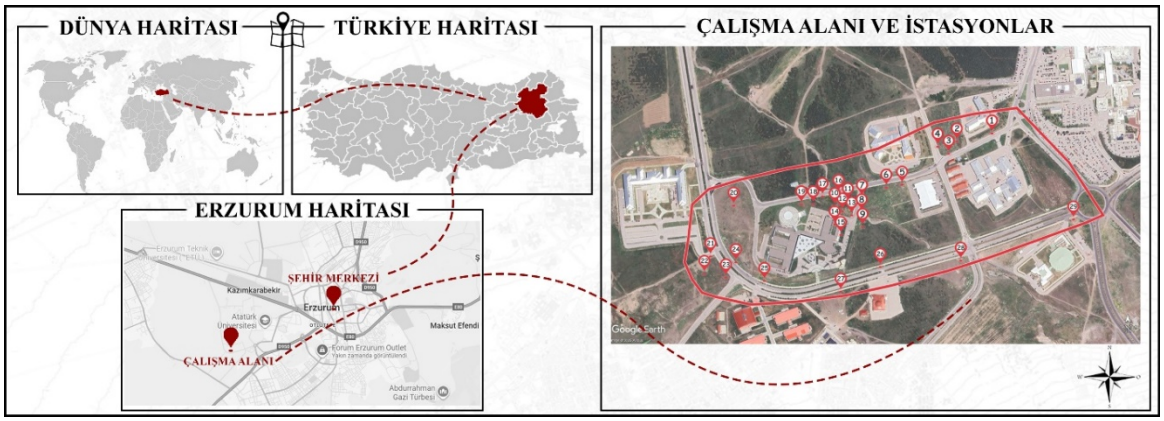


Figure 1. Location Map Showing the Study Area and Measurement Stations (Created by the Authors)

Herbaceous plants are defined as plants that lack a woody stem and have life cycles lasting one, two, or multiple years. Their leaf and stem characteristics allow them to rapidly adapt to environmental conditions, playing a significant role in ecosystem functions. Additionally, they support soil microorganisms, contributing to the preservation of biodiversity, and are widely utilized in landscape design and ecological applications (Spicer et al., 2022; Stefanowicz et al., 2022).

Thermal cameras are highly sensitive devices that detect the infrared radiation emitted by surfaces and objects, allowing temperature distributions to be visualized without physical contact. These systems enable the early detection of potential faults or structural issues by identifying temperature differences that are imperceptible to the naked eye. In thermal images, temperature variations are represented through color tones, with hot areas shown in lighter shades and cold areas in darker tones. Due to these capabilities, thermal cameras have

a wide range of applications, from industrial inspections to environmental analyses (Çalışan & Türkoğlu, 2011).

In this study, a high-thermal-sensitivity, manual-focus, long-wave infrared Optris® PI-450 thermal camera was used, and measurements were conducted via the “Optris PI Connect” software. To determine the Sky View Factor (SVF) values, plants were photographed at ground level using a Nikon D5200 camera equipped with a fisheye lens. Additionally, during the measurements, temperature and humidity values were recorded simultaneously using an Anemometer AM-4247SD device.

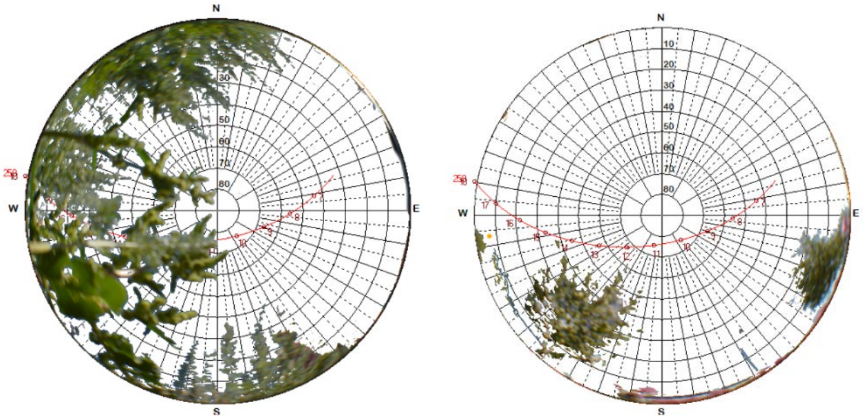


Figure 2. An example image of the SVF visuals used in the analyses is provided (Created by the Authors)



Figure 3. Images from the Time of Measurement (Created by the Authors)

The measurements were conducted on July 1, 2025, during the hottest hours of the day. In the study, seven different flower color groups (White, Blue, Purple, Yellow, Orange, Green, and Pink) were identified, and analyses were performed using data collected from the stations. For each plant, thermal camera and SVF images were captured, and temperature measurements were taken at the stations using the Anemometer AM-4247SD. The obtained thermal images were transferred to the “Optris PI Connect” software for temperature analysis. In the images, temperature values of different surfaces such as plant flowers, pavement, soil, and walls were determined, allowing for comparative analyses between these points.

3. Findings and Discussion

In this study, the measurements of seven different color groups of natural herbaceous plants at Atatürk University's West Campus were conducted outdoors during the hottest hours of the day. During the measurements, environmental conditions were recorded as an air temperature of 28°C, wind speed of 5 m/s, and humidity of 23.1%. The obtained data were compared with measurements from the Atatürk University Housing Station and the Erzurum Meteorology Station taken on the same day and at the same hours.

Four separate stations with **white-colored** plants were evaluated. Their SVF analysis values indicated high sky visibility. Thermal camera analysis revealed that areas with white-colored plants exhibited temperatures approximately 7°C lower compared to their surroundings.

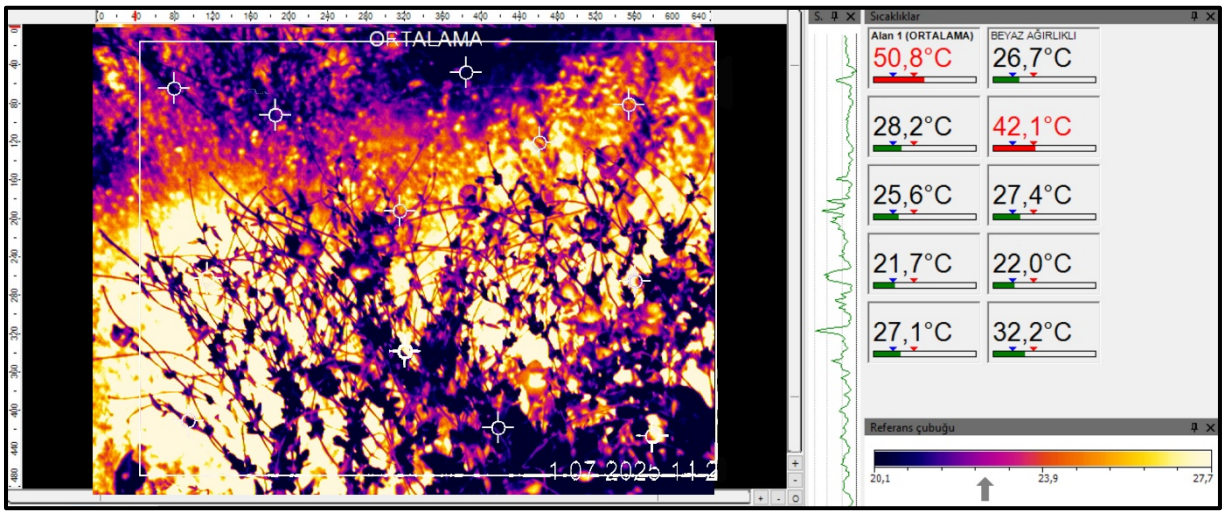


Figure 4. An example image of the thermal visuals used in the analyses is provided (Created by the Authors)

Four different stations within the **purple-color** group were evaluated. SVF analyses indicated that sky visibility was open at these stations. Thermal camera analyses revealed that purple-colored plants exhibited approximately 2°C higher temperatures compared to their surrounding environment.

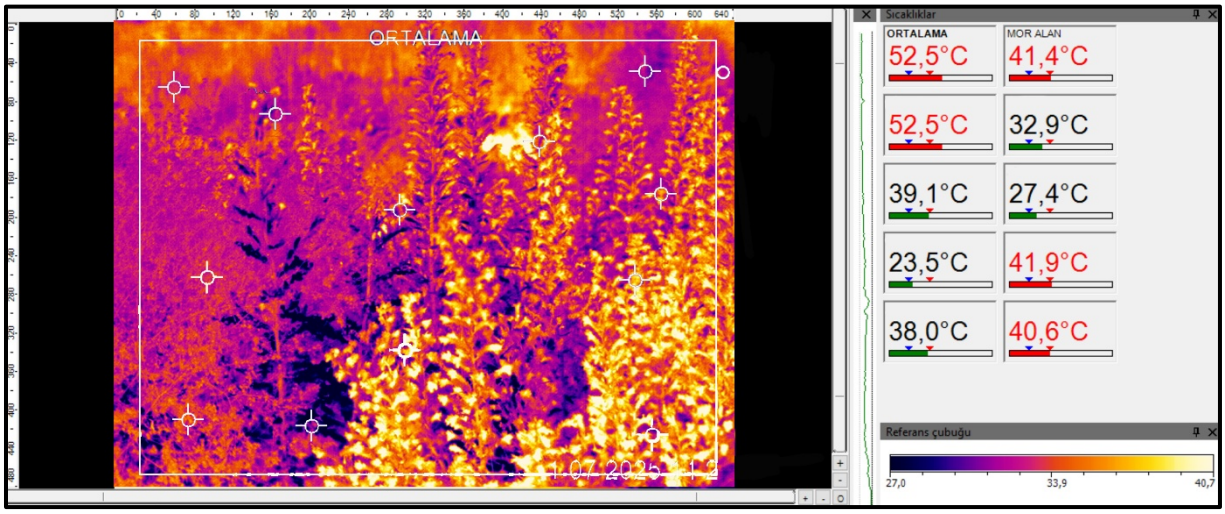


Figure 3. An example image of the thermal visuals used in the analyses is provided.

Three stations were identified for **blue-colored** plants, and SVF analysis showed that sky visibility was open at these locations. Additionally, thermal camera analysis indicated that blue-colored plants exhibited approximately 4°C lower temperatures compared to their surrounding environment.

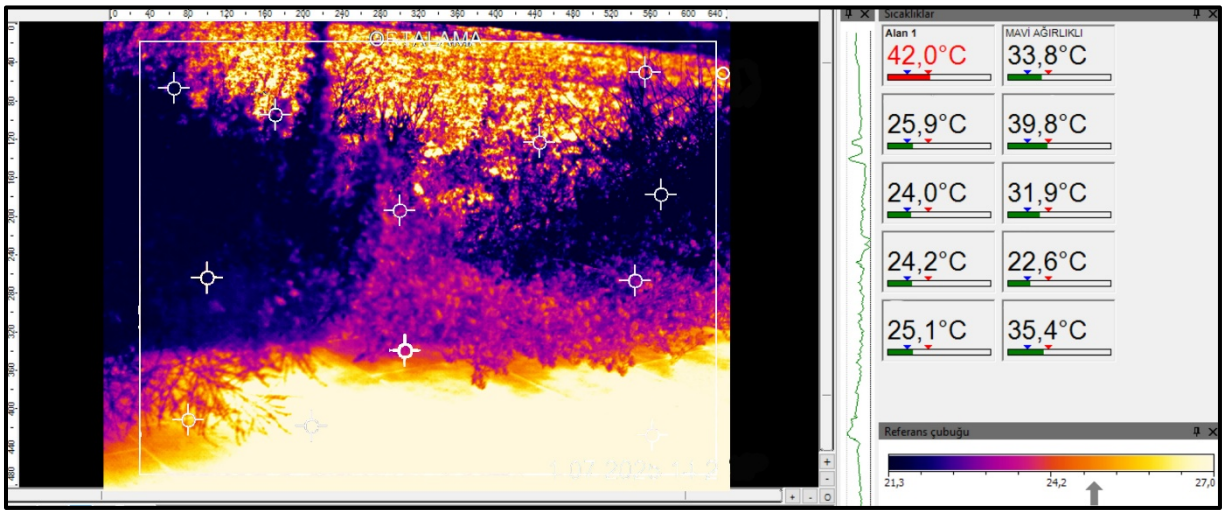


Figure 5. An example image of the thermal visuals used in the analyses is provided (Created by the Authors)

Two stations representing **yellow-colored** plants were examined, and SVF analysis confirmed that sky visibility was open at these sites. Thermal camera results indicated that the yellow flowers were approximately 7°C cooler than their immediate surroundings.

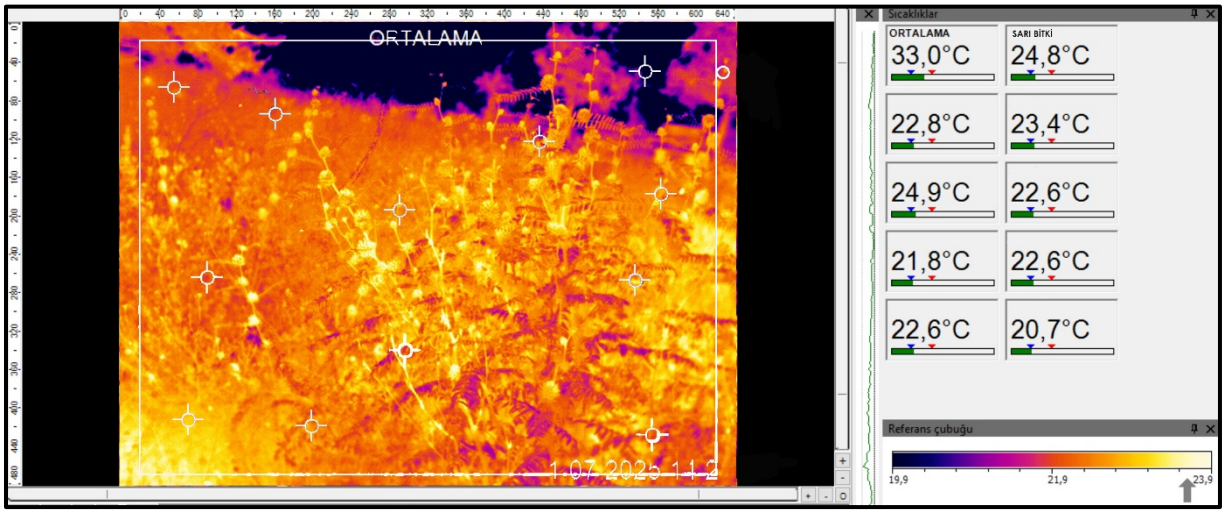


Figure 6. An example image of the thermal visuals used in the analyses is provided (Created by the Authors)

For the **orange-colored** plant group, two stations were evaluated. SVF analysis indicated that sky visibility was limited at these locations, and thermal camera measurements revealed that the orange flowers exhibited approximately 3°C higher temperatures compared to their surrounding environment.

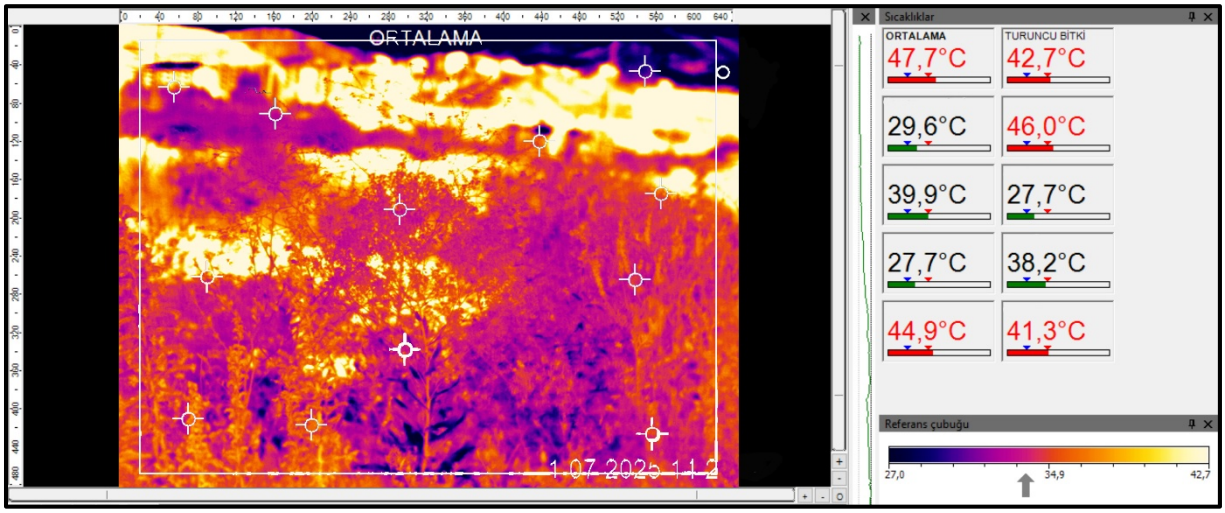


Figure 7. An example image of the thermal visuals used in the analyses is provided (Created by the Authors)

In the evaluation of **green-colored** plants, two stations were identified. SVF analysis indicated that sky visibility was open at both locations, and thermal camera measurements showed that the green flowers exhibited approximately 3°C lower temperatures compared to their surrounding environment.

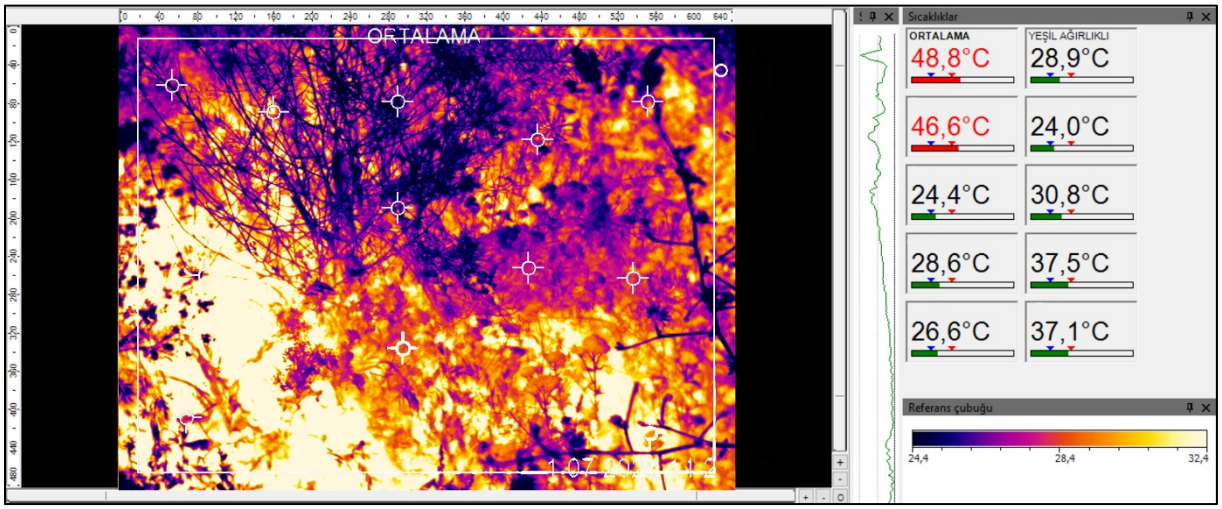


Figure 8. An example image of the thermal visuals used in the analyses is provided (Created by the Authors)

In the evaluation of **pink-colored** plants, one station was examined. SVF analysis indicated that this plant had the highest level of sky visibility among all stations, and thermal camera analysis revealed that the pink-colored plant exhibited approximately 3°C lower temperature compared to its surrounding environment.

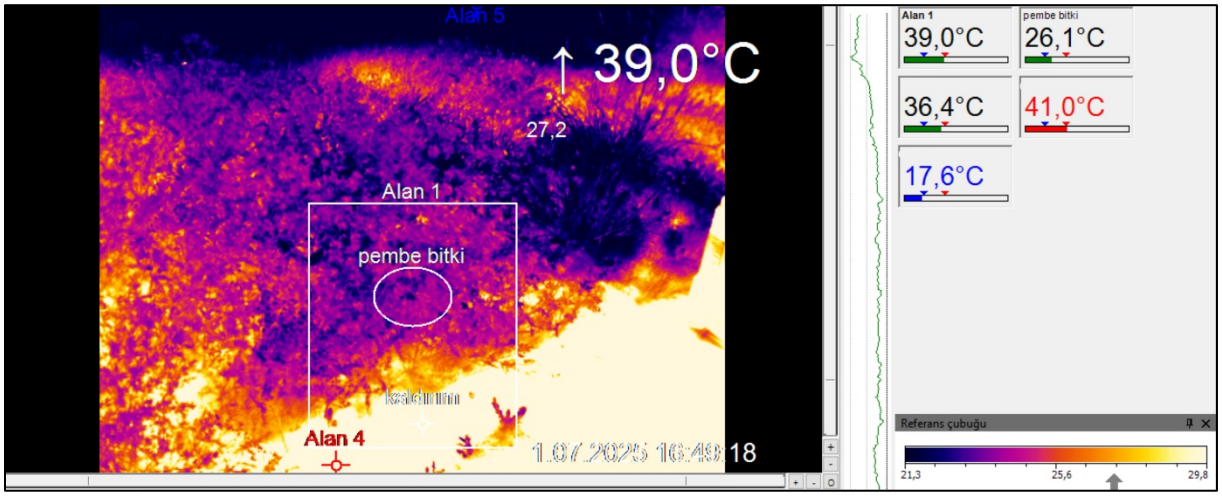


Figure 9. An example image of the thermal visuals used in the analyses is provided (Created by the Authors)

4. Conclusion and Recommendations

In conclusion, flower color in herbaceous plants has been identified as an important factor for enhancing thermal comfort in urban landscape design. The study demonstrates that the color diversity of natural herbaceous plants can be considered a design criterion in sustainable and climate-responsive landscape planning. White, yellow, and light-toned pink, blue, and green flowers reduce surface temperatures and alleviate heat stress due to their high reflectance, making them highly suitable for warm climates. In contrast, dark-colored flowers such as

purple and orange increase surface temperatures and should be used sparingly in shaded or cooler areas. The flower color of plants should be planned according to microclimatic conditions. In this way, flower colors in landscape design are selected not only for aesthetic purposes but also with consideration of their thermal effects, and the color distribution optimizes both visual diversity and temperature regulation.

Thanks and Information Note

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All authors contributed equally to the manuscript. The authors declare no conflict of interest. Artificial intelligence tools were employed to assist in producing the English text of this article.

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Protection Status of Caves as Natural Heritage in Türkiye

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Abstract

Today, many people, whether as visitors or to meet their recreational needs, seek to explore and experience diverse natural resources. Türkiye, home to rich cave ecosystems, has numerous caves registered as natural assets, protected by national laws, and either included on or candidates for the UNESCO World Heritage List. The preservation of caves depends on maintaining the delicate balance of their microclimates. Maintaining parameters such as CO_2, light, humidity, and temperature within scientifically determined ranges for sustainable management in both caves open and closed to tourism. Achieving this balance requires the combined implementation of continuous monitoring, visitor management, energy-efficient lighting, and educational programs. Caves opened to tourism and daily recreational use, with conservation requirements in mind, contribute to the region's economy and provide exploration opportunities for local residents and visitors. The applicability of conservation statuses established under international agreements and national regulations to caves is an important issue. Caves considered under these statuses should be evaluated not only for their natural resource values but also for their lithological structure, ecological characteristics, and all the features within the cave ecosystem. Oversight of decisions and practices requires a participatory management process involving responsible institutions, civil initiatives, and the public. In Türkiye, the General Directorate of Natural Heritage Protection, affiliated with the Ministry of Environment, Urbanization and Climate Change, conducts registration and conservation efforts for caves with geological heritage value, whether protected under various statuses or not yet protected, as "natural assets." This report examines studies on caves under protection in Türkiye and research revealing the geological and ecological characteristics of natural caves (terrestrial and marine) in Türkiye. Furthermore, information is provided about the "Terrestrial and Marine Cave Research Project" launched in 2022, and the registered and protected caves and their characteristics are described.

Keywords: Cave, natural asset, conservation status, natural resource value

1. Introduction

15% of the World's surface, and 40% of Türkiye's, consists of carbonate and sulfate rocks suitable for dissolution and cave development. Within this widespread distribution of rocks,

numerous caves have developed (Nazik, 2003). Caves are defined as underground cavities with surface openings wide and high enough to allow at least one person to enter.

Caves, which develop depending on the geological, geomorphological, hydrological-hydrogeological characteristics of their region, climate, vegetation, time factors, and reach lengths of hundreds of kilometers and depths of 1,000-1,500 meters, have been primary habitats for humans and animals since ancient times (the Paleolithic Age) (Nazik, 1989).

Today, many people, both as visitors and recreationally, yearn to discover and experience the diverse and rich natural resources that meet their needs.

Due to its geological structure, Türkiye boasts numerous caves. Most of these caves are concentrated in Southern Anatolia. Of the estimated 40,000 caves in Türkiye, 3,900 have been identified to date by various domestic and international research institutions, associations, and clubs (Nazik, 2008). These caves were investigated by Mineral Research and Exploration General Directorate (MTA) and other caving-related associations, clubs, communities, and organizations, and only 2,510 of these were mapped to be included in the Turkish Cave Inventory (Nazik et al., 2005).

Over 30 caves in Türkiye have been opened to tourism, and many others are reserved for special interest groups and can only be entered with a guide and appropriate equipment. The Ministry of Culture and Tourism of the Republic of Türkiye has opened 13 caves to tourism to date (Republic of Türkiye Ministry of Culture and Tourism, General Directorate of Investments and Enterprises, 2025). In Türkiye, which has rich cave ecosystems, we also have caves, like many other natural resource values, which are registered as natural assets and have protection status under national laws, and which have been added to the World Heritage List by UNESCO and are candidates.

Cave exploration in Türkiye was initiated by the Cave Research Association (MAD), founded in 1964. The first university club, the Boğaziçi University Cave Research Club (BÜMAK), was later established in 1973. Subsequently, the Karst and Cave Research Unit, established within the MTA Geological Research Department in 1979, conducted a large portion of cave exploration (Republic of Türkiye Ministry of Culture and Tourism, General Directorate of Investments and Enterprises, 2025). The Speleology Federation was established in 2009. The associations, clubs, and institutions affiliated with the Speleology Federation are listed below, in the order of their founding dates (Mağaracılık Federasyonu, n.d.).

- **Cave Research Association (MAD):** Founded in Ankara in 1964, the club was the first caving association in Türkiye. To date, the association has organized joint studies and conferences with numerous local and international cave groups. Playing a significant role in the development of Türkiye's cave inventory and the training of new cavers, the association continues its activities in Ankara and Bursa.
- **Boğaziçi University Cave Research Club (BÜMAK):** Founded in 1973, the club was the first university caving club in Türkiye. Having achieved numerous successes, the club completed its work in the Peynirlikönü Sinkhole in 2004, descending to 1,429 meters. The Peynirlikönü Sinkhole in İçel is currently Türkiye's deepest cave. The club continues its activities in Istanbul.
- **General Directorate of Mineral Research and Exploration Caving Unit (MTA):** Founded in 1978, the unit is the first government agency in Türkiye to conduct caving work. The unit, which has pioneered the preparation of Türkiye's cave inventory

through its work to date, has made a significant contribution to the development of caving in Türkiye through its assistance and knowledge transfer to other associations, clubs, and communities. The institution continues its activities in Ankara.

- **Hacettepe University Cave Research Club (HÜMAK):** Founded in 1988, the club has completed numerous research projects and organized symposiums and photography competitions related to caving. The club continues its activities in Ankara.
- **Dokuz Eylül University Cave Research Club (DEÜMAK):** Founded in 1994, the club continues its activities in Izmir.
- **Eskişehir Cave Research Association (ESMAD):** The group began cave research in 1995 and became an association in 2006. The association continues its activities in Eskişehir.
- **Ege University Cave Research Club (EMAK):** Founded in 1996, the club continues its activities in Izmir.
- **Toros Cave Research and Protection Association (TAMAK):** The group, which began its activities in 2002 within the Toroslar Nature Sports Club in Antalya, became an association in 2008. The association continues its activities in Antalya.
- **Ankara University Cave Research Unit (ANÜMAB):** The club, founded in 2004, continues its activities in Ankara.
- **Aegean Cave Research and Protection Association (EGEMAK):** The association, founded in 2008, continues its activities in Izmir.
- **Boğaziçi International Cave Research Association (BUMAD):** The association, founded in 2007, continues its activities in Istanbul.
- **Istanbul Technical University Cave Research Club (İTÜMAK):** The club, founded in 2007, continues its activities in Istanbul.
- **Anadolu University Nature Sports Club (ANADOSK):** The club, founded in 2000, continues its activities in Eskişehir with the speleological sub-unit it established in 2008.
- **İzmir Cave Research Association (İZMAD):** The association, founded in 2008, continues its activities in Izmir.
- **Akdeniz University Cave Research Club (AKÜMAK):** Founded in 2006, the club continues its activities in Antalya.
- **General Directorate of Conservation and National Parks Cave Protection Unit (DKMP-MKB):** Established in 2006 under the Ministry of Forestry and Water Affairs, the unit continues its activities in Ankara.
- **Uludağ University Cave Research Society (UMAST):** Founded in 2012, the club continues its activities in Bursa.
- **Anatolian Speleology Group Association**: The group, which began its activities in 2008, became an association in 2011.

Over the last fifty years, caves have occasionally suffered damage due to illegal artefact hunting and reckless management. This issue, debated by international caving organisations, has necessitated modern cave management and necessitated legal and organisational regulations.

The International Union of Speleology (ISU), a scientific non-governmental organization founded in 1965 as a member of the International Council of Science in Paris, collaborates

with UNESCO. The Federation is a member of the International Speleologists' Association. Since 2006, it has also been a founding member of the Balkan Speleological Union (BSU). The Federation has also been a member of the European Speleological Federation (ESF) since 2014. The International Show Caves Association (ISCA), the International Association of Caves Open to Tourism, was founded in Italy in 1990, and the Dim Cave Operation was admitted to this association in 2002 (Güner et. al, 2003).

The Ministry of Environment and Urbanization (General Directorate for the Protection of Natural Assets) and the Ministry of Agriculture and Forestry (General Directorate for Nature Conservation and National Parks) must be consulted regarding the use of caves in Türkiye for tourism.

2. Legal and Organizational Regulations in Türkiye

The conservation statuses of Türkiye's caves, established within the framework of national legal regulations and international texts, demonstrate our legal basis for protecting and using caves. These legal texts also define the framework of our practical work and responsibilities. Caves under protection status should be evaluated not only as natural formations requiring protection for their rock structures and geomorphological features, but also as ecological assets, encompassing the environmental values and habitats they harbor within and around them.

Since 1985, the idea of opening caves to tourism has been a key agenda item in government policies. However, it has been observed that efforts to address this issue have been rushed, driven by unplanned, seasonal approaches lacking infrastructure, leading to a stalemate. The desire for short-term profit maximization has led to the long-term opening of natural heritage, especially caves considered important natural assets, to tourism, leading to the destruction of features formed over millions of years within a few years (Altınok, 2005).

3. International Conventions and Protection Regulations

When examining legal regulations related to protected areas, it is clear that regulations for nature protection cannot be considered independently, assuming that the spatial distribution of natural, cultural, historical, and archaeological values is a unified whole. International agreements enacted in accordance with Article 90/5 of our Constitution have the force of law and are applicable as part of domestic law without any amendments. Those related to caves are listed below (Demirel, 2005);

- Convention Concerning the Protection of the World Cultural and Natural Heritage, (1972) (Official Gazette dated 14.2.1983 and numbered 17959) / to ensure the identification, protection, preservation, presentation and transmission of cultural and natural heritage to future generations,
- Barcelona Convention and Protocol on Specially Protected Areas in the Mediterranean (1975) (Official Gazette dated 23.10.1988 and numbered 19968) / to take all appropriate measures in marine areas for the protection of cultural heritage, natural resources and natural sites in the mediterranean region,
- Especially the "Convention on Wetlands of International Importance as Waterfowl Habitat" (Ramsar Convention) (1971) (Official Gazette dated 17.05.1994 and numbered 21937) / to encourage the identification of areas containing representative, rare or unique wetlands or wetlands of importance for the conservation of biological diversity,

- Convention on the Conservation of European Wildlife and Natural Habitats/BERN Convention (1979) (Official Gazette dated 20.2.1994 and numbered 18318) / to safeguard the conservation of natural habitats

In addition, it is certain that EU directives (Habitats Directive, Birds Directive, Water Framework Directive) will be heavily utilized during the harmonization process with the European Union.

• The European Union Bird Protection Directive (79/409/EEC)

• The European Union Habitats and Species Protection Directive (92/43/EEC) mandates the designation of SPA (Special Protected Areas) and SAC (Specific Areas of Conservation) areas.

• Regulations Regarding Natura 2000 Areas (European Ecological Network)

Special measures for caves, particularly within the scope of the EU Water Framework Directive and the Groundwater Framework Directive, are essential for the protection, improvement, and restoration of underground water bodies, the balance of groundwater abstraction and recharge, pollution reduction, characterization, and, in particular, monitoring (Altınok, 2005).

4. National Legal Texts and Protection Agreements (Demirel, 2005)

At the national level, caves are protected primarily by the Constitution and the 5-Year Development Plans, as well as the following laws;

Forest Law No. 6831 (1956),

Aquaculture Law No. 1380 (1971),

Environmental Law No. 2872 (1983),

National Parks Law No. 2873 (1983),

Cultural and Natural Heritage Protection Law No. 2863 (1983),

Land Hunting Law No. 4915 (2003)

and by regulations issued based on relevant regulations, international agreements, decrees having the force of law, and supplementary texts, as well as by court decisions issued in accordance with these regulations.

The most important national regulation regarding the protection of caves is Law No. 2863 on the Protection of Cultural and Natural Assets, promulgated in 1983.

Among the national legal regulations, "Natural Assets," specifically defined in Article 3 of the Law on the Protection of Cultural and Natural Assets, adopted on July 21, 1983, are as follows: "Moveable and immovable assets, located above ground, underground, or underwater, dating from geological, prehistoric, and historical periods, and requiring protection due to their rarity or their characteristics and beauty. Historic caves, rock shelters, characteristic trees and tree groups, and similar are examples of immovable natural assets." Furthermore, "Protected Areas," specifically Natural and Mixed Protected Areas, also include sections on caves.

"Protected areas" are the product of various civilizations from prehistory to the present day. Cities and urban ruins, reflecting the social, economic, architectural, and similar characteristics of their eras, are sites where significant historical events took place, and areas requiring protection due to their identified natural features. Protected areas are divided into urban, archaeological, historical, and natural protected areas. Areas of exceptional natural beauty, scientific merit, and universal value are designated as natural protected areas.

Another legal regulation related to caves is the "Technical Principles Regarding the Conditions for Identification, Registration, Protection, and Use of Caves to be Designated as Natural Assets." The purpose of these Technical Principles is to determine the procedures and principles regarding the identification, registration, protection, use, and approval processes for caves designated or to be designated as immovable natural assets within the jurisdiction and authority of the Ministry of Environment and Urbanization (General Directorate for the Protection of Natural Assets), based on geological, geomorphological, hydrogeological, biological, and ecological data.

5. Responsible Institutions and Organizations in Türkiye for the Protection of Caves Within the Framework of the Law (Public-Civil)

Three institutions are primarily responsible for the protection of caves and cave life in Türkiye. These are the Department of Natural Protected Areas and Natural Assets under the General Directorate of Natural Assets Protection of the Ministry of Environment, Urbanization and Climate Change; the Department of Landscape and Cave Protection under the Wetlands Department of the General Directorate of Nature Conservation and National Parks of the Ministry of Agriculture and Forestry; and the General Directorate of Cultural Assets and Museums of the Ministry of Culture and Tourism.

Caves are administratively managed by the Department of Landscape and Cave Protection under the Wetlands Department, which operates under the General Directorate of Nature Conservation and National Parks of the Ministry of Agriculture and Forestry. The duties of these units are listed below.

a) To conduct or commission surveys and inventories on landscape areas and caves that are not protected by any status and require protection against natural and environmental impacts, and to propose these to the relevant units for granting status,

b) To prepare and ensure the implementation of projects for the restoration and rehabilitation of unprotected, degraded, deteriorating, or threatened landscapes,

c) To determine national landscape character types and areas within the scope of the "European Landscape Convention," to compile landscape inventories and prepare landscape atlases. To carry out related work and procedures, and to ensure cooperation and coordination by integrating landscape protection, planning, and management, as well as sustainable use, with sectoral or intersectoral plans, programs, and policies,

ç) To form the department's opinion by conducting an evaluation of the Landscape Restoration Plan,

d) To conduct or commission training and awareness-raising activities on caving.

6. Evaluation

Legal regulations alone cannot solve the problem. Clearly, the key is to develop these regulations and ensure their effective implementation. Therefore, cooperation and organization among stakeholders in Türkiye concerned with cave protection in the legal fight against them are essential.

In Türkiye, it would be beneficial to prioritize cave conservation activities undertaken by relevant public and non-governmental organizations within the framework of a "Basic Document" and a "Guide." The "Cave and Karst Conservation Guide," prepared by the International Union for Conservation of Nature and Natural Resources (IUCN), could be used as a comprehensive resource to form the basis for pioneering work on this topic. Furthermore, a "Turkish Caving Ethics Document," which would establish the rules to be jointly prepared and implemented by public and non-governmental cave research organizations, should be among the priority issues to be addressed in the development of (Bayarı, 2003).

Türkiye boasts a remarkable number of caves, reaching nearly 40,000 in number, incomparable to any other country. The number of caves opened to tourism is increasing daily, and they represent a significant natural resource for both domestic and international tourism. These natural systems and habitats must be preserved and maintained to both preserve their biodiversity and contribute to the country's economic growth through tourism.

In addition to increasing the effectiveness and efficiency of existing legal regulations, it is necessary to implement practices similar to those seen in other countries, both in terms of legal regulations and organizational structure, in Türkiye. A striking example of this is the enactment of cave protection laws (California Cave Protection Act, Australian Speleology Federation Minimum Impact Caving Act) in countries where environmental awareness regarding cave protection has increased (Bayarı, 2003).

Another protective measure is the "Cave Management Plan," prepared for each cave planned to be opened to visitors, taking into account local conditions. This plan also requires implementing "Minimum Impact Caving" rules, similar to those seen abroad, while simultaneously conducting regular carrying capacity studies (physical, ecological, economic, and social).

Cave protection is not a process completed by implementing legal and administrative regulations; it also has a dynamic structure that includes continuous monitoring and inspection activities.

Caves are administratively handled by the Landscape and Cave Protection Branch Directorate, which is affiliated with the Wetlands Department, which operates under the General Directorate of Nature Conservation and National Parks of the Ministry of Agriculture and Forestry. Within this job description, the task of "conducting or commissioning training and awareness-raising activities on caving" is particularly important and defines an area of action requiring joint action by public and civil organizations.

Thanks and Information Note

The article complies with national and international research and publication ethics. Ethics Committee approval was not required for the study. All authors contributed equally to the article. There is no conflict of interest.

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Urban Agriculture and Nature Conservation Relationship

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Abstract

Under rapid urbanization and increasing population pressure, "urban agriculture," an innovative approach to environmental sustainability and food security in urban life, is seen as an important area of research. This approach is increasingly emphasizing the importance of protecting urban soil, particularly in urban areas, within the scope of sustainable development goals. Developed countries are at the forefront of efforts to address climate change, food security, sustainable urbanization, and biodiversity. Urban farming areas, which are one of the ecosystem applications and are evaluated within productive landscape areas, are seen as an effective strategy for reducing the health, socio-cultural, economic, and environmental impacts on urban living areas by promoting development with natural resources. However, agricultural activities carried out under unsuitable conditions also bring negative environmental consequences. This study evaluates the environmental, socio-cultural, and economic dimensions of urban agriculture practices. Drawing on examples from Turkey and around the world, it emphasizes that urban agriculture plays a critical role in providing green spaces, improving the built environment, mitigating climate change, and raising environmental awareness and nature conservation.

Keywords: Urban farming practices, sustainable cities, nature onservation

1. Introduction

Population growth, rural migration, and urban planning that lacks an understanding of sustainable development in urban areas, coupled with the reduction of green spaces, are causing a deterioration in people's relationship with nature. In this context, the economic (Keskin & Yıldırım 2019), ecological (Yaman & Yenigül, 2022; Halaj et al., 2000), environmental (Durgun & Koçal 2025) and social challenges brought about by urbanization, urban agriculture activities have become an important component of sustainable development (Tekin, 2025). In recent years, with the relocation of agricultural areas in and around cities to the outskirts, the issue of accessible food security (Ceylan, 2024) has emerged, leading to increased interest in urban agriculture, which has begun to be supported by public policies.

Urban agriculture is conceptually defined as activities encompassing all agricultural practices within and around cities (Kanbak, 2018). According to FAO (2024), agriculture offers potential benefits to urban areas, primarily in terms of food systems. Poulsen & Spiker (2014) grouped the benefits of urban agriculture into four categories:

1) Health impacts (ease of access to fresh, healthy, and affordable food)

2) Social impacts (strengthening social bonds, raising awareness among young people about food production, cultural preservation)
3) Economic impacts; (employment opportunities and increased property and land values) (Keskin Yıldırım, 2019).
4) Environmental impacts (mitigating the effects of climate change in urban areas, ecosystem services, improving the built environment, and environmental education (Poulsen & Spiker, 2014, Karakaya Aytin, 2022).

Urban agriculture activities have historically been primarily an application to meet food needs and have been evaluated within urban planning (Dobele & Zvirbule, 2020, Tandoğan & Özdamar, 2022). In urbanization models, they contribute to sustainable, resilient (Kavanoz Ersavaş, 2020) and urban ecological services (such as rainwater management and urban carbon sequestration) (Mok et al., 2013; Philips, 2013). Under current conditions, urban agriculture activities play a critical role in creating a sustainable urban environment by increasing access to affordable and clean food, adapting to climate change, ensuring biodiversity, connecting with nature, and reducing environmental problems. Urban agriculture, a developed form of agriculture within the urban system, is classified into categories such as “farm,” “garden,” “areas near farms,” “non-agricultural land,” and “vertical farming” (Opitz et al., 2015). Urban agriculture is fundamentally divided into two groups based on type: “non-commercial” and “commercial” (Fig.1).



Figure 1. Urban Agriculture (Şahin & Öztopçu, 2024).

In this study, it is argued that urban agriculture, as a new approach, is not merely a multidimensional concept that addresses conditions such as food security, social structure, and economy. Rather, it should also be seen as a complementary component supporting nature-based development, urban ecology, and environmental sustainability goals.

National and international examples of urban agriculture activities have been examined in terms of land and resource management practices. Urban agriculture has increased food access in developing countries, while in developed countries it has become an area that reduces environmental problems and is integrated into urban planning.

2. The Effects of Urban Agriculture on Nature Conservation

Urban agriculture can help reduce the negative impacts on the natural environment in countries with higher levels of urbanization, from an eco-environmental perspective. One of the greatest ecological contributions of urban agriculture, which can offer nature-based and holistic solutions to climatic and social challenges, is its support for biodiversity and sustainable environmental practices. It is well known that urban agriculture has the capacity to mitigate/adapt to climate change, enhance ecosystem services, and improve food security, well-being, and social cohesion (Cabral et al., 2017; Artmann & Sartison, 2018; Edmondson et al., 2020). In particular, converting underutilized urban areas into productive landscapes increases vegetation cover and mitigates the urban heat island effect by enhancing evaporation (Qiu et al., 2013). Urban vegetation not only reduces urban heat but also acts as potential carbon sinks, lowering atmospheric carbon dioxide and improving air quality (Lwasa et al., 2014; Thornbush, 2015). According to the IPCC, air temperatures are projected to increase by 2.5-3°C by 2050 and 4-6°C by 2100 (Karapınar et al., 2020). With these temperature increases, humanity will face serious risks in terms of climate change and environmental hazards. These include:

- Rising sea levels,
- Degradation of marine and coastal ecosystems,
- Drought and desertification due to changes in rainfall patterns,
- Decline in agricultural productivity,
- Epidemics caused by air pollution and acid rain,
    - Increase in natural disasters (Karaca et al., 2024).

Urban agriculture also reduces the impact of strong winds, creates shaded areas by blocking sunlight, improves urban water management through the integration of municipal wastewater, domestic wastewater treatment, and hydroponic systems, mitigates the effects of floods and landslides, and promotes environmental awareness among individuals (Yaman & Yenigül, 2022).

3.World and Turkey Urban Agriculture Practices

Urban agriculture activities in Turkey can be carried out in detached house gardens, vacant lots between apartment buildings, or in urban peripheries. The vast majority of non-commercial and individual farming activities are based on vegetable cultivation and are rapidly declining due to urbanization (Orpak, 2021). In our country, the importance given to “urban agriculture” is only reflected in Measure 491 of the Twelfth Development Plan (2024-2028). 3 of the Twelfth Development Plan (2024-2028), which states, “Special importance will be given to the development of urban agriculture on the outskirts of major consumption centers in order to ensure that consumers have access to agricultural products at affordable prices by reducing product losses and logistics costs” (Işıklar & Yalçıntaş, 2020). In our country, although there are very few examples of planned urban-scale implementation, green

roof applications (Akmerkez Shopping Mall, Kanyon Shopping Mall), use for socializing and spending time (hobby gardens in Istanbul and Ankara), use of medicinal gardens (Zeytinburnu Medicinal Plants Garden), and soil-less farming practices (Yıldız Technical University), gardening activities, and agricultural production (Yedikule Gardens-Sarıyer, Beykoz) are considered important urban agriculture applications (Özfırtına & Yamaçlı, 2025).

Akmerkez Permaculture Roof Farm / Istanbul

Located in Akmerkez Shopping Mall, one of Istanbul's shopping centers, it is Turkey's first roof farm application, created using permaculture methods. Established in 2013, the rooftop farm covers an area of 1,800 square meters and utilizes ecological and economic sustainability tools, including windbreaks on top of passive drainage insulation layers, raised beds, hügelkultur, compost units, a greenhouse, a seed library, vertical production elements, approximately 92 different plant species that increase biodiversity, consisting of perennial and annual plants, a medicinal herb spiral, and insect hotel applications (Fig.2). Akmerkez Permaculture Roof Farm is an important example of productive landscapes at the urban scale, laying the foundations for social entrepreneurship (Url-1).



Figure 2. Image of Akmerkez Permaculture Roof Farm (Url-1).

Zeytinburnu Medicinal Plant Garden/Istanbul

Turkey's first medicinal aromatic plant garden opened in 2005 and operates on an area of 14,000 square meters. The garden contains over 750 species of medicinal plants (Fig.3). The plants are cultivated without the use of synthetic fertilizers, herbicides, or pesticides. The project, run by Zeytinburnu Municipality and the Merkez Efendi Traditional Medicine Association, aims to research, produce, and promote medicinal plants, contribute to the preservation and development of plant diversity, encourage the effective and safe use of medicinal plants, promote their cultivation, organizing educational programs at all levels, and offering health solutions sensitive to human balance based on the heritage of traditional medicine and the possibilities offered by nature (Url-2).



Figure 3. Image of Zeytinburnu Medicinal Plants Garden (Url-3).

Soil-Free Agriculture Application and Research Greenhouse / Istanbul

Established in 2017 through a collaboration between Yıldız Technical University and the Istanbul Metropolitan Municipality, it is Turkey's first greenhouse for hydroponic, vertical, and wet farming. Built on an area of 2000 square meters and utilizing the most advanced agricultural technologies, the greenhouse grows strawberries, tomatoes, and lettuce varieties using hydroponic and coconut coir systems. In the soil-less farming system, unlike traditional farming, plants are pollinated using liquid organic fertilizers and bumblebees (Fig.4). The greenhouse produces 400,000 heads of lettuce annually on an area of 1,000 square meters, and the products, grown using good agricultural practices, contribute to the clean food needs of the local community (Url-4).



Figure 4. Soil-Free Agriculture Application and Research Greenhouse (Url-5)

It is estimated that 60% of the world's population will live in cities by 2030, creating a need for innovative solutions for growing and distributing food in urban areas. National organizations and local governments, especially in regions where urban agriculture is widely practiced, have developed programs to facilitate urban agriculture (Keskin & Yıldırım, 2019). One such international organization is the Urban Agriculture Network (TUAN). The Resource Centers on Urban Agriculture and Forestry, which operates worldwide, is an organization based in the Netherlands that aims to accelerate the transformation of food systems for environmental, social, economic, and sustainability reasons (RUAF, 2025). Dubai Agriculture Park, New York City, and Paris Expo Porte de Versailles Roof Farm are important examples of urban agriculture implemented on a city scale around the world.

Dubai Agricultural Park/Dubai

The project, implemented on Sheikh Zayed Road, is recognized as the world's longest urban agricultural park. Designed to transform Dubai's busiest street into an eco-valley, the project converts 25 km of land and 350 hectares into urban agricultural land, supporting sustainable growth by contributing economically to social capital development. The park consists of climate-controlled indoor urban farming gardens and open-air date palm farms (Fig.5). It aims to improve environmental quality by reducing the environmental carbon footprint associated with the transportation and storage of food grown in the city center. In addition to the urban farming area, the park features recreational areas, local materials, and large-scale green spaces (Url-6).



Figure 5. Dubai Agricultural Park (Url-6).

New York City/ USA

New York has long been a champion of urban agriculture. Considering high land costs and limited space, there are over 550 community gardens, more than 745 school gardens, and over 700 gardens in public housing on city land. The city places great importance on education and the revaluation of abandoned areas. Supported by the GrowNYC association, the teaching garden is a 21,000-square-meter urban garden filled with vegetable beds made from recycled materials, hosting workshops and events for agricultural education (Fig.6). Vegetables, greens, potted plants, and flowers produced using biodynamic and ecological methods are sold to wholesalers, nearby restaurants/markets, and communities that support local products (Url-7).



Figure 6. New York City urban farming areas (Url-8).

Paris Expo Porte de Versailles Rooftop Farm /France

Paris Expo Porte de Versailles, the garden established on the roof of the exhibition center covers an area of approximately 14,000 square meters. With 30 different plant species and 20 expert employees, it has the capacity to produce 1 ton of fruit and vegetables per day. Using organic farming methods, the garden has created a small habitat rich in biodiversity (Figure 7). The aim of the rooftop garden is to grow high-quality produce in harmony with nature's cycles in the heart of Paris, thereby generating economic benefits. To this end, the rooftop garden features specially designed wooden production boxes available for rent (Url-9).



Figure 7. Paris Expo Porte de Versailles Roof Farm (Url-10).

4.Conclusion and Recommendations

Today, with population growth, practices carried out under the concept of "urban agriculture," which is one of the more inclusive solutions, particularly in the fight for food security and climate change, are becoming widespread, although they vary according to the approaches of different countries.

Looking at global practices, community gardens and vertical farming systems are more common in large cities such as New York and Chicago in the US, while green roofs and greenhouse-based urban agriculture practices are more prevalent in France and the Netherlands. In Turkey, community gardens and municipality-supported urban agriculture projects are prominent in large cities such as Istanbul, Ankara, and Izmir (Şahin & Kahraman, 2021). In international examples, technology and infrastructure-supported applications are more common, promoting a sustainable, environmentally friendly lifestyle. In Turkey, urban agriculture comes to the fore with social solidarity and local government-supported applications (Yenigül, 2016). The spread of urban agriculture applications, especially in our large cities (such as Istanbul, Izmir, and Ankara), will contribute to social harmony, environmental sustainability, and local economic growth for city dwellers. Urban agriculture practices such as community gardens, rooftop gardens, vertical farms, and the effective use of vacant land resources (Carlet et al., 2017) require urban agriculture to be evaluated within a national agriculture and ecology system (Soga & Gaston, 2020). This will facilitate the integration and coordination of urban plans that can be implemented in future urban-regional-rural transitions. Consequently, urban agriculture, which is part of nature-based solutions for the urban environment and city dwellers, must be widely promoted and evaluated within policies based on agroecology principles.

Thanks and Information Note

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Protection And Sustainable Management of Cultural Landscapes

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Abstract

Cultural landscape areas, which are important in terms of the long-term relationship between humans and nature and its transmission to future generations, are becoming increasingly important to protect and manage due to population growth resulting from rapid urbanization, economic changes, technological developments, and environmental factors. These areas, which are of particular cultural, historical, and archaeological importance, are considered a source of cultural, physical, and socio-economic income in the regions where they are located. An effective management system must be established to enable sustainable planning by achieving a balance between the protection and use of cultural landscapes. The applicability of management plans prepared for protected areas depends, first and foremost, on the political system. It must be integrated within an effective, holistic, and socially conscious approach to conservation, alongside the political and economic structure and legal regulations. However, when these management practices are inadequate, the transformation of cultural landscape areas will lead to a loss of identity, the disappearance of urban spaces important to society, and a deterioration in the quality of the urban and rural environment. This study emphasizes the importance of holistic and participatory approaches to the protection and management of cultural landscape areas by analyzing historical gardens, rural landscapes, and traditional agricultural areas within cultural landscape areas and evaluating examples from Turkey and around the world.

Keywords: Cultural landscape, sustainable landscape, sustainable management

1. Introduction

Today, the concept of cultural landscape evaluates the environment a product of the interaction between nature and humans within culture-based approaches by transforming it into historical and social contexts in line with needs and tastes, alongside nature-based approaches (Baylan, 2025). According to the report of the European Landscape Convention, “a landscape is not a collection of separate natural and cultural components, but a whole that must be considered together,” and it is emphasized that the protection, management, and planning of cultural landscape areas can be a complex issue requiring multidisciplinary work (Demir & Demirel, 2018).

Traditional cultural landscape areas are generally considered valuable due to their high ecological, economic, and social functionality. They are perceived as well-balanced assets that have developed distinct characteristics through the continuous interaction of human and natural elements throughout history and that provide pathways for future land management (Dossche et al., 2016). Furthermore, these areas are also recognized as fundamental components of cultural heritage and local community identity (Güleç & Yalçın, 2025).

Since the end of the last century, the acceleration of the socio-environmental crisis due to urbanization, pollution, and changes in land use (IPPES, 2019, Diaz et al., 2019) has led to the increasing fragmentation and degradation of cultural landscape areas. Conservation efforts in cultural landscape areas are essential, particularly for cultural heritage sites in and around cities, biodiversity, climate regulation, and cultural identity (Aykan & Başyurt, 2019). In this context, the concept of sustainable management, which is an interdisciplinary approach, plays an important role for both our country and global conservation areas. This study provides examples from Turkey and the world on the importance of cultural landscape areas and sustainable management approaches in conservation efforts. It emphasizes the development of holistic, participatory, and interdisciplinary approaches to ensure the sustainable management of economic, cultural, and tourism issues for the protection of cultural landscape areas of national or international importance against all threats.

2.Protection of Cultural Landscapes

While the cultural landscape conservation approach initially prioritized material culture, works of art, and historical structures, the European Landscape Convention (Florence Convention), approved by the Council of Europe in 2000, emphasized the importance of considering these structures and elements holistically with the surrounding landscape areas. It is necessary to establish a balance between conservation and use by addressing historical and social values together with physical elements within the environmental management system (Bozkurt, 2021).

Among the challenges that emerged in 2003 regarding the conservation of cultural landscape areas, as identified by UNESCO, are the failure of partnerships between countries, limitations in the global strategy for creating the World Heritage List, 70% of registered areas being located in Europe, insufficient capacity for reliable cultural landscape area proposals, insufficient resources for effective management, socio-economic change, and tourism issues (Yinanç & Sönmez, 2022).

Protected areas in our country (including wetlands and special environmental protection areas) cover 5.6% of the country's total area. As a result of examining Law No. 2863 on the Protection of Cultural and Natural Assets, Law No. 2872 on the Environment, and Law No. 2873 on National Parks, which aim to protect cultural and natural values, it is seen that these areas of natural and cultural heritage in our country are protected by multiple laws. However, there is no definition of cultural landscape areas in the legislation. Worldwide, areas with cultural landscape characteristics form the World Heritage List in accordance with the criteria set by UNESCO. When examining the cultural landscape areas included in this list, it is seen that they include island settlements such as Cuba, the Philippines, and Iceland, or parts of islands such as Portugal and Italy. Looking at these areas in general, it can be seen that they share common characteristics such as traditional production that continues in their region, an environment sensitized by the interaction between nature and humans, and traditional settlements or land use that represent a culture (Öztürk & Nemutlu, 2018). In areas where bio-cultural practices in cultural landscape areas have disappeared or been neglected, innovative approaches and legal measures aimed at sustainability, encompassing all components of socio-ecological systems, are seen as significant progress in conservation (Yılmaz Bakır, 2025).

3.Sustainable Management Approaches

The concept of sustainability was defined in 1987 in the United Nations Brundtland Report as meeting the needs of the present without compromising the ability of future generations to meet their own needs. Environmental sustainability has been developed as a sustainable management approach to protect nature and minimize the negative impacts of human activities. With this approach, all stakeholders (government, businesses, civil society organizations, and individuals) aim to address environmental, social, and economic sustainability in a holistic manner and pass it on to future generations in accordance with certain principles. These principles are: resource efficiency, environmental protection, social responsibility, long-term perspective, areas of application of sustainable management (Yüksel, et al., 2024), corporate strategy, supply chain management, innovation and technology, reporting, and transparency. The sustainable management approach brings long-term economic success in line with these principles (Purvis, et al., 2019).

In order to manage cultural landscape areas in a sustainable manner, it is important to develop holistic, participatory, and interdisciplinary approaches, and scientific research is particularly important in terms of understanding the protection of natural resources and the functioning of ecosystems (Tozar & Ayaşlıgil, 2008). The preparation of management plans, one of the criteria for inclusion in UNESCO's World Heritage List, has become a requirement for protected areas. The management plan defines how the area will be protected in a sustainable and holistic manner, specifying the resources, experts, and programs to be used. In addition, UNESCO has developed a “biosphere reserve zoning system” to solve problems in protected areas, providing a solution-oriented assessment of the conservation of biological diversity, the sustainability of cultural values, and economic aspects. Biosphere reserves have three main functions: conservation, development, and logistics (Yilmaz & Solak, 2021).

4.World and Turkey Applications

There are 1,154 cultural and natural properties on the UNESCO World Heritage List on an international scale, of which 897 are cultural, 218 are natural, and 39 are mixed (cultural/natural) properties. In our country, there are 19 registered properties (Url-1). Regional and scientific meetings held in different parts of the world on various themes have increased awareness of cultural landscape areas, leading to the development of more measures for their protection and management approaches for sustainability. In UNESCO World Heritage sites such as the Wachau Valley (Austria) and Cinque Terre (Italy), the participation of the local community, the sustainable use of tourism revenues, and management plans based on international legislation are at the forefront. In cultural landscape areas such as Cappadocia, Safranbolu, and Cumalıkızık, conservation efforts within the framework of national legislation and approaches to the sustainability of tourism and cultural heritage under the leadership of local authorities are being addressed.

Wachau Valley/Austria

Stretching along the Danube River, the Wachau Valley covers an area of approximately 1,400 hectares and has been known for centuries for its vineyards in the Wachau, Riesling, and Grüner Veltliner regions (Fig.1). The villages of Dürnstein and Weißenkirchen, Melk Abbey, and the wine taverns are important cultural landscape elements for visitors to the region and have been included in the World Heritage List since 2000 (Url-2). The Wachau project, carried out by the Welterbegemeinden Wachau association, is a life project that aims to protect endangered habitats. Three important conservation points have been established in this project:

1) Reproduction of the Danube fish species in the Danube River, creation of resting and breeding areas for water birds,

2) Protection of dry meadows and natural forests,

3) Projects aimed at protecting endangered habitats and the fauna and flora in these areas have been implemented (Url-3).



Figure 1. Wachau Valley (Url-3).

Cinque Terre /ITALY

Cinque Terre National Park is one of Italy's smallest national parks (3,868 hectares) and also has the highest population density. Spread across five villages—Riomaggiore, Manarola, Corniglia, Vernazza, and Monterosso al Mare—Cinque Terre's defining features are its colorful houses, natural coastline, and rich cultural heritage (Fig.2). The area is protected under the provisions of Italy's Cultural Heritage and Landscape Law, and all interventions can only be carried out with the approval of the relevant authorities. Since 1990, a "Regional Coordination Landscape Plan" has been in place for the entire area, operating at regional, local, and detailed levels, defining the possible levels of intervention related to the landscape characteristics of each designated area. In addition, the Cinque Terre Marine Protected Area Regulation, which came into force in 2005, and a structured management system that ensures the control of implemented actions have been in place since 2016 (Url-4).



Figure 2. Cinque Terre (Url-5).

Göreme National Park and Cappadocia/Kayseri

One of two mixed heritage sites in Turkey, Göreme National Park features a landscape formed by natural volcanic formations known as "fairy chimneys." Along with its natural cultural landscape, it is home to churches from the Iconoclastic period and rock-cut architecture from the Middle Byzantine period (10th-12th centuries). Furthermore, the Byzantine frescoes found in the churches make Cappadocia an area of universal importance (Fig.3). The first conservation efforts in the region date back to the 1960s. However, conservation efforts have been insufficient due to the desire to highlight the region's tourism

potential (Demirçivi, 2017). Since 2020, a conservation model specific to the area has been implemented, establishing a sustainable tourism relationship in line with the legal, social, and economic framework (Solmaz Şakar, 2022).



Figure 3. Göreme National Park and Cappadocia (Url-6).

Cumalıkızık Village/Bursa

Cumalıkızık Village is one of the best examples of civil architecture from the Ottoman period in Bursa, the first capital of the Ottoman Empire (14th-15th centuries). It consists of eight urban and rural areas dating back to the founding period, including five public infrastructure complexes containing social spaces such as mosques, commercial inns, bathhouses, kitchens, and educational institutions (Fig.4). In addition, Cumalıkızık Village, which has served as a 700-year-old waqf village belonging to the complexes of Osman Gazi and Orhan Gazi, the founders of the Ottoman dynasty, is one of the well-preserved examples of cultural and historical heritage within the urban planning system (Çuhadar, 2024, Anonymous). In order to ensure the sustainability of the cultural heritage areas of Bursa (Hanlar Region-Sultan Complexes) and Cumalıkızık Village, which have been on the World Heritage List since 2014, a management plan covering the period 2021-2026 and involving stakeholders has been created (Url-7).



Figure 4. Cumalıkızık Village - Osman Gazi-Orhan Gazi Mausoleum (Url-8-9-10).

Bergama Multi-Layered Cultural Landscape Area/Izmir

The ancient city of Bergama, capital of the Hellenistic Attalid Dynasty in the 3rd century BC and later capital of the Roman Empire's Asia Province, was an important center of culture, art, science, and politics in the ancient world. Among the ruins of this city are theaters, the Temple of Trajan, the Red Courtyard, the Temple of Cybele, and most importantly, the Altar of Zeus in Bergama. The steep city layout, particularly in urban planning during the Hellenistic period, had a major impact worldwide (Figure 5). The city, which was added to the UNESCO World Heritage List in 2014, continued to be a settlement during the Byzantine and Ottoman periods and was home to one of the Seven Churches of Asia (Aktürk, 2021).

In addition to structures from the ancient period, this area also contains structures from the Ottoman and Republican periods, bringing together elements of urban archaeological heritage. Documentation and analysis studies were carried out within the scope of the "Bergama Urban Cultural Heritage Inventory Project," a comprehensive conservation approach, and within the scope of the "Documentation of Monuments, Building Groups, and Sites" created by ICOMOS (ICOMOS, 2014). Structures compatible with Bergama's traditional urban architectural fabric were identified and recommended for registration. The preservation of traditional structures in the area is also among the priorities and has been evaluated within a comprehensive planning approach (Tezer Altay et al., 2025).



Figure 5. Bergama Multi-Layered Cultural Landscape Area (Url 11).

5.Conclusıons And Recommendatıons

Cultural landscapes and historic environments should be evaluated within sustainable management policies for their preservation and transmission to future generations, rather than being viewed solely as resources or objects to be protected for their visual appeal.

Important cultural landscape areas such as the Wachau Valley in Austria and Cinque Terre in Italy, which are included in UNESCO's World Heritage List, serve as examples of sustainable management approaches. In these regions, the participation of the local community, the reinvestment of tourism revenues, and the balance between conservation and use are at the forefront. The Cinque Terre National Park is a good example of how values can be preserved not only through conservation but also through economic gains. In Turkey, areas such as Cappadocia, Safranbolu, and Cumalıkızık stand out in terms of both cultural heritage and tourism potential. While planning processes in global examples are mostly carried out with international legislation and participatory approaches, in Turkey, they are mostly shaped by national legislation and local government leadership.

Studies show that national conservation policies vary according to the diversity of stakeholders and needs. In particular, sustainable management of rich biocultural landscapes requires sufficient political support, community participation, leadership, social capital, and support from local institutions (Purnomo et al., 2024). Furthermore, participatory action research (Khanyari et al., 2023), multi-centered governance, and gender-focused approaches (James et al., 2021) must be integrated into the management cycle alongside community participation in environmental management plans (Başdoğan Deniz, 2022). The management of protected areas in our country by different institutions requires that agricultural and forestry policies be evaluated as a whole with landscape policies in the planning to be carried out in order to ensure sustainability (Bozkurt, 2021). Furthermore, disaster management efforts implemented within urban planning can ensure the protection of both people and cultural landscapes (Kart Aktaş, 2022). The study reveals that success in the protection and management of cultural landscapes is possible through community participation and the

implementation of long-term sustainable plans. In conclusion, the protection of cultural landscape areas of national or international importance against all threats requires the development of holistic, participatory, and interdisciplinary approaches to ensure the sustainable management of issues such as economy, culture, and tourism.

Thanks and Information Note

The article complies with national and international research and publication ethics.Ethics Committee approval was not required for this study.All authors contributed equally to the article.

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The Potential Use of Aeroponic Systems in Urban Landscapes

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Abstract

In today's world, increasing urbanisation, decrease in agricultural production areas and rapid depletion of natural resources have made sustainable food production a necessity. In this context, aeroponic systems, which are among the soilless agricultural technologies, attract attention due to efficient use of water, reduction of chemical inputs and year-round production. The low water and energy consumption of aeroponic systems supports environmental sustainability in urban areas. Future applied studies can contribute to the development of guidelines that enable aeroponic systems to be integrated into landscape design in a more effective and aesthetic way. The discipline of landscape architecture encompasses not only aesthetic and ecological functions, but also the design of production-oriented sustainable spaces. The aim of this study is to reveal how aeroponic systems can be utilised in the field of landscape architecture and to discuss their potential contribution to sustainable urban landscape design. Through a literature review, the study examines the working principles, environmental advantages and application areas of aeroponic systems and explores their potential integration with landscape components such as urban agriculture, vertical gardens and green roofs. The findings show that aeroponic systems are an innovative solution that can combine aesthetic and productive functions, especially in cities with limited space. As a result, integrating aeroponic systems into landscape design is considered as an important approach that can contribute to sustainable food production, ecological balance and urban quality of life.

Keywords: Aeroponic systems, sustainable agriculture, urban landscape, productive landscapes

1. Introduction

Today, food production and consumption are increasing due to the increasing human population. This situation causes a rapid decrease in the resources necessary for the continuation of life such as water, energy and food. In addition, habitat loss is occurring due to climate change, and negative situations are emerging in the sustainability of biological diversity (Durul, 2025). Access to suitable agricultural land has become increasingly difficult, leading to traditional farming being replaced by alternative farming methods such as hydroponics, aquaponics and aeroponics (Mutlubaş & Milli, 2025). In these systems, plants are cultivated in vertical spaces using LED technology. These methods are designed as innovative applications aimed at increasing the efficiency of vertical farming and saving time and labour in agricultural production (Bingöl, 2019).

Hydroponics is a system in which plant roots grow directly in a nutrient solution. This solution contains all the nutrients the plant needs and ensures optimum growth of the plants.

In this method, the plant roots are suspended in water or supported in a medium and there is no soil (İpek, 2024).

In an aquaponic system, fish and plants are cultivated in the same environment. In this production model, aquaculture and soilless agriculture production systems are combined. In this system, the fish and plant tanks are interconnected. Fish wastes provide the organic nutrients necessary for plant growth (Mirici & Baykır, 2020). As a result of the researches, it is stated that the amount of water used for agricultural production in aquaponic systems is reduced to approximately one tenth compared to other traditional methods and thus maximum water efficiency is achieved (İzci et al., 2020). Aquaponics systems can be defined as systems created by combining a hydroponic production system with a fish farming environment (AlShrouf, 2017). In these systems, environmental impacts are reduced to create ecological environments, and in these environments, nutrient loading is carried out to achieve commercial plant production through species interaction (Türker, 2018).

One of the newest applications used in soil-less farming is aeroponic production systems (Ahmed et al., 2018). Aeroponic systems can be seen as the least water consuming system compared to other systems (İkiz, 2018). When we look at the term Aeroponics, it is taken from Greek; It consists of the combination of the words 'Aero' and 'ponik', which means air and labour in Latin. The root zone of the plant grows in a completely dark and controlled environment. The nutrients and water required for this are applied by spraying from the air (Lakhiar et al., 2020).

Research into aeroponic systems began in the first quarter of the 20th century. In the early 1940s, it was generally used for research purposes rather than for growing produce. In 1944, Klotz described a method of supplying plant nutrients to plant roots using water vapour in his work on growing plants in air. By the 1990s, research conducted by NASA in space revealed that growing plants without soil and with very little water was much more efficient than existing production systems (Kumari & Kumar, 2019).

In an aeroponic system, plants are suspended in the air on a support. Plant nutrients are supplied to the root zone in the form of water vapour with an average particle size of 30 microns. In this way, plant nutrients are delivered to the plant via the roots along with the irrigation water. On the other hand, the irrigation water obtained from the created recycling is mixed at certain intervals with the help of a mixer, preventing the plant nutrients coming to this part from settling at the bottom and transferring them to the system to be reused. As the materials necessary for plant growth are provided through the roots, plants tend to grow much faster. However, it cannot be guaranteed that this will be the case for every plant (Li et al., 2018). In addition, as the growing medium is not soil, there is no risk of soil-borne diseases and pests harbouring and infecting the plants. However, as the growing medium is moist, the system is disinfected at certain intervals to prevent the development of fungal diseases. Furthermore, as cultivation takes place in a closed and controlled environment, harvesting can be carried out more quickly and with lower labour costs (Sahoo, 2020). Thanks to this method, microgreens, sprouts and garden greens can be grown at a much faster rate than traditional cultivation methods, enabling them to reach consumers more quickly (Singh et al., 2022). (Figure 1).

In aeroponic systems, since the plants are placed on foam panels, the plant roots remain suspended in the air beneath the panel. The panels used are designed as light-impermeable closed boxes to stimulate root formation and prevent algae growth. The roots being suspended

in the air facilitates access to oxygen and other necessary gases, and lighting is provided by artificial LED lights (Şimşek & Gül, 2018; Goddek & Körner, 2019). Additionally, this system includes pumps, sprayers, timers and nutrient tanks (Al-Chalabi, 2015).

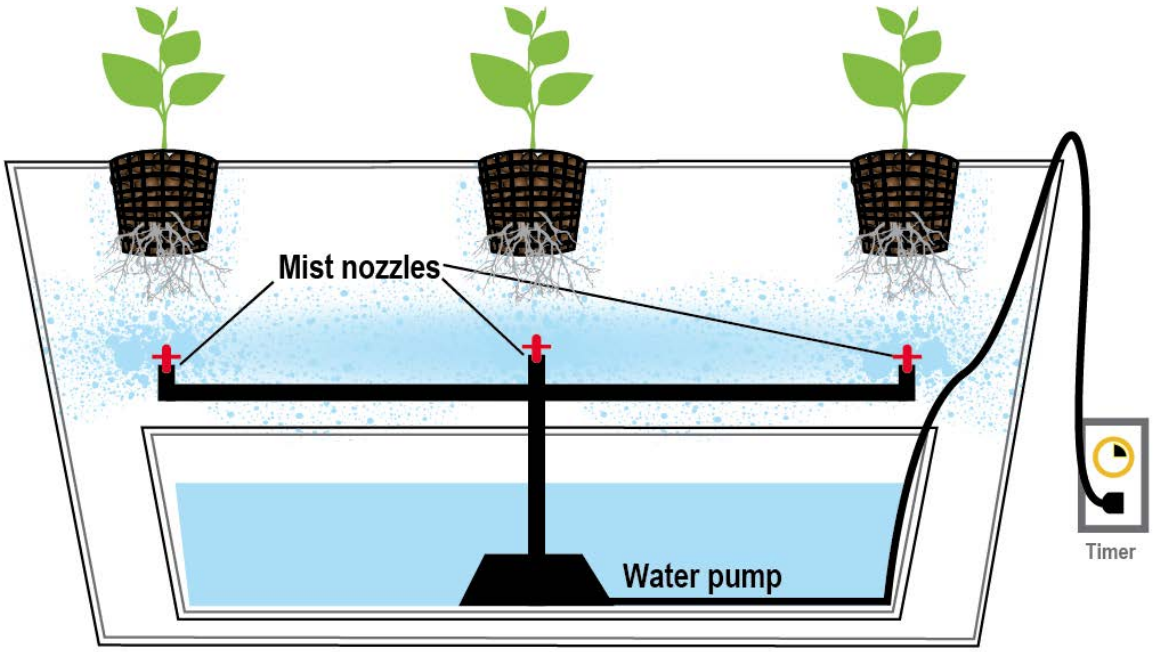


Figure 1. Schematic view of the aeroponic system (Akalın, 2025).

Aeroponic systems have both advantages and disadvantages. Firstly, the initial setup cost is higher than other systems (Faisal et al., 2024). On the other hand, any systemic or electrical malfunction can adversely affect the entire structure. The application of plant nutrients from the air can sometimes lead to microbial contamination or disease due to the high moisture content in the environment (Saldinger et al., 2023). As the root structure of the crop to be cultivated affects the design of the system, changes may be required in the current situation when plants with different root structures are to be cultivated (Min et al., 2022).

The discipline of landscape architecture encompasses not only aesthetic and ecological functions, but also the design of production-oriented sustainable areas. Today, the goals of landscape architects include improving urban ecosystems, ensuring environmental sustainability, increasing the quality of human life and developing productive landscape approaches. To this end, it is becoming increasingly important to incorporate innovative technologies into urban landscape design for the efficient use of natural resources and the promotion of food security. Aeroponic production systems are among the efficient and visually valuable applications that stand out among these innovative approaches. They also have the potential for application in urban landscapes. These systems save water and energy in limited urban areas and contribute to the sustainable continuation of plant production.

The aim of this study is to reveal how aeroponic systems can be evaluated within the scope of landscape architecture discipline. It examines the potential of integrating the aesthetic, ecological and productive aspects of these systems into urban landscape designs. The study

also discusses the positive effects of aeroponic systems on the development of sustainable urban landscapes. The results of the study will enable the development of new approaches for production-oriented urban landscapes in the future.

2. Materials and Methods

The material for this study consists of data from national and international literature on aeroponic systems. Within the scope of the study, books on the subject, articles published in peer-reviewed journals, symposium papers, master's and doctoral theses, and current online sources were examined. Literature review, one of the qualitative research techniques, was preferred as the method.

3. Findings and Discussion

Studies on aeroponic systems in the literature show that this method gives successful results in various plant production areas. Mehandru et al. (2014) conducted studies to test the effect of aeroponic culture on the propagation of cuttings of some endemic plants grown in India. They analysed the effect of different hormone forms and doses and reported that aeroponic media gave significantly more successful results compared to soil media in all species they used. Şimşek (2015), in a study on ornamental plants, reported that aeroponic system provided higher rooting rate and faster seedling production compared to conventional rooting media. The study by Ahmed, Uranbey and Koçak (2017) shows that aeroponic system provides higher yields than traditional methods in potato mini-tuber production and constitutes an important alternative for disease-free seed production. Sharma et al. (2018) used aeroponic media in cuttings propagation studies on an evergreen tree species (Tamarix aphylla L. Karst) and reported successful results. In the spring onion trial conducted by İkiz (2018), it was determined that intermittent spraying intervals in aeroponic system affected yield and quality and it was found that the spraying interval of 18 seconds gave the most suitable results. The research conducted by İpek (2024) on grapevine rootstocks emphasised that aeroponic method can be applied effectively in vegetative propagation and has a high potential for use in different species.

When these findings are evaluated in general, it is seen that aeroponic systems offer controlled production capacity, optimise water and nutrient use and provide high reproduction success. These features make aeroponic systems a strong alternative to conventional methods.

4. Conclusion and Recommendations

The use of aeroponic systems in urban landscapes is considered both as a production-oriented approach and as a holistic design component that combines aesthetic, ecological and social functions. These systems enable more efficient use of the few open and green areas in cities, support environmental sustainability and offer innovative solutions. Research shows that aeroponic systems can be effectively applied on roofs, building facades, balconies, courtyards and idle urban spaces, thus creating productive and aesthetically pleasing urban spaces. The modularity, portability, ease of maintenance and low water demand of the systems make them compatible with the principles of sustainable urban design. These features give aeroponic systems, an innovative approach, the flexibility to be integrated into design projects of different scales.

Integration of aeroponic systems into urban landscape design supports sustainable food production in cities, improves microclimate conditions, reduces carbon footprint and

strengthens biophilic design approaches. In this direction, it is necessary to adopt an interdisciplinary planning approach for the effective dissemination of aeroponic system applications. The co-operation of disciplines such as landscape architecture, urban and regional planning, agricultural engineering, environmental engineering and architecture should be strengthened. In addition, it is important to develop public policies, local government strategies and technical infrastructure standards in a harmonised manner to support the implementation of systems at the urban scale.

In the future, developing examples of aeroponic systems adapted to different climatic conditions and suitable for urban texture, increasing pilot projects and creating design guidelines will make these applications more aesthetic, functional and widespread. In this context, it is recommended that aeroponic systems be considered and supported as a part of sustainable urban designs in urban planning and policy processes.

Thanks and Information Note

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Enviromental Examination of The Rehabilitation Process in Ivrindi Gold-Silver Mine

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Abstract

This study examines the rehabilitation and land reclamation efforts implemented at the İvrindi Gold and Silver Mine and Processing Facility, located within the boundaries of İvrindi district in Balıkesir province. The main objective is to reduce the environmental impacts of mining activities and restore the affected areas to a state compatible with natural ecosystems. The planning and implementation phases of the rehabilitation process were evaluated, with an emphasis on site-specific practices that differ from conventional methods in the literature. Key focuses include restoring areas altered by mining activities, improving the visual landscape, and conducting continuous post-closure monitoring to ensure long-term environmental recovery.Progressive rehabilitation activities, such as afforestation, soil improvement, and greenhouse operations, were assessed, particularly in the northern section of the waste rock storage area, which spans approximately 425,000 m². Environmental conditions and engineering geology factors were also taken into consideration, with the goal of enabling future land uses such as supporting wildlife habitats and animal husbandary. A total of 211 kilograms of compost has been produced for use in greenhouse operations, rehabilitation efforts, and ecological restoration activities involving the cultivation of plant species. To date, 10,000 saplings have been grown in the greenhouse. An ecological overpass has been constructed to support wildlife conservation. In addition, the mining site and its surrounding area are being monitored using 21 phototraps for stock population of wildlife.

Keywords: Mine rehabilitation, land reclamation, environmental restoration, gold mining, mine closure

1. Introduction

Although mining activities make significant contributions to national economies, they also cause serious environmental impacts such as the depletion of natural resources, habitat fragmentation, and soil and water pollution. In particular, open-pit mining operations disrupt land integrity and lead to the degradation of ecosystem functions (Koç, 2022). Therefore, the “rehabilitation” process following mining operations is considered an integral component of environmental management. The goal of rehabilitation is to restore the disturbed areas to a state that is safe, ecologically functional, and compatible with the surrounding natural landscape (Yıldız, 2020). The necessity of rehabilitation activites in mining operations, just as production planning is essential, the mine closure plan should also continue throughout the entire lifespan of the site and be an integrated part of the overall operation. In a mine site where production has ended, appropriate rehabilitation must be carried out with the following main objectives (Kaya, 2022).

- Ensuring the safety and health of present and future generations,

- Leaving an environment for future generations that is free from physical and chemical degradation,
- Ensuring that the post-mining area can be used in a sustainable and socially beneficial manner,
- Minimizing all potential socio-economic damages and considering alternatives that can enhance socio-economic benefits.

The İvrindi Gold and Silver Mine is located within the boundaries of İvrindi district in Balıkesir province, between the neighborhoods of Değirmenbaşı and Küçük Ilıca. The facility processes 21,260 tons of ore per day, with an annual production target of approximately 7.76 million tons. Within the scope of the environmental management plan for such a large-scale mining operation, rehabilitation activities were initiated concurrently with the operation phase.

The İvrindi project presents not only a technically sound mine closure plan but also a model for biodiversity conservation and land-use planning that aligns with the local ecosystem. This paper evaluates the rehabilitation strategies and biodiversity monitoring results implemented at the site from both environmental and socio-economic perspectives.

2. Materials and Methods

2.1. Study Area

The study area is the İvrindi Gold and Silver Mine and Processing Facility, located within the boundaries of İvrindi district in Balıkesir province, between the neighborhoods of Değirmenbaşı and Küçük Ilıca. The site operates as an open-pit mining area. Within the scope of this study, the *Biodiversity Management Plan*, *Rehabilitation Plan*, and *Closure Plan* prepared for the project were examined.

In addition, field observations, revegetation practices, and topographical analyses were utilized to assess the ongoing rehabilitation works. The evaluation was supported by literature reviews, project documents, and on-site inspections to ensure a comprehensive understanding of the implemented environmental management strategies.



Figure 2.1. TÜMAD Gold and Silver Mine Operating as an Open-Pit Facility within the İvrindi District Boundaries (Koç, 2022)

3. Findings and Discussion

3.1. Rehabilitation Practices at the İvrindi Gold and Silver Mine

3.1.1. Hydroseeding Application

Hydroseeding is a modern sowing technique based on the principle of spraying a mixture of mulch, seeds, fertilizer, and water onto the soil surface using a pressurized system. This method is particularly preferred for steep, erosion-prone, or hard-to-reach areas to achieve rapid vegetation cover. It not only protects the soil surface from erosion but also promotes uniform plant growth across the rehabilitated area.

At the İvrindi Gold and Silver Mine rehabilitation site, a specially formulated mixture of grass and legume species was selected, taking into account the region's climatic conditions, soil structure, and ecological resilience characteristics. The composition of the seed mixture used in the hydroseeding process is as follows:

- Festuca rubra (95%)
- Trifolium pratense (86%)
- Festuca sp. (86%)
- Lolium sp. (93%)
- Festuca arundinacea (88%)
- Poa pratensis (81%)
- Trifolium repens (70%)
- Yonca Mirna (97%)
- Korunga (Onobrychis viciifolia) (97%)

The total area covered by the hydroseeding application is 95,000 m².



Figure 3.1. Areas Subjected to Hydroseeding and Post-Germination Appearance(Koç, 2022)

3.1.2 Seeding and Terracing of the Waste Area

Seeding and Rehabilitation of the Waste Rock Dump

In the reclaimed waste rock dump area, where fill material and fertile soil layers were placed, seeding was carried out to enable local communities to continue their grazing activities. A total of 200,000 square meters were seeded with native pasture species. This initiative not

only restored soil productivity but also supported socio-economic continuity for local livestock farmers.



Figure 3.2. Condition of the waste dump area before and after seeding (Koç, 2022)



Figure 3.3. Visual Appearance of the Waste Dump Area Following Germination (2023)



Figure 3.4. Terracing of the waste dump area (Koç,2022)

3.1.3 Greenhouse and Composting Studies

As part of the rehabilitation efforts, greenhouse work has begun to cultivate habitat-appropriate species.

10,000 saplings of Black Pine, Red Pine, London Plane Tree, Taurus Cedar, Laurel, Fragrant Juniper, Aleppo Pine, Black Cypress, and Arborvitae have been cultivated. Composting efforts have begun to increase cultivation efficiency, and compost is being produced from organic waste. The resulting compost is used in cultivation. A total of 211 kilograms of compost has been produced.



Figure 3.5. The completed greenhouse established by TÜMAD Gold and Silver Mining (2024)



Figure 3.6. Seedling greenhouse and Sapling greenhouse




Figure 3.7. Compot machine and resulting compost

3.1.4. Landscape Design and Afforestation

Post-rehabilitation landscape design aimed to harmonize the visual appearance of the site with the surrounding natural texture. Native plant species were prioritized in afforestation and landscaping works, while natural stone coverings were used to improve aesthetics and surface stability. These measures significantly enhanced the visual integration of the rehabilitated area into its environment.




Figure 3.8. Planted trees (Koç,2022)

Figure 3.9. Landscape (Koç,2022)

3.2. Biodiversity-Related Applications at the İvrindi Gold and Silver Mine

3.2.1. Tortoise Passage

Two turtle passageways are used on site to protect turtles, a critical animal species, from traffic congestion and to protect the species (Koç,2022).





Figure 3.10. Tortoise(Testudo greaca) Passage

3.2.2. Bird Balls and Warning Flags in Solution Ponds

Bird balls and colorful warning flags were deployed to prevent birds from entering cyanide solution ponds and heap leaching areas. These methods also help minimize cyanide evaporation losses by reducing surface exposure. The flags, particularly effective during summer months, serve as visual deterrents to keep birds away from high-risk zones.





Figure 3.11. Warning Flags (Koç,2022) **Figure 3.12.**Bird Balls (Koç,2022)

3.2.3. Detonator Sound Devices

Sound-emitting devices were installed in solution areas, particularly around heap leach pads, to deter birds, mammals, and reptiles. These devices create controlled noise disturbances that discourage wildlife from entering hazardous areas, especially during rainy seasons when animal activity increases.



Figure 3.13. Detonator Sound Devices

3.2.4. Camera Traps

A total of 21 camera traps were installed to monitor the presence and behavior of fauna in and around the mining site. The data collected provide valuable insights into the biodiversity of the region and help assess the effectiveness of wildlife management strategies within the rehabilitation framework.





Figure 3.14. Camera Trapsy

3.2.5 Relocation of Endemic Plant Species

Bulbs of Crocus biflorus subsp. nubigena are collected and transplanted to areas outside the mining site where they will not be affected by mining activities. The development of the population is continuously monitored.



Figure 3.15. *Crocus biflorus* subsp. *nubigena*

4. Conclusion and Recommendations

Rehabilitation constitutes a fundamental element of sustainable mining. In the context of the evolving global economy, mining activities remain indispensable; however, they necessitate strategic planning that encompasses not only operational phases but also the post-mining closure and restoration of affected areas.

Evidence from both global and national contexts indicates that environmental restoration plans should be formulated at the onset of mining operations. Restoration activities should be implemented progressively, in accordance with these plans, rather than waiting for the complete cessation of mining operations (Aktaş, 2008).

When conducted within the framework of regulatory requirements and internal management plans, mining activities can function as catalysts for socio-economic development. Such activities must concurrently respect the natural landscape, flora, and fauna of the affected region (Koç, 2022). The incorporation of diverse rehabilitation techniques and improvement processes ensures that the field remains dynamic and open to innovation.

Post-closure mine sites offer opportunities for alternative land uses. In Turkey, reforestation has typically been prioritized; however, rehabilitated areas may also be repurposed as botanical gardens, golf courses, walking trails, or camping sites (Kalaycı & Uzun, 2017).

This study provides a comprehensive assessment of the environmental, ecological, and social impacts of rehabilitation initiatives implemented at the İvrindi Gold and Silver Mine. The findings demonstrate that the project serves as an exemplary model for sustainable mining and environmental management practices in Turkey.

The application of a variety of technical rehabilitation methods enhances both the efficacy and quality of ecological restoration efforts. These practices facilitate sustainable mining operations capable of maintaining long-term ecosystem resilience.

Topsoil conservation and reuse have positively influenced vegetation establishment, while hydroseeding has proven highly effective in erosion control and the development of surface plant cover. Within greenhouse programs, a total of 10,000 seedlings were cultivated, achieving high post-planting survival rates. Camera trap data further illustrated the diversity of local fauna, highlighting the direct linkage between sustainable mining practices and ecological coexistence.

Additionally, community engagement and environmental education programs have strengthened the social sustainability dimension of the project. These initiatives have increased local awareness, fostered stakeholder participation, and contributed to the long-term success of the rehabilitation program.

In conclusion, the İvrindi Project emphasizes the critical importance of integrating ecological restoration, biodiversity conservation, and community participation with mine closure strategies and post-mining land-use planning. Sustainable mining can only be achieved through such comprehensive and carefully planned approaches.

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Improving Local Heatwave Risk Assessment: An Integrated Approach to Antalya in the CLIMAAX Framework

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Abstract

Urban heatwaves (HWs) and Urban Heat Island (UHI) effects are becoming more widely accepted as the most visible climate-related threats in Mediterranean coastal urban areas. High-density urbanized Antalya, Türkiye, with rapid population growth and high influx of seasonal tourists, is at risk of enhanced pressure from long-lasting heat events. These impacts not only endanger human health but also put additional stress on surrounding ecosystems and protected natural areas, where extreme heat accelerates biodiversity loss and weakens ecosystem resilience. Within the Horizon Europe-funded project CLIMAAX, Antalya Metropolitan Municipality developed a flagship example of Climate Risk Assessment (CRA) using CLIMAAX Jupyter portal and local data assessments, which is the MUHIR project (Strategies for Mitigating the Urban Heat Island Effect). This paper will present first-stage findings and details to advance understanding of urban heat.

The evaluation was based on the open-source CLIMAAX workflows and data such as: (1) EUROHEAT and Xclim workflows to quantify hazard under RCP4.5 and RCP8.5 scenarios and (2) Landsat-8 LST data combined with WorldPop demographic layers to perform spatially explicit UHI risk assessment. Results reveal considerable heatwave rises projected by 2046–2085, particularly with RCP8.5. MUHIR shows us replicability and feasibility of locally initiated, open-source-founded CRAs under limited resources.

Keywords: CLIMAAX, Urban Heat Island, heatwave, Antalya, climate projections

1. Introduction

The effects of climate change in the Mediterranean region are becoming apparent in urban areas with the emergence of Urban Heatwaves (UHW) and the Urban Heat Island (UHI) effect. The UHI effect refers to the phenomenon whereby average air temperatures in urban environments are up to 3–4°C higher than in rural areas. These temperature fluctuations can exceed the threshold of living comfort, especially for those living in hot climates.

In urban areas, average air temperatures are generally 1.5–4.8°C higher than in rural areas due to the UHI effect; with this difference peaking during summer months and nighttime hours (Salvati et al., 2017; Martinelli et al., 2020; Keppas et al., 2021; Donateo et al., 2023; Pappaccogli et al., 2024). Dense urbanization, reduced green spaces, and anthropogenic heat sources (traffic, cooling systems) increase the intensity of the UHI (Salvati et al., 2017; Manoli et al., 2019; Martinelli et al., 2020). Especially in the Mediterranean cities, although sea breezes have a partial cooling effect in coastal areas, the UHI effect is pronounced in city centers (Table 1) (Martinelli et al., 2020; Keppas et al., 2021; Donateo et al., 2023).

Table 1. Effects and consequences of UHI and heatwaves in Mediterranean cities.

Impact Area	Findings	Sources
Energy consumption	UHI increases the need for cooling in homes by 18–28%	(Vardoulakis et al., 2013; Salvati et al., 2017)
Thermal comfort	Serious discomfort, especially in summer and in the afternoon, in city centers	(Kalogeropoulos et al., 2022; Donateo et al., 2023; Donateo et al., 2023)
Health risk	Persistently high nighttime temperatures increase the risk of heat-related deaths	(Founda & Santamouris, 2017; Papadopoulos et al., 2024; Pappaccogli et al., 2024)

Although there appears to be no universal definition for a heatwave, definitions vary by country, region, and even research objectives (Robinson, 2001; Perkins & Alexander, 2013; Smith et al., 2013; Barriopedro et al., 2023). A heatwave (HW) is a period of abnormally hot weather that lasts for a consecutive period of time. HWs are typically defined using air temperature thresholds and the persistence of this condition (number of days). Most methodologies use the criterion that daily maximum and/or minimum temperatures exceed the 90th or 95th percentile of the reference period (usually 30 years) for at least 2 or 3 (or 5) consecutive days (Robinson, 2001; Perkins & Alexander, 2013; Zschenderlein et al., 2019). Some definitions also consider additional factors such as humidity, nighttime temperatures, and heat index (Robinson, 2001; Heo et al., 2019).

With climate change, the frequency, duration, and intensity of HWs are rapidly increasing. By 2100, the number of annual HW days in the Mediterranean cities is expected to increase from 8 to 60, with some waves exceeding 30 days (Papadopoulos et al., 2024). The UHI effect intensifies during heatwaves; for example, in Athens, UHI intensity can increase by up to 3.5°C during heatwaves (Ward et al., 2016; Founda & Santamouris, 2017; Pappaccogli et al., 2024). This synergy increases heat stress and heat-related health risks, especially during nighttime hours (Founda & Santamouris, 2017; Papadopoulos et al., 2024; Pappaccogli et al., 2024).

The frequency, duration, and intensity of heatwaves across Türkiye have increased significantly since the 1950s. Statistically significant increases in the number, duration, and magnitude of heatwaves have been observed, particularly since the 1990s (Erlat et al., 2021; Aksu, 2021; Tatli & Serkendiz, 2025). While the annual average number of HWs was approximately 5 in the 1970s, this number has exceeded 10 since the 2000s (Tatli & Serkendiz, 2025). The largest increases have been experienced on the Marmara, Black Sea, and Mediterranean coasts, i.e., in regions including Antalya (Erlat et al., 2021; Tatli & Serkendiz, 2025).

Antalya and its surroundings are among the coastal regions most exposed to HWs in Türkiye. In recent years, the number of person-days exposed to heatwaves in Antalya is projected to increase by over 1 million (Donmez et al., 2024). The summers of 2000, 2007, and 2010 were years of record temperatures and prolonged HWs in Türkiye, including Antalya (Demirtaş, 2017; Demirtaş, 2018). In the summer of 2007, all-time high temperature records were broken in 34 cities across Türkiye, with temperatures exceeding 40°C in Antalya and its surroundings (Table 2) (Demirtaş, 2018).

Table 2. Notable HW years and their effects in Türkiye and Antalya.

Year	Characteristics and Effects	Sources
2000	Record-breaking, short but extremely intense heatwave in 42 cities	(Demirtaş, 2017)
2007	Record-breaking heatwave in 34 cities, lasting 60-70 days, with temperatures exceeding 40°C in Antalya	(Demirtaş, 2017; Demirtaş, 2018)
2010	Record-breaking heat in 9 cities, long and intense heatwave	(Demirtaş, 2017; Demirtaş, 2018)
2020	Record temperatures in May, affecting the West and South	(Erlat et al., 2022)

To combat the threats mentioned above, the CLIMAAX (Climate Risk and Vulnerability Assessment Framework and Toolbox) project was funded under the European Union's Horizon Europe research and innovation program (grant agreement No. 101093864) (Vuckovic & Wetterhall, 2024; CLIMAAX, 2025). CLIMAAX is a four-year initiative (January 2023–December 2026) that provides financial, analytical, and practical support for the development of regional climate and emergency risk management plans (CLIMAAX, 2025). Within the framework of the CLIMAAX, Antalya Metropolitan Municipality (AMM) has developed the MUHIR (Strategies for Reducing the Urban Heat Island Effect in Antalya: Integrating High-Resolution Local Data for Enhanced Climate Resilience) project, one of 32 projects selected from 119 project proposals in the first call. This project, which received €146,000 in funding for AMM, will be carried out between October 1, 2024, and August 1, 2026.

This study aims to present the findings of the first and second phases of the MUHIR project, which is being carried out by the Antalya Metropolitan Municipality (AMM), led by the Climate Change and Zero Waste Department, in collaboration with the Geographic Information Systems Branch of the Information Processing Department, the Disaster Management Department and the EU Projects Branch of the Foreign Relations Department.

2. Materials and Methods

The MUHIR project is a study that uses different computer software, web software, and datasets. Detailed information is provided in Table 3.

Table 3. Software, web tools, and data used in the MUHIR project.

Software & Web Software	Dataset	Reference	Purpose of Use
CLIMAAX ECMWF JupyterHub		https://jupyterhub.ecmwf.int/hub/login?next=%2Fhub%2F	All Python-based studies related to HW and UHI
Google Earth Engine		https://earthengine.google.com/	Obtaining of NASA NEX-GDDP data and related analyses
ESRI ArcGIS Pro		https://www.arcgis.com/index.html	UHI 3D visualization
RSLab		https://rslab.gr/Landsat_LST.html	Satellite imagery for Muratpaşa district for the period 2014-2024 for UHI analysis
	Copernicus Climate Change Service (CCCS)	https://cds.climate.copernicus.eu/	All climatological data from the ECMWF (European Centre for Medium-Range Weather Forecasts)
	NASA NEX-GDDP	https://developers.google.com/earth-engine/datasets/catalog/NASA_NEX-GDDP?hl=tr	Data for temperature thresholds
	WorldPop	https://www.worldpop.org/	Data for vulnerability analyses in the CLIMAAX risk assessment
	General Directorate of Meteorology (TMI)	https://mgm.gov.tr/	Data for determining temperature thresholds based on local stations

A heatwave is a period of abnormally hot weather that persists for a long time. There are different approaches to defining a heatwave. However, in general, a heatwave is determined using threshold values for air temperature and duration (minimum number of days). The most common definition of a heatwave is when the maximum air temperature exceeds a certain threshold value for several consecutive days. Some methodologies also define threshold values for minimum air temperature. Within the CLIMAAX, the Heatwaves-Urban heatwaves Workflow (HWWf) focuses on estimating the frequency of heatwave events for current and future climate based on EURO-CORDEX climate scenario data (12 km spatial resolution dataset). HWWf helps users understand the impact of climate change on the formation of heatwaves under different climate change scenarios (Global Climate Model-GCMs, Regional Climate Model-RCMs and Representative Consentration Pathways-RCPs) in a user-defined region in Europe. These data are obtained for annual time resolutions. Changes in the duration

of heatwaves (total number of days) are also analyzed. HWWf also includes an analysis of the relative change in heatwave occurrence at the regional level. It offers a methodology that combines the magnitude of this relative change with data on vulnerable population groups. The risk posed by heatwaves to vulnerable population groups can be analyzed by combining heatwave hazard data with information on the distribution of vulnerable population groups (CLIMAAX, 2025).

The Climate Risk Assessment (CRA) in the MUHIR project, carried out by Antalya Metropolitan Municipality as part of the CLIMAAX initiative, is based on CLIMAAX open-source workflows and four main risk assessment stages related to HWs and UHI. These are listed under the following sections.

2.1. HAZARD Assessment and Climate Projections

Two main methodologies were used to quantify climate HAZARDS within the CLIMAAX HWWf framework:

1-EuroHEAT-based Methodology (run in the JupyterHub environment): According to an EU-wide health-related definition, heatwaves are defined as the maximum apparent temperature (Tappmax) and daily minimum temperature (Tmin) exceeding the 90th percentile threshold for the relevant months for at least two consecutive days during the summer months (June-August). The perceived temperature is a measure of relative discomfort caused by combined heat and high humidity, calculated as a combination of air and dew point temperatures.

The methodology is based on a dataset obtained from the EuroHEAT project, which offers two options for defining heatwaves (Hooyberghs et al., 2023):

- **EU-wide health-related definition:** For the June-August summer period, heat waves are defined as days when the maximum apparent temperature (Tappmax) exceeds the threshold (the 90th percentile of Tappmax for each month) and the minimum temperature (Tmin) exceeds the threshold (the 90th percentile of Tmin for each month) for at least two consecutive days. Apparent temperature is a measure of relative discomfort caused by the combination of heat and high humidity and was developed based on physiological studies related to the cooling of the skin through evaporation. It can be calculated as the combination of air and dew point temperatures.
- **National heatwave definition**: Each country uses a different methodology. For example, in Belgium, a heat wave day is defined as a day between April and September when the daily minimum and maximum temperatures exceed the thresholds of 18.2°C and 29.6°C for three consecutive days. In this example, the source of the heat wave definition is the Belgian federal public health agency.

Advantages of using this methodology and dataset

- Pre-calculated indicators - less data to download and process (compared to the Peseta-IV and Xclim hazard workflows).
- Data available for the entire EU in a 12x12 km grid for the years 1986-2085.
- The heatwave definition is based on both maximum and minimum daily temperatures, thus also accounting for the impact of minimum temperature on heatwave intensity

(e.g., a significant drop in temperature at night and, consequently, a reduction in heatwave intensity).

Disadvantages

- There is no possibility to change the temperature and number of days thresholds in the heatwave definition.
- It only includes annual aggregate values.
- National heatwave definitions are not available for all EU countries (only for some).

2-XClim Package-based Methodology (run in the JupyterHub environment): Used to assess the risk of heatwaves under the RCP4.5 and RCP8.5 climate scenarios.

Projections are based on 12 km resolution EURO-CORDEX climate projections. RCMs are critical for adaptation planning because they capture local features (typically at 1–50 km resolution) that the GCMs (100–300 km resolution) cannot resolve, such as mountains, coastal strips, and land use.

The Xclim package included in this methodology enables the identification of hot and cold periods in the data, the calculation of heatwave frequency (annual), and the total duration of heatwaves.

In this methodology, the heatwave definition is based on absolute temperature thresholds for maximum and minimum daily temperatures (i.e., daytime and nighttime temperatures) defined by the user and a minimum duration (e.g., 2 or 3 days). The use of absolute thresholds for temperature requires user input; these limits can be set specifically for the region of interest and based on expected health impacts.

The calculation is based on 12x12 km resolution climate data (EURO-CORDEX) for which data is available for the years 1971-2100.

Advantages of using this methodology:

- Heatwave calculations based on minimum and maximum temperatures are also suitable for regions where temperatures can drop significantly at night.
- Flexibility of the methodology: temperature thresholds can be adjusted according to user needs. Additional information on thresholds will be provided in the next section (2.2.).

Disadvantages:

- It is computationally intensive due to the large amount of data.
- Heat waves are predicted on an annual basis—it is not possible to analyze seasonal heatwaves.

2.2. Temperature Threshold Selection and Local Calibration

It is known that the detection and characterization of heatwaves are greatly affected by the maximum (Tmax) and minimum (Tmin) temperature thresholds used. Therefore, different thresholds were compared in the MUHIR project:

Mediterranean Thresholds (from the CLIMAAX Handbook): 25-29°C for Tmax (daily maximum temperature) and approximately 22°C for Tmin (Baccini et al., 2008; Casati et al.,

2013; CLIMAAX, 2025). Although these temperature thresholds are generally given for the Mediterranean, they are not specific to Antalya. Therefore, it is thought that these fixed thresholds may be insufficient in hot regions such as Antalya because they do not reflect the local climate. For this reason, other calculations have been conducted on temperature thresholds in this study. These studies are listed below.

Dynamic Thresholds (90th Percentile): Within the scope of the MUHIR, dynamic, locally adapted thresholds (percentile-based) have been proposed to more accurately reflect Antalya's local norms and sensitivities. These have been calculated using two different data sources. One of these data sources is data from the Turkish General Directorate of Meteorology (TMI), representing station data specific to Antalya (airport's weather station). These data were accessed through the TMI's 4th Regional Directorate. The data include daily Tmax, Tmin, and precipitation (Precip) values for the period 1950-2025. Another dataset used in calculating the threshold data is NASA's NEX-GDDP (NASA Earth Exchange Global Daily Downscaled Climate Projections). The historical and estimated range of the data varies between 1950 and 2100 and includes daily Tmax, Tmin, and Precip. values. The NASA NEX-GDDP dataset consists of downscaled climate scenarios conducted under the GCMs. These scenarios were run under the Fifth Phase of the Coupled Model Intercomparison Project (CMIP5, Taylor et. al., 2012) and under two of the four greenhouse gas emission scenarios known as RCPs (Meinshausen et. al., 2011). The CMIP5 GCM runs were developed to support the Intergovernmental Panel on Climate Change (IPCC AR5) Fifth Assessment Report. This dataset was prepared by the Climate Analytics Group and NASA Ames Research Center using NASA Earth Exchange and distributed by the NASA Center for Climate Simulation (NCCS) (Thrasher et. al., 2012; Earth Engine Data Catalog, 2025). Within the scope of the MUHIR, these data were accessed via the Google Earth Engine (Earth Engine Data Catalog, 2025). Data extracted from these datasets were saved as .csv files, and Tmax and Tmin thresholds were determined based on the 90th percentile. The 1991-2020 reference period was used to determine these thresholds. The 1991-2020 period stands out as a current and meaningful reference period for determining Tmax and Tmin thresholds in climate change studies. The reasons for selecting this period are as follows:

- Current Climate Reference: 1991-2020 is the most recent 30-year climate normal period recommended by the World Meteorological Organization (WMO). This period reflects recent climate changes and current trends, providing a more realistic basis for determining Tmax and Tmin thresholds (Thomas et al., 2023; Li et al., 2025).
- Detection of the Climate Change Signal: Using the current period allows for more sensitive and meaningful tracking of climate change-induced trends and extreme events. However, the transition to the new period may cause a delay or reduction in the detection of temperature extreme events, which may affect the perception of the climate change signal (Li et al., 2025; Thomas et al., 2023).

The dynamic threshold values calculated based on all this information are as follows:

METEO-TMI Threshold (1991–2020 Reference): TX90: 35.6°C / TN90: 24.5°C.

NASA NEX-GDDP Threshold (1991–2020 Reference): TX90: 35.89°C / TN90: 23.68°C.

Additionally, GCMs such as MPI-ESM-LR (Max Planck Institute for Meteorology-based model) within the Mediterranean threshold and HadGEM2-ES (Hadley Centre Global Environment Model) within the dynamic threshold values were used in future projection

studies. For RCM, a single model was desired, and datasets containing RCM as CLMcom-CCLM4-8-17 (Climate Limited-area Modelling Community-based model) were used.

2.3. Spatial RISK Assessment

UHI risk assessment was conducted using Geographic Information Systems (GIS):

Land Surface Temperature (LST): LST data from the Landsat-8 satellite for the period 2014–2024 were used to identify overheated areas (hotspots) in urban areas. The focus area of this study was the Muratpaşa district, which was studied using the RSLab tool (RSLab, 2025). After obtaining the satellite images from the RSLab, the analyses were performed in the JupyterHub.

Vulnerability Assessments (run in the JupyterHub environment): WorldPop 2020 demographic data (particularly vulnerable age groups such as 5 years and younger; 65 years and older) were combined with LST data for the Muratpaşa district (Antalya's center). This enabled the creation of exposure-vulnerabilty-risk analyses.

3. Findings and Discussion

3.1. Findings Regarding Heatwaves-HAZARD Assessments

Results predict significant increases in heatwaves until the period 2046–2085, particularly under the RCP8.5 scenario. It is noted that model pairings such as HADGEM2-ES/CCLM4-**8-17** have been validated for Türkiye and the Mediterranean and simulate temperature extremes and heatwave characteristics, except for 95th percentile calculations. In studies conducted in Türkiye and its surroundings, the combined use of CCLM4-8-17 and HADGEM2-ES has provided reliability, particularly in temperature changes and extreme temperature analyses (Dosio et al., 2015; Sørland et al., 2021; Mesta et al., 2025). The study aims to reduce model uncertainty using the IPCC AR6 Multi-Model Ensemble approach, which involves the combined use of different GCMs and RCMs. According to this approach, MUHIR results are presented in three stages: (1) the EuroHEAT approach for a fixed threshold value in the CLIMAAX Handbook (Figure 1), (2) the default Mediterranean Tmax and Tmin temperature thresholds provided in the CLIMAAX Handbook, RCP 4.5 and RCP 8.5 results for the MPI-ESM-LR GCM and CCLM4-8-17 RCM included RCP 4.5 and RCP 8.5 results (Figure 2), and (3) HADGEM2-ES GCM and CCLM4-8-17 RCM for RCP 4.5 and RCP 8.5 results based on METEO-TMI and NEX-GDDP Tmax and Tmin thresholds (Figure 3). All projections are made up to the year 2050. These combinations were used in this phase of the MUHIR. The combinations to be used in the subsequent phases of the project are given in Table 4.

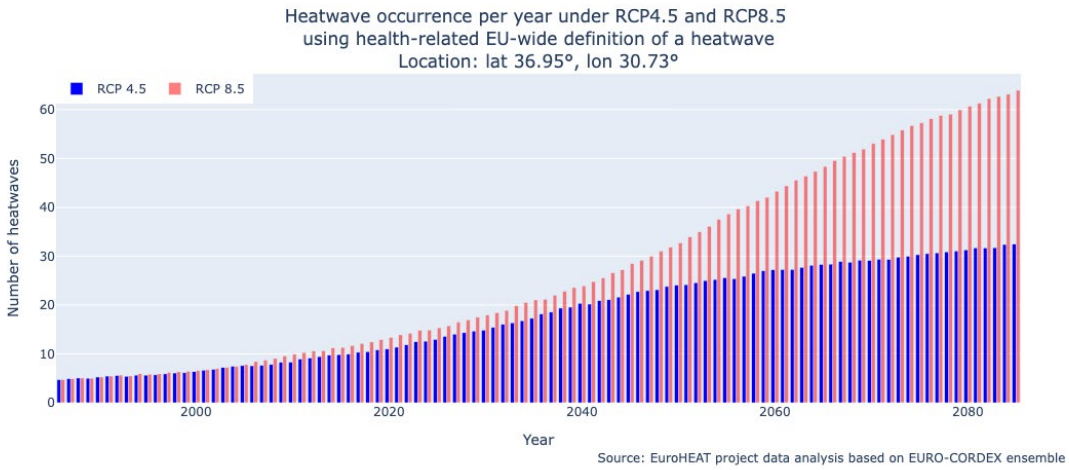


Figure 1. Heatwave occurrence per year under RCP 4.5 and RCP 8.5. These results are based on the health-related EU-wide definition under the EuroHEAT methodology (section 2.1).

(a)

(b)

(c)

Figure 2. CLIMAAX Handbook-based evaluations: (a) Heatwave Index above a threshold of 25°C and (b) Heatwave Frequency and (c) Total number of heatwave days based on temperature thresholds for day and night: 28°C and 22°C. The data coordinates are in the Muratpaşa district.

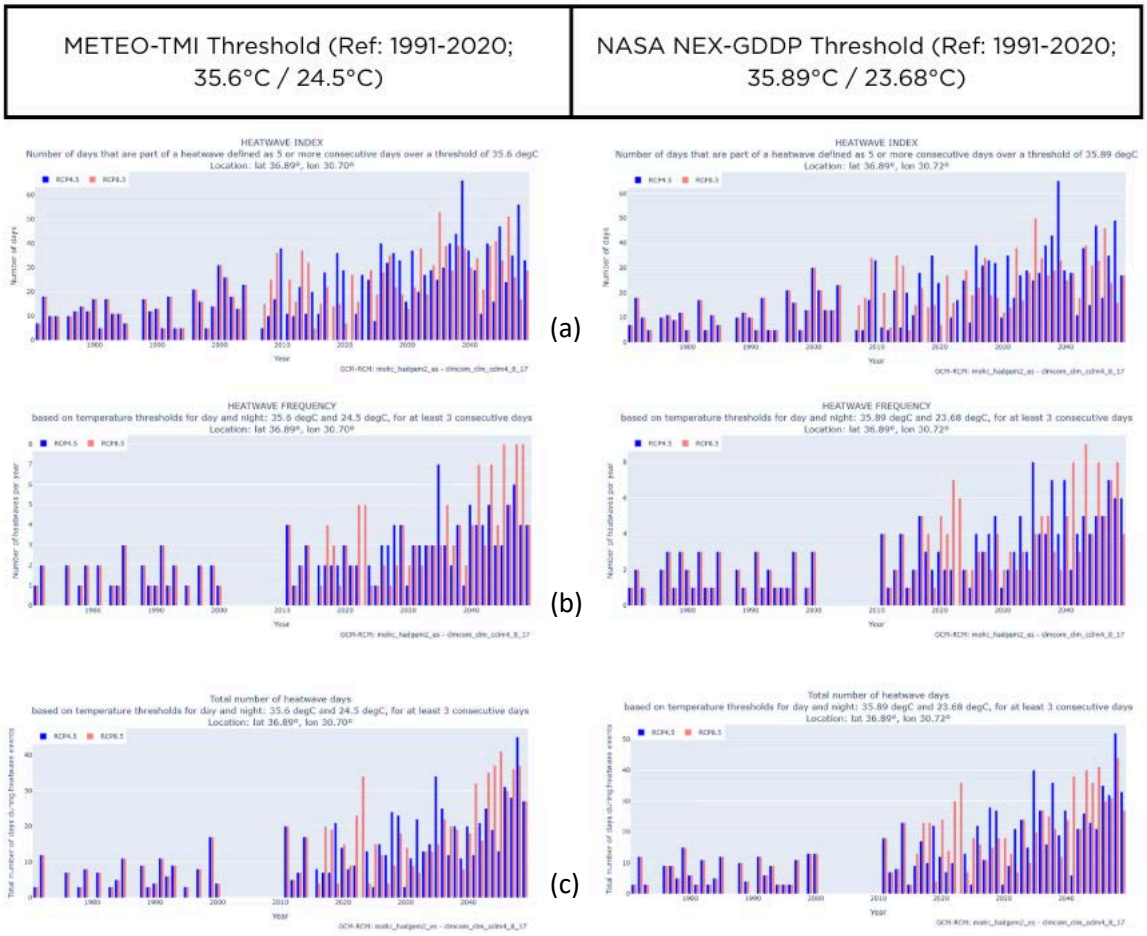


Figure 3. Results for RCP 4.5 and RCP 8.5 for the HADGEM2-ES GCM and CCLM4-8-17 RCM according to METEO-TMI and NEX-GDDP Tmax and Tmin thresholds. (a) Heatwave Index, (b) Heatwave Frequency, and (c) Total number of heatwave days. The data coordinates are in the Muratpaşa district.

As seen in Figure 2 and Figure 3 in the MUHIR, the definition of HW is largely influenced by the maximum (Tmax) and minimum (Tmin) temperature thresholds used, and this is important for heatwave detection and characterization. The study demonstrated the necessity of thresholds appropriate to local norms by comparing different risk thresholds:

The thresholds of Tmax 28°C and Tmin 22°C are frequently exceeded in a hot Mediterranean city like Antalya. Therefore, the CLIMAAX Handbook-based assessments (Figure 2) detected a high number of HW days and showed that the hazard is widespread throughout the year. While this approach is useful for "comprehensive and continuous" heat stress assessment, particularly in tourism-intensive cities, it does not fully reflect the level of local adaptation. The TX90 and TN90 thresholds (≈ 35.6°C and 24.5°C) calculated according to the 1991–2020 reference period, as recommended by the CLIMAAX for cities to use their thresholds and critical for the MUHIR, represent Antalya's current climate norms. Analyses using these thresholds (Figure 3) have identified fewer but much more severe and impactful heatwaves. This approach provides a more realistic basis for identifying public health risks and developing adaptation strategies.

Table 4. Combinations to be performed in the later stages of the project; sections pertaining to new studies are highlighted in red.

Threshold Type	GCM(s)	RCM(s)	Dataset
METEO-TMI-based	HadGEM2-ES / MPI-ESM-LR / GFDL-ESM	CLMcom-CCLM4-8-17 / NCAR-WRF / ISU-RegCM4 / CSIRO-CCAM-2008	TMI (1950–2024)
NEX-GDDP-based	HadGEM2-ES / MPI-ESM-LR / GFDL-ESM	CLMcom-CCLM4-8-17 / NCAR-WRF / ISU-RegCM4 / CSIRO-CCAM-2008	NASA NEX-GDDP (1991-2024)
Mediterranean CLIMAAX Handbook-based	MPI-ESM-LR	CLMcom-CCLM4-8-17	Euro-CORDEX

3.2. Urban Heat Island and RISK Assessments

Analysis of Landsat-8 LST data reveals that average surface temperature values frequently **exceed 45°C** during the summer months in the **Muratpaşa** district of central Antalya (Figure 4).

Figure 4. Land Surface Temperature (LST) data from Landsat-8 (2014–2024) reveals persistent overheated zones in central Antalya (e.g., Muratpaşa), with average values frequently exceeding 45°C during summer months.

These overheated areas have been confirmed as risk hotspots when compared with demographic data:

Vulnerability Overlap: Most of these overheated areas overlap with dense vulnerable populations (5 years and younger, 65 years and older) according to the WorldPop data, with the northern Muratpaşa region being among the most affected (Figure 5).

Figure 5. WorldPop 2020 pop. data (age g. 5, 65+, 70+, 75+, 80+) shows that many of these overheated areas overlap with dense elderly populations, particularly in the northern Muratpaşa region.

3.3. Future Heatwave RISK Projections

Climate projections anticipate a significant increase in HW formation.
Seasonal Increase: Under the RCP8.5 scenario, "High" to "Very High" increases in the relative change in Heatwave Risk (HWR) are expected, especially during the 2046–2075 period. These increases are concentrated in central districts (Konyaaltı, Muratpaşa, Kepez) that already have dense vulnerable populations (Figure 6).

Figure 6. The relative change in HWR (vs. 1986–2015 base.) shows that areas with already dense vulnerable populations (e.g., Konyaaltı, Muratpaşa, Kepez) are expected to experience "High" to "Very High" risk increases, esp. under RCP8.5.

Indirect Risks: The findings also highlight the potential indirect heat-induced forest fire risks posed by extreme heat to protected and natural areas.

4. Conclusion and Recommendations

HWs are periods of persistently high temperatures, often accompanied by dry air conditions, that can significantly impact human health, agriculture, and ecosystems. They are typically

defined relative to local climate norms, with temperatures exceeding a certain threshold for several days or weeks. These extreme heat events can cause a range of adverse effects, including heat-related illnesses, increased mortality rates, forest fires, and severe droughts. Due to climate change, this phenomenon is becoming more frequent and intense, posing an increasingly serious threat in many parts of the world. Heatwaves pose significant risks to public health, infrastructure, and food security. Understanding the likelihood, duration, and intensity of heatwaves is crucial for developing mitigation and adaptation strategies to protect vulnerable populations and reduce overall climate risks. The increasing impact of heat waves highlights the importance of integrating heatwave hazard assessments into broader climate resilience planning.

UHI effect, a significant problem that both creates and is affected by cities, increases the impact of HW. In these cities, concrete and asphalt absorb and retain heat, making residents even more vulnerable. The factors that most determine UHI intensity are urban morphology, building density, reduced vegetation cover, and anthropogenic heat. Green infrastructure and afforestation are particularly effective in reducing the UHI during summer. However, the impact of these measures may be limited unless they are implemented across large areas. Especially in Mediterranean cities, UHI and HWs, combined with climate change, are significantly increasing temperature rises and thermal discomfort. Urban planning and green infrastructure applications are critical in mitigating these effects.

MUHIR, through its work under the CLIMAAX initiative, demonstrates the significance of the aforementioned HW and UHI effects for Antalya through scientific analysis. This study, which comprehensively covers local CRA studies using two risk and two hazard analysis methods and a multi-comparison technique incorporating different temperature thresholds and different GCMs and RCMs, complements Antalya's existing AMM-SECAP (Antalya Metropolitan Municipality Sustainable Energy and Climate Action Plan) and is preparing its own action plan, similar to some cities that are significantly affected by extreme heat. The MUHIR results provide scientific and highly accurate evidence that will form the basis and justification for this plan and, through the CLIMAAX initiative, will convey the importance of climate risk assessment in combating the effects of climate change to the institutional capacity of the AMM.

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The article complies with national and international research and publication ethics.

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Fulya Kandemir (Team Leader of MUHIR) is leading the study; conducted the calculations presented in Section 2.2, performed interpretation of the results; and wrote the full manuscript; Abdulkadir Yıldız performed the CLIMAAX JupyterHub operations and contributed to obtaining RSLab LST data; Mustafa Kaynarca conducted MGM and Google Earth Engine operations to obtain TMI and NASA NEX-GDDP data; Volkan Sepetci and Mehmet Doğan contributed to ESRI ArcGIS pro 3D UHI mapping; Nusret Demir and Murat Türkeş provided scientific consultancy and guidance based on their expertise in climate science and geospatial analysis; Özlem Kılıçarslan and Esra Aksoy contributed to the administrative coordination of the MUHIR project; Melike Kireççibaşı was responsible for project administration on behalf of Antalya Metropolitan Municipality; Güliz Yaman contributed to the project's EU framework and financial aspects; Lokman Atasoy is responsible for environmental aspects on behalf of the Mayor's Office of Antalya Metropolitan Municipality.

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A Multidimensional Framework for Urban Green Space Quality

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Abstract

Assessing the quality of urban green spaces (UGS) is essential because it determines whether these environments can deliver their full potential benefits to urban populations. The quality aspects of UGS strongly influence patterns of use, health, and social relations. High-quality UGS have been linked to improved physical activity, reduced stress, enhanced mental health, stronger social cohesion, and even lower morbidity and mortality rates. Beyond social and health dimensions, high-quality green spaces also contribute to urban resilience by supporting biodiversity, reducing heat islands, and enhancing ecological services, underscoring the importance of integrating quality assessment into urban planning and research.

This study examines six major multidimensional tools designed to assess UGS quality: the Public Open Space Tool (POST), Environmental Assessment of Public Recreation Spaces (EAPRS), Neighborhood Green Space Tool (NGST), Community Park Audit Tool (CPAT), Natural Environment Scoring Tool (NEST), and the uRban grEen spaCe qualITy Assessment tooL (RECITAL). Using a comparative qualitative framework, the study analyzes each tool's conceptual orientation, dimensions, scoring systems, and health relevance. Findings reveal a clear methodological evolution from early tools focusing on physical activity and accessibility toward integrated frameworks encompassing ecological, social, and perceptual dimensions. RECITAL emerges as the most comprehensive and health-relevant model, offering 11 thematic dimensions and 90 measurable items that address surroundings, facilities, aesthetics, safety, and biodiversity. Despite its advantages, challenges remain in observer subjectivity, data intensity, and large-scale applicability. This study highlights the need for standardized, multidimensional, and adaptable frameworks for UGS quality assessment. Integrating physical, ecological, and social indicators such as those in RECITAL can support more equitable, resilient, and health-promoting urban landscapes worldwide.

Keywords: Urban green, assessment tool, sustainable development goals

Introduction

Urbanization continues to reshape landscape in dense built environments where opportunities for contact with nature are often scarce. Within this context, urban green spaces (UGS)

including parks, gardens, urban forests, playgrounds, greenways, and other vegetated open areas have emerged as critical components of sustainable and livable cities. UGS are defined as publicly accessible, vegetated areas situated within urban settings that serve ecological, social, and health-related functions (Knobel, Dadvand, & Maneja-Zaragoza, 2019). They represent multifunctional landscapes that support biodiversity, regulate environmental processes, and provide citizens with places for recreation, relaxation, and social interaction.

A growing body of research has demonstrated a strong association between exposure to UGS and a variety of health and well-being benefits. Numerous studies have linked the presence and proximity of green spaces to improved mental health, increased physical activity, better pregnancy outcomes, enhanced child development, and reduced morbidity and mortality among urban residents (Gascon et al., 2015; de Keijzer et al., 2016; Lachowycz & Jones, 2014; Maas et al., 2009; Knobel et al., 2019). For example, Maas et al. (2009) found that living in greener environments correlates with lower disease prevalence, while Gascon et al. (2015) reported that long-term exposure to residential greenery contributes to better mental and general health. Besides, UGS contribute indirectly to urban resilience and environmental sustainability. They mitigate the impacts of urban heat islands, absorb air pollutants, buffer noise, and regulate stormwater runoff. These functions not only improve urban environmental quality but also enhance psychological restoration and social cohesion, both of which are critical to public health (Gidlow et. al., 2018). The relationship between UGS and human health is multifactorial and multidimensional (Knobel et al., 2019). Nieuwenhuijsen et al. (2017) proposed six primary pathways through which UGS can influence human well-being:

1. ***Mental restoration and stress reduction***, by providing aesthetically pleasing and tranquil environments;
2. ***Promotion of physical activity***, through accessible recreational and sports facilities;
3. ***Facilitation of social contact and cohesion***, by offering shared public spaces for interaction;
4. ***Mitigation of environmental hazards***, such as air pollution, heat, and noise;
5. ***Microbial enrichment***, by exposing individuals to natural microbiota that strengthen immune function;
6. ***Ecological exposure and biodiversity,*** which fosters psychological restoration and cognitive benefits.

Complementing these pathways, Pretty (2004) describes three levels of human–nature engagement: viewing nature (visual contact with greenery), incidental engagement (unintentional exposure during other activities), and direct engagement (intentional participation in green environments).

The quality of these environments, however, largely determines whether they can deliver their potential benefits to urban populations. Knobel et al. (2021) notes that quality determines how people perceive, use, and benefit from green spaces. They define UGS quality as the attributes that influence population use and interaction with green spaces, encompassing characteristics (e.g., size, location), features (e.g., amenities, facilities), and condition (e.g., maintenance, cleanliness). High-quality UGS promote regular visitation and active use (McCormack et al., 2010), whereas poorly maintained or unsafe spaces can discourage participation and limit potential health benefits. Wheeler et al. (2015) also emphasize that variations in quality

among green spaces can lead to unequal health outcomes, underlining the need for equitable distribution of both green space access and quality.

This study examines and compares six widely used multidimensional UGS quality assessment tools; the Public Open Space Tool (POST), Environmental Assessment of Public Recreation Spaces (EAPRS), Neighborhood Green Space Tool (NGST), Community Park Audit Tool (CPAT), Natural Environment Scoring Tool (NEST), and the uRban grEen spaCe qualITy Assessment tooL (RECITAL). By analyzing their scope, dimensions, scoring systems, and applicability, the study provides a comprehensive understanding of how UGS quality has evolved from single-dimensional physical activity metrics toward integrated frameworks linking environmental, social, and ecological values. The comparison contributes to the standardization of UGS quality research by clarifying overlaps and distinctions among tools; practically, it supports planners and decision-makers in selecting the most appropriate and context-sensitive assessment methods for evaluating and improving green spaces. Ultimately, this work reinforces the paradigm that urban sustainability requires not just the quantity of green areas, but their quality, inclusiveness, and health-promoting potential ensuring that urban landscapes equitably deliver environmental and social benefits to all residents.

Materials and Methods

This study employed a qualitative, comparative document analysis approach to examine six major multidimensional tools developed for assessing urban green space (UGS) quality namely the Public Open Space Tool (POST) (Giles-Corti et al., 2005), Environmental Assessment of Public Recreation Spaces (EAPRS) (Saelens et al., 2006), Neighborhood Green Space Tool (NGST) (Gidlow et al., 2012), Community Park Audit Tool (CPAT) (Kaczynski et al., 2012), Natural Environment Scoring Tool (NEST) (Gidlow et al., 2018), and the uRban grEen spaCe qualITy Assessment tooL (RECITAL) (Knobel et al., 2021). The selection of these tools was guided by four criteria: their multidimensional scope, peer-reviewed publication, relevance to human health and well-being, and applicability to urban settings. Primary data were obtained from original methodological publications, complemented by supplementary documents such as technical manuals and validation studies. Each tool was systematically reviewed to extract information on its conceptual framework, assessment dimensions, scoring systems, and intended application scale.

Findings and Discussion

The comparative review of multidimensional assessment tools (Table 1) illustrates a clear evolution in the conceptualization and measurement of urban green space (UGS) quality. Early instruments such as the Public Open Space Tool (POST) (Giles-Corti et al., 2005) and Environmental Assessment of Public Recreation Spaces (EAPRS) (Saelens et al., 2006) were primarily designed to investigate relationships between physical activity, recreation, and park features. These tools emphasized accessibility, amenities, and safety dimensions directly linked to public use but offered limited attention to ecological and aesthetic qualities.

Table 1. Multidimensional Urban Green Space Quality Assessment Tools

Tool	Key Dimensions / Indicators	Scoring System	Key Advantages
POST *Public Open Space Tool* (Giles-Corti et al., 2005)	Access, aesthetics, safety, amenities, facilities, environmental quality, and usability.	5-point Likert scale; presence/absence and quality ratings.	Simple, field-based; strong focus on **physical activity relevance**.
EAPRS *Environmental Assessment of Public Recreation Spaces* (Saelens et al., 2006)	Accessibility, safety, aesthetics, amenities, natural features, play structures, incivilities.	Detailed categorical scoring (0–3) for each item; summed domain scores.	Comprehensive coverage of **amenities and play features**; good reliability.
NEST *Natural Environment Scoring Tool* (Gidlow et al., 2018)	Quantity, quality, accessibility, safety, facilities, incivilities, biodiversity, aesthetics.	Categorical and Likert-type scales; 7-point scales for quality.	Integrates **environmental and perceptual dimensions**; health relevance.
CPAT *Community Park Audit Tool* (Kaczynski et al., 2012)	Park access, facilities, amenities, maintenance, safety, and aesthetics.	Binary and scaled responses; total composite score.	User-friendly; short audit form; suitable for **community participation**.
NGST *Neighborhood Green Space Tool* (Gidlow et al., 2012)	Accessibility, safety, maintenance, facilities, aesthetics, and environmental quality.	Likert-type scales and observer notes.	Useful for linking **objective audits with health data**; adaptable.
RECITAL *uRban grEen spaCe qualITy Assessment tooL* (Knobel et al., 2021)	11 dimensions (90 items): surroundings, access, facilities, amenities, aesthetics, incivilities, safety, potential usage, land cover, animal & bird biodiversity.	5-point Likert and mixed scoring (quantity, quality, combined, reversed, Braun–Blanquet).	Broadest and most **holistic** tool; strong reliability; links **quality to health outcomes**.

Subsequent tools, including the Neighborhood Green Space Tool (NGST) (Gidlow et al., 2012) and Community Park Audit Tool (CPAT) (Kaczynski et al., 2012), introduced broader considerations of maintenance, environmental quality, and social usability, reflecting growing awareness of how physical and perceptual factors jointly influence user experience and well-being. However, their scope remained relatively narrow, focusing mainly on community-scale parks and excluding ecological diversity.

A major methodological advance came with the Natural Environment Scoring Tool (NEST) (Gidlow et al., 2018), which explicitly connected environmental quality dimensions to health-relevant outcomes. NEST integrated both objective and perceived indicators such as safety, incivilities, biodiversity, and aesthetics thus bridging epidemiological research with environmental auditing. Nevertheless, the need for a more comprehensive, standardized, and health-oriented tool persisted.

Addressing this gap, the RECITAL (uRban grEen spaCe qualITy Assessment tooL) (Knobel et al., 2021) represents the most holistic approach to date. It expands beyond prior frameworks by incorporating ecological indicators (biodiversity, land cover) alongside social and functional attributes (access, facilities, safety, incivilities, potential usage). RECITAL's multidimensional structure rooted in 11 domains and 90 measurable items enables a more integrated understanding of how physical, social, and ecological factors collectively influence health outcomes (Table 2).

Table 2. Dimensions and Items of the RECITAL Tool (Knobel et al., 2021)

Dimension	No. of Items	Example Indicators / Items	Scoring Type
Surroundings	6	Land use around site (residential, commercial, traffic); presence of pollution sources; surrounding noise and visual quality; green continuity with surroundings.	Quantity / Quality
Access	6	Number and width of entrances; accessibility for pedestrians and cyclists; signage and visibility; public transport connectivity; parking availability.	Quantity / Quality
Facilities	11	Sports courts, playgrounds, picnic areas, benches, drinking fountains, toilets, lighting, pathways, and shelters; maintenance status.	Quantity / Combined
Amenities	7	Waste bins, information boards, dog areas, kiosks, restrooms, water features, seating quality.	Quantity / Quality
Aesthetics and Attractions	10	Variety of vegetation; presence of water elements; landscape design quality; cleanliness; shade; scenic views; diversity of textures and colors.	Quality / Potential Use
Incivilities	8	Litter, vandalism, graffiti, dog excrement, evidence of alcohol or drug use, neglected infrastructure.	Reversed Quantity (higher = worse)
Safety	6	Visibility, lighting adequacy, signs of antisocial behavior, fencing, surveillance or presence of others, perceived security.	Quality / Potential Use
Potential Usage	10	Space multifunctionality; area suitability for rest, walking, play, social gathering, and relaxation; user density and accessibility gradient.	Potential Use
Land Covers	8	Surface composition (grass, trees, shrubs, paved areas); proportion of natural vs. artificial surfaces; water presence; canopy cover.	Braun–Blanquet / Quantity
Animal Biodiversity	9	Presence and diversity of small mammals, insects, amphibians, and other observable fauna; habitat features supporting fauna (logs, ponds, hedges).	Presence / Likert
Bird Biodiversity	9	Number and diversity of bird species; presence of nesting or feeding sites; auditory and visual detection.	Presence / Likert

In summary, the development trajectory of these tools reflects a paradigmatic shift in UGS research: from assessing where green spaces are located and how much they provide, to evaluating how good and health-relevant their qualities are. This shift underscores a contemporary urban planning priority ensuring not only equitable access to green spaces but also ensuring high-quality, ecologically functional, and socially inclusive environments that maximize the benefits of nature for urban populations.

Conclusion and Recommendations

This study examined six major multidimensional tools designed to assess urban green space (UGS) quality—the Public Open Space Tool (POST), Environmental Assessment of Public Recreation Spaces (EAPRS), Neighborhood Green Space Tool (NGST), Community Park Audit Tool (CPAT), Natural Environment Scoring Tool (NEST), and uRban grEen spaCe qualITy Assessment tooL (RECITAL). The comparative analysis demonstrated a clear evolution in the conceptualization, scope, and methodological sophistication of these instruments over the past two decades. Early generations of tools (POST, EAPRS) were rooted in the fields of public health and behavioral science, primarily focusing on physical activity, accessibility, and infrastructure. Middle-generation instruments (NGST, CPAT) introduced maintenance, aesthetics, and social interaction as integral quality dimensions,

reflecting a growing awareness of the experiential aspects of UGS. The most recent frameworks (NEST, RECITAL) have expanded this approach by incorporating ecological indicators such as biodiversity and land cover, while explicitly linking environmental quality with human health outcomes. Among these, RECITAL emerges as the most comprehensive and health-relevant tool to date. Its multidimensional structure comprising eleven thematic domains and ninety measurable items enables a holistic evaluation of UGS by integrating physical, social, and ecological dimensions. Empirical validation in diverse urban contexts has confirmed its reliability and adaptability, offering a strong foundation for comparative research and evidence-based planning. However, despite these advancements, challenges persist in terms of practical application, observer subjectivity, and scalability. Many existing tools require trained field auditors and substantial time investment, limiting their feasibility for large-scale or long-term monitoring. Moreover, certain dimensions such as aesthetics, biodiversity, and perceived safety remain partly subjective, underscoring the need for standardized training and digital support systems.

Thanks and Information Note

The article complies with national and international research and publication ethics. All authors contributed equally to the article.

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The Role of Solar Energy in Rural Development: An Environmental Solution to Energy Poverty

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Abstract

Rural development encompasses more than economic advancement; it also involves enhancing social inclusion, environmental sustainability, and overall living standards. In Türkiye, limited infrastructure and low household incomes in rural areas create persistent challenges, particularly in securing reliable and affordable energy. Energy poverty, defined as the inability to meet essential energy needs such as heating and lighting, constitutes a structural barrier that restricts social welfare and exacerbates environmental inequalities. This study investigates the role of solar energy as an environmentally sustainable approach to mitigating energy poverty within a rural development context. The analysis evaluates the technical, economic, and ecological feasibility of solar energy systems and reviews current national programs alongside international best practices. The study also offers policy recommendations tailored to the needs of rural communities. Findings indicate that solar energy contributes not only to reducing energy poverty but also to enhancing agricultural productivity, supporting women's socio-economic participation, improving education and healthcare conditions, and discouraging rural-to-urban migration. Strengthening local cooperatives and participatory governance mechanisms further increases social acceptance and supports long-term project sustainability. The study concludes that expanding solar energy can foster a transformative rural development model aligned with Türkiye's 2053 Net Zero Carbon target.

Keywords: Rural development, sustainable development, solar energy, renewable energy policies

1. Introduction

Rural areas hold significant economic and strategic value due to their role in conserving natural resources, sustaining agricultural production, and supporting regional development. However, infrastructural deficiencies, low income levels, and limited public services in many rural regions of Türkiye hinder the pace of development. In this context, rural development must be understood not only as economic growth but as a comprehensive process that integrates social inclusion, environmental sustainability, and improvements in quality of life.

One of the primary challenges affecting rural development is energy poverty, which refers to the economic or physical inability of individuals and households to access basic energy services such as heating, lighting, and cooking. This issue represents not only a social inequity but also an environmental concern. The widespread use of traditional fuels increases indoor air pollution, elevates carbon emissions, and accelerates the depletion of natural resources. Consequently, energy poverty has become a multidimensional barrier to development, disrupting the ecological balance of rural environments and limiting social well-being.

The aim of this study is to examine the strategic role that solar energy can play in rural development and to propose environmentally sustainable, economically viable, and socially acceptable solutions to energy poverty. The study first explores the conceptual framework of rural energy poverty, followed by an analysis of the technical and economic feasibility of solar energy applications. It further evaluates existing support mechanisms in Türkiye alongside international best practices and offers policy recommendations to promote the widespread adoption of solar energy–based solutions in rural areas.

2. Energy Poverty: Conceptual Framework and Its Implications for Rural Areas

Xxxxxx Energy poverty refers to the economic or physical constraints that prevent households from accessing essential energy services such as heating, lighting, cooking, and information access (Bouzarovski & Petrova, 2015). The concept is multidimensional and cannot be reduced solely to energy consumption levels; rather, it is shaped by factors including income, energy prices, energy efficiency, and the availability of infrastructure. Common indicators used in measuring energy poverty include the ratio of energy expenditures to income, access to minimum energy services, and the condition of physical infrastructure (Boardman, 1991; Healy & Clinch, 2002).

In Türkiye, energy poverty is particularly pronounced in rural areas. According to the Turkish Statistical Institute (TÜİK), more than 35% of rural households experience irregular or insufficient access to energy (TÜİK, 2023). In regions with weak electricity infrastructure, the use of traditional fuels such as wood and dung remains widespread, generating significant health and environmental impacts. Insufficient heating during winter months increases health risks for women and children while also limiting educational attainment and productivity (UNDP, 2022).

From a socio-economic perspective, energy poverty reinforces the cycle of deprivation. Restricted access to energy limits mechanization and cold chain applications in agriculture, reduces income, and contributes to migration trends. Environmentally, biomass combustion elevates greenhouse gas emissions and accelerates the depletion of natural resources (International Energy Agency [IEA], 2021).

Energy poverty continues to represent a major structural challenge for rural households in Türkiye. Data published by TÜİK in 2022 indicate that approximately 30% of rural households report inadequate heating, while 18% are unable to pay their electricity bills on time (TÜİK, 2023). These findings demonstrate that access to energy is not solely a technical matter but also a form of economic inequality. Key drivers of rural energy poverty include low income levels, distance from centralized energy infrastructure, persistent reliance on traditional fuels, and thermally inefficient housing. These conditions disproportionately affect vulnerable groups such as the elderly, women, and children. Increased domestic labor burdens for women, children's exposure to unhealthy indoor environments, and the prevalence of respiratory illnesses among older adults illustrate the socio-economic depth of the issue (Ürge-Vorsatz et al., 2014).

Environmentally, the continued use of traditional biomass in rural areas diminishes indoor air quality, raises carbon emissions, and contributes to local deforestation (IEA, 2021). Unsustainable fuel use also reduces soil productivity, undermining the ecological balance of rural landscapes. Ultimately, energy poverty constitutes not only a barrier to development but also a matter of environmental injustice. Table 1 summarizes the primary indicators used to assess energy poverty.

Table 1. Indicators for measuring energy poverty (Boardman, 1991; Bouzarovski & Petrova, 2015; Healy & Clinch, 2002).

Indicator	
Ratio of Energy Expenditures to Household Income	Indicates the proportion of household income allocated to energy expenditures
Access to Minimum Energy Services	Reflects the level of access to essential energy services such as heating and lighting
Condition of Physical Infrastructure	Represents the degree of access to electricity and clean fuel infrastructure

According to data from the Turkish Statistical Institute (TÜİK), energy poverty rates in rural areas are significantly higher than those observed in urban regions. Table 2 presents the key indicators of energy poverty among rural households in Türkiye.

Table 2. Energy poverty indicators for rural households in Türkiye (TÜİK, 2023)

Indicator	Rate
Households unable to maintain adequate heating	%30
Households unable to pay their electricity bills	%18
Households lacking regular access to energy services	%35

3. Renewable Energy Policies in Rural Development

Rural development policies in Türkiye have traditionally centered on agricultural support and infrastructure investments. In recent years, however, these policies have increasingly aligned with sustainability and energy-access objectives. Within the Rural Development Investments Support Program (KKYDP) of the Ministry of Agriculture and Forestry, grants and incentives for renewable energy installations—particularly solar energy systems—have been expanded (Ministry of Agriculture and Forestry, 2022). These incentives play a critical role in meeting the energy needs of agricultural irrigation, cold storage facilities, and livestock operations in rural areas.

Türkiye has also promoted small-scale solar energy investments through mechanisms such as Renewable Energy Resource Areas (YEKA) and unlicensed electricity generation. The unlicensed generation model has facilitated energy self-sufficiency for farmers and cooperatives, reducing energy costs and increasing production capacity. Nevertheless, regulatory complexity, bureaucratic procedures for cooperative applications, and high initial investment costs remain significant barriers to implementation (Karaman Investment Guide, 2017).

International experiences offer valuable insights. India's "KUSUM" (Kisan Urja Suraksha evam Utthaan Mahabhiyan) program provides farmers with solar-powered irrigation systems and enables them to sell surplus electricity to the grid (International Renewable Energy Agency [IRENA], 2016b). In Kenya, off-grid solar systems have expanded rural electrification, while Brazil has supported solar energy adoption through micro-financing programs targeting agricultural cooperatives. These initiatives demonstrate that solar energy functions not only as an energy source but also as a catalyst for income generation and employment in rural communities.

Solar energy plays a strategic role in promoting sustainable rural development. Türkiye employs several support mechanisms to advance this sector. The Renewable Energy Support Scheme (YEKDEM), established in 2011, offers fixed purchase guarantees for electricity generated from renewable sources. The updated post-2021 YEKDEM tariffs further incentivize domestic equipment use, aiming to strengthen rural manufacturing and employment. Additionally, the regulation on unlicensed electricity generation has created notable opportunities for small-scale solar investments. Under this framework, farmers, cooperatives, and rural enterprises can install solar power plants sized to meet their own consumption needs, thereby reducing energy expenditures while generating revenue from surplus electricity. Despite these advantages, challenges persist in areas such as administrative procedures, land-use permits, and access to financing.

At the international level, the European Union's "Clean Energy for EU Islands" initiative supports solar energy deployment in rural and isolated regions by strengthening energy cooperatives, enhancing technical capacity, and providing financial guidance (European Commission, 2020). Adapting similar models in Türkiye could strengthen local cooperative structures and accelerate solar energy adoption in rural communities.

Globally, renewable energy policies contribute significantly to rural development objectives. Countries such as India, Kenya, and Brazil view solar energy-based solutions as strategic tools for reducing energy poverty and enhancing rural productivity. India's KUSUM program stands out for integrating solar energy into agricultural irrigation systems and enabling farmers to sell excess electricity, with over three million farmers supported by 2022. Kenya leads Africa in deploying off-grid solar systems through micro-financing initiatives such as "M-KOPA Solar," which has expanded household-level energy access and supported social inclusion (IEA, 2019). In Brazil, the "Programa Luz para Todos" (Light for All Program) has provided electricity to nearly 17 million people since 2003, with recent phases heavily emphasizing solar energy systems. Solar electrification in remote Amazonian settlements has significantly improved energy access and environmental sustainability (World Bank, 2020).

These cases illustrate that solar energy-based rural development policies contribute not only to energy supply but also to income generation, social inclusion, and environmental sustainability. Table 3 summarizes the primary mechanisms supporting solar energy investments in rural areas of Türkiye.

Table 3. Renewable energy support mechanisms in Türkiye (Karaman Yatırım Rehberi, 2017; Tarım ve Orman Bakanlığı, 2022)

Support Mechanism	Application Area
Rural Development Investments Support Program	Agricultural irrigation, cold storage facilities, and livestock operations
Renewable Energy Resource Areas	Large-scale renewable energy investments
Unlicensed Electricity Generation	Installation of solar power systems for farmers, cooperatives, and small-scale enterprises

International examples demonstrate the economic and social contributions of solar energy to rural development.

4. Conclusion and Recommendations Feasibility of Solar Energy Applications in Rural Areas

The feasibility of solar energy in rural regions varies according to technological advancements as well as local technical, economic, and environmental conditions. Solar power systems offer significant opportunities for improving energy access and reducing energy poverty in rural settlements. The modular structure of photovoltaic (PV) panels and their relatively low maintenance requirements make them highly suitable for integration into rural infrastructure (IEA, 2020).

Microgrid systems can be deployed in both on-grid and off-grid configurations, providing flexible energy management options. Off-grid systems are particularly beneficial for remote and sparsely populated rural areas that lack access to centralized electricity networks, enabling the provision of essential energy services. On-grid systems, on the other hand, allow surplus electricity generated from solar installations to be fed into the grid, creating an additional source of income (IRENA & ILO, 2021). In Türkiye, unlicensed on-grid solar power systems have become increasingly common in rural areas, especially for agricultural irrigation.

From a technical perspective, regions with high solar irradiation demonstrate substantial efficiency potential. With an annual average of 2,737 hours of sunlight, Türkiye ranks among the leading countries in Europe (Turkish Electricity Transmission Corporation [TEİAŞ], 2022). Economically, declining panel costs and expanded incentive mechanisms have shortened payback periods for rural solar investments. Environmentally, the absence of carbon emissions and minimal ecological disturbance associated with solar energy systems contributes to the preservation of rural ecosystems.In this context, the widespread adoption of solar power technologies serves as a structural transformation tool that supports rural development goals, enhances environmental sustainability, and improves social well-being. Table 4 summarizes the main types of solar energy systems applicable in rural areas.

Table 4. Characteristics of solar energy systems in rural areas

Solar Energy System Type	Characteristics
PV Panels	Modular structure, low maintenance requirements, and ease of integration into rural infrastructure
On-Grid Microgrid	Grid-connected system enabling the sale of surplus electricity, providing opportunities for income generation
Off-Grid Microgrid	Independent from the central grid, offering access to essential services in remote rural settlements

The technical, economic, and environmental contributions of solar energy in rural areas of Türkiye are presented in Table 5.

Table 5. Contributions of solar energy to rural areas in Türkiye (IEA, 2020; IRENA & ILO,2021; TEİAŞ, 2022)

Contribution Area	
Technical	An annual solar irradiation duration of 2,737 hours, offering high efficiency
Economic	Declining panel costs, financial incentives, and shortened payback periods
Environmental	Absence of carbon emissions and minimal environmental disturbance

5.Contribution of Solar Energy to Energy Access for Rural Households

Solar energy functions not only as an energy source for rural households but also as a transformative instrument for development, health, education, and gender equality. In developing countries such as Türkiye, rural electrification rates appear technically high; however, access to uninterrupted, reliable, and affordable energy remains limited (IEA, 2022). Solar-based solutions offer a dependable alternative for household electrification, agricultural irrigation, and domestic uses such as lighting, heating, and cooking. The use of solar-powered pumps in irrigation systems significantly reduces diesel-related costs, thereby lowering farmers' operational expenses (IRENA, 2016a).

The impacts of these systems on rural women and children are multifaceted. For women, the time spent collecting traditional fuels decreases, while health problems associated with indoor air pollution are substantially reduced (UNDP, 2021). For children, access to consistent lighting at night improves study conditions, positively influencing educational outcomes. Solar energy applications also promote women's participation in economic and social activities, generating additional momentum for rural development.

From an economic perspective, the installation of solar energy systems leads to significant reductions in household energy expenditures, and in some cases, surplus electricity can be sold

to the grid, enabling additional income generation. This supports energy independence and income diversification in rural settings. Thus, solar energy constitutes a strategic development tool with both environmental and socio-economic benefits.

Solar energy provides multidimensional advantages for rural households. Table 6 presents an overview of these contributions.

Table 6. Contributions of solar energy to rural households (IEA, 2022; IRENA, 2016a; UNDP, 2021)

Contribution Area	
Development	Rural electrification, agricultural irrigation, and domestic uses such as lighting, heating, and cooking
Health	Reduction of indoor air pollution and prevention of respiratory diseases
Education	Improved study conditions through uninterrupted lighting at night, leading to enhanced educational performance
Gender Equality	Reduced workload for women and increased participation in productive and social activities

Solar energy enhances household energy independence and supports income diversification. Table 7 presents the economic contributions of solar energy systems.

Table 7. Economic contributions of solar energy systems (IEA, 2022; IRENA, 2016a)

Economic Impact	
Reduction in Energy Costs	Reduced diesel and fuel consumption lowers farmers' operational expenses
Increase in Household Income	Additional income is generated through the sale of surplus electricity to the grid

6. Social Acceptance, Participatory Models, and Local Capacity Development

The successful dissemination of solar energy systems in rural areas requires more than technological and economic feasibility; social acceptance, local participation, and capacity development efforts also play a decisive role. Community-based energy models enhance public involvement in decision-making processes, strengthen the social sustainability of projects, and promote long-term ownership (Renewables 2021 [REN21], 2021). Within these models, energy users assume not only the role of consumers but also that of producers and managers, contributing to the advancement of energy democracy at the local level.

Local cooperatives, non-governmental organizations (NGOs), and public–private partnerships are central actors in implementing such approaches. Energy cooperatives, which are widespread in Europe, offer a replicable framework for Türkiye by distributing the ownership of solar

energy projects across communities and generating shared social benefits. As of 2022, agricultural development cooperatives in Türkiye have increasingly participated in solar energy investments, supported by collaborative initiatives between municipalities and NGOs.

Furthermore, education, employment, and awareness-raising activities are critical elements for integrating solar technologies into rural communities. Strengthening local populations through technical training, creating employment opportunities, and enhancing energy literacy significantly improve public trust and social acceptance (IRENA, 2018). Solar energy projects contribute to youth employment by developing technical skills and encourage women's involvement in energy cooperatives and community-based initiatives. This process supports not only energy access but also broader social transformation.

Social acceptance is shaped not only by economic and technical suitability but also by the extent of local participation and capacity development. Table 8 presents the key factors that enhance social acceptance in rural areas.

Table 8. Factors enhancing social acceptance in rural areas (IRENA, 2018; Özgül et al., 2020; REN21,2021)

Factors	
Community-Based Energy Models	Participation of local communities in decision-making processes and the advancement of energy democracy
Cooperatives	Distribution of ownership of solar energy projects across the community
NGO and Public–Private Partnerships	Promotion of projects through financial and institutional support mechanisms
Education and Awareness	Enhancement of local technical capacity and increased community ownership of projects

Participatory models contribute not only to social acceptance but also to broader social transformation. Table 9 presents the societal impacts of participatory models in solar energy systems.

Table 9. Societal impacts of participatory models in solar energy (IRENA, 2018; Özgül et al., 2020; UNDP, 2021)

Participatory Model	**Societal Impact**
Energy Cooperatives	Local employment, community benefit, and income sharing
Women's Participation	Active participation of women in energy cooperatives and the advancement of gender equality
Youth Participation	Development of technical skills and increased employment opportunities in the energy sector

7. The Potential of Solar Energy in Addressing Rural Energy Poverty

Energy poverty in rural areas represents not only a lack of infrastructure but also a broader issue encompassing social justice, economic equity, and environmental sustainability. Solar energy offers an effective and environmentally sound solution to this multidimensional challenge. Through distributed energy generation models and microgrid systems, access to energy becomes feasible for rural settlements that are geographically distant from centralized power infrastructure. In this respect, solar energy directly contributes to reducing energy poverty (IRENA & ILO, 2021).

Expanding solar energy investments in rural regions also supports the reduction of regional disparities. In areas of Türkiye where electricity infrastructure remains limited—such as Eastern and Southeastern Anatolia—local solar solutions enhance energy access, strengthen production capacity, and promote economic development. This, in turn, contributes to mitigating rural-to-urban migration. Energy justice involves not only the physical availability of energy but also the equitable economic, environmental, and socio-cultural distribution of energy resources. Solar energy, with its carbon-free nature and potential for localized generation, stands out as a key mechanism for advancing environmental equity (Sovacool & Dworkin, 2015).

Additionally, increasing community participation in project development enhances social acceptance and supports a just energy transition. Thus, solar energy acts not only as an energy provider but also as an instrument for social transformation and equity. Table 10 presents the multidimensional role of solar energy in reducing rural energy poverty.

Table 10. The role of solar energy in reducing rural energy poverty (IEA, 2021; IRENA & ILO, 2021; Sovacool & Dworkin, 2015)

Impacts	Societal Impact
Energy Access	Access to essential energy services in rural areas increases through distributed generation and microgrid systems.
Economic Development	Energy costs decline, production capacity improves, and regional disparities are reduced.
Social Transformation	Community participation strengthens, supporting energy justice and social equity.

The three dimensions of energy justice—access, economic, and environmental—are supported by the contributions of solar energy. Table 11 presents the dimensions of energy justice and the corresponding contributions of solar energy.

Table 11. Dimensions of energy justice and the contributions of solar energy (IEA,2021; IRENA & ILO, 2021; Sovacool & Dworkin, 2015)

Dimension of Energy Justice	Contribution of Solar Energy
Access Justice	Provides access to electricity in rural areas by overcoming inadequacies in local energy infrastructure
Economic Justice	Reduces energy costs and alleviates the financial burden on low-income households
Environmental Justice	Enables low-carbon, environmentally sustainable energy production

8. Case Studies from Türkiye

Türkiye offers numerous successful examples that illustrate the potential of solar energy in rural development. The Southeastern Anatolia Project (GAP) Region, in particular, holds significant advantages due to its high solar irradiation levels and the intensity of agricultural activities. Within the scope of "Renewable Energy and Energy Efficiency" initiatives led by the GAP Administration, agricultural irrigation systems in several villages in Şanlıurfa and Diyarbakır have been converted to operate on solar power. These projects have reduced energy costs while ensuring continuity in agricultural production.

In Karaman and its surrounding areas, pilot projects supported by the Ministry of Agriculture and Forestry have demonstrated that solar-powered irrigation systems reduce dependence on energy for groundwater extraction and contribute to increased farmer incomes (Ministry of Agriculture and Forestry, 2022). Owing to their ease of maintenance and low operational costs, these systems have rapidly expanded across the region (Karahocagil et al., 2019). Another notable area of implementation involves community-based projects developed through rural cooperatives. In regions such as İzmir and Aydın, small-scale solar power plants have been established through energy cooperatives, enabling electricity generation and revenue creation through the sale of surplus electricity back to the grid (Özgül et al., 2020).

Such initiatives not only promote community participation but also significantly enhance social acceptance. These success stories demonstrate that solar energy applications across different geographical regions of Türkiye generate substantial environmental, economic, and social benefits.

9. Challenges and Policy–Administrative Barriers

Although solar energy investments offer an environmentally sustainable solution for rural development, their implementation faces several structural obstacles. One of the primary challenges is the high initial investment cost, which poses a significant barrier for small-scale producers in rural areas. Because most components used in the installation of solar power systems are imported, fluctuations in foreign exchange rates further increase overall project costs, thereby limiting access for low-income rural investors (IEA, 2022).

Regulatory barriers constitute another major constraint. Despite progressive developments in Türkiye's regulations on unlicensed electricity generation, agricultural producers and rural

cooperatives still encounter numerous bureaucratic procedures—including land-use permits and technical compliance documentation—when attempting to develop solar energy projects (Ağır et al., 2023; Tüzün et al., 2024). Frequent regulatory amendments also diminish predictability for investors and undermine the long-term sustainability of projects.

Financial limitations and insufficient incentives further hinder the expansion of solar energy in rural areas. High loan interest rates reduce private sector interest in rural projects, while government support mechanisms typically prioritize large-scale investments. However, in rural contexts, small-scale and decentralized systems require greater policy attention and dedicated support (IRENA, 2021). In this regard, tailored financing models and micro-grants delivered through regional development agencies should be considered as viable solutions.

Energy infrastructure deficiencies also complicate the integration of solar systems in rural regions. In areas with weak distribution networks, obtaining technical connection approvals can be delayed, or overall project feasibility may be compromised. Therefore, modernizing energy infrastructure and strengthening local technical capacity are prerequisites for the effective adoption of solar energy in rural settings. Table 12 presents the key challenges encountered in rural solar energy investments.

Table 12. Challenges in rural solar energy investments (IEA, 2022; IRENA, 2021; Tüzün et al., 2024)

Challenge	
High Initial Investment Cost	The reliance on imported equipment and fluctuations in foreign exchange rates significantly increase overall investment costs.
Regulatory Barriers	Bureaucratic procedures, land permit requirements, and technical certification processes continue to pose barriers for unlicensed electricity generation.
Financing Constraints	High interest rates and the concentration of public support on large-scale projects limit access to financing for small rural initiatives.
Infrastructure Deficiencies	Inadequate distribution networks and delays in obtaining technical connection approvals hinder the timely integration of solar energy systems.

10. Conclusion and Policy Recommendations

Solar energy represents an environmentally sustainable, economically viable, and socially transformative resource that can be integrated into the multifaceted structure of rural development. Persistent energy poverty in Türkiye's rural regions is not solely the result of inadequate technical infrastructure; it is also closely intertwined with social inequality, environmental injustice, and economic vulnerability. Within this context, solar-based solutions play a strategic role in addressing deficits in rural energy access.

Solar energy offers a sustainable option for meeting the energy needs of both households and agricultural production processes in rural areas. Through distributed energy generation models, dependence on the central grid is reduced, energy security is enhanced, and rural productivity is strengthened. At the same time, the reduction of carbon emissions provides significant benefits for environmental sustainability and national climate objectives. In line with Türkiye's 2053 Net-Zero Carbon target, the transition to renewable energy in rural areas constitutes not only a necessity but also a domain rich in opportunities. Solar energy directly contributes to several Sustainable Development Goals (SDGs), including poverty reduction (SDG 1), access to affordable and clean energy (SDG 7), gender equality (SDG 5), climate action (SDG 13), and sustainable communities (SDG 11).

Policy Recommendations for Reducing Energy Poverty

- Tailored incentive packages should be developed for local-scale solar energy projects, with expanded microcredit, interest-free financing, and grant mechanisms.
- Procedures for unlicensed electricity generation should be simplified, and bureaucratic barriers—particularly for village cooperatives and women-led initiatives—should be reduced.
- Solar-powered irrigation systems should be promoted to lower the energy costs of agricultural production.
- Women's participation in energy cooperatives should be encouraged through measures that support social inclusion and gender equality.
- Educational programs aimed at enhancing energy literacy should be implemented to ensure that rural communities understand, adopt, and use solar systems efficiently.

In conclusion, the future of rural development depends not only on infrastructure investments but also on innovative solutions that uphold equity in energy access, environmental sustainability, and community participation. Solar energy stands as a powerful and promising tool at the center of this transformation. With appropriate policy frameworks, it is possible to improve the quality of life of millions of rural residents, strengthen energy independence, and contribute to Türkiye's green development objectives.

Thanks and Information Note

The article complies with national and international research and publication ethics. All authors contributed equally to the article.

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The Presence of Indoor Plants in Elderly Care and Rehabilitation Centers: The Case of Antalya City

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Abstract

This study examines the effects of indoor plants on psychosocial well-being, spatial perception, and care practices in nursing homes. A survey was administered to a total of 100 participants (39 residents, 61 staff members) in nine nursing homes located in the districts of Kepez, Muratpaşa, and Konyaaltı in Antalya. The findings show that indoor plant cultivation rates are high in both groups (61.5% among residents; 70.5% among staff) and that plants generate strong positive emotions (happiness, peace, relaxation). The placement of plants differed between groups: residents mostly placed plants in their rooms to enhance feelings of privacy/belonging, while staff placed them in common areas to support spatial aesthetics and social interaction. In terms of preferences, the elderly tend toward decorative flowering plants, while employees prefer decorative foliage plants. Care practices are limited to basic tasks; while regular watering is common, there are notable gaps in knowledge regarding pruning, fertilization, and pest management, as well as the use of "unknown" products. The study recommends selecting non-toxic species that tolerate low light and irregular care in nursing homes; positioning them according to ecological requirements; simplified care protocols; integrated pest management; and converting user/staff training into institutional standards. The results reveal that indoor plants are not merely aesthetic elements but also a nature-based design strategy that enhances individual well-being, spatial quality, and social interaction.

Keywords: Biophilic design, Nursing homes, Psychosocial well-being, Indoor plant care, Spatial perception

1. Introduction

Indoor plants are defined as plant species that are cultivated in enclosed environments (such as homes, offices, schools, hospitals, etc.) for aesthetic, psychological, and ecological purposes, having been removed from their natural habitats and capable of adapting to climatic conditions. These plants are typically selected from species that tolerate shade and low light intensity and have relatively low maintenance requirements (Chen, McConnell & Henny, 2002). According to Wolverton et al. (1989), indoor plants are not merely decorative elements, but also living systems that improve air quality in enclosed spaces, support psychological well-being, and are part of sustainable design. In the environmental psychology literature, indoor plants are considered biophilic design elements that bring individuals' connection with nature into the space (Kellert, Heerwagen & Mador, 2008). Research shows that indoor plants reduce stress levels in individuals, increase focus, and positively affect overall mood (Bringslimark, Hartig & Patil, 2009; Han & Ruan, 2020). Studies conducted particularly in workplaces, educational

institutions, and healthcare facilities have revealed that the presence of plants supports productivity, creativity, and learning processes, while also accelerating the healing process (Ulrich, 1984; Dijkstra, Pieterse & Pruyn, 2008).

From a physiological perspective, it has been determined that indoor plants improve air quality, reduce CO_2 levels, and absorb volatile organic compounds (VOCs) (Wolverton, Johnson & Bounds, 1989; Irga, Paull & Torpy, 2018). In addition, plants used indoors improve quality of life by regulating humidity balance.

From a landscape architecture perspective, indoor plants are valuable as design tools that alter the perception of space, strengthen user-space interaction, and confer identity. Plants have the power to shape the scale and atmosphere of spaces; in this respect, they enhance spatial quality not only in outdoor spaces but also in indoor arrangements (Lohr, Pearson-Mims & Goodwin, 1996). Furthermore, in today's world where sustainable design is increasingly important, indoor plants offer nature-based solutions that support energy efficiency, user health, and ecological balance (Kellert, 2018).

In this context, indoor plants play an indispensable role in landscape architecture studies in terms of aesthetics and functionality, as well as human health and ecological sustainability. Therefore, the use of plants in contemporary landscape architecture and interior design is approached not only as a visual element but also as a multidimensional design strategy.

Considering these numerous benefits, various studies have shown that indoor plants are not merely an aesthetic element, but also have significant effects on employee productivity, concentration levels, and overall work performance. Studies conducted in the fields of environmental psychology and workplace ergonomics show that natural elements—especially indoor plants—positively affect employees' psychological well-being and cognitive functions (Bringslimark, Hartig & Patil, 2009).

In a classic experimental study, Lohr et al. (1996) found that the presence of indoor plants in windowless office environments increased employee task performance and reduced stress levels. It was found that employees completed their tasks faster and more accurately in spaces with plants, while stress-related physiological responses (e.g., heart rate, blood pressure) remained at lower levels.

As can be explained within the scope of the “Attention Restoration Theory (ART)” defined by Kaplan (1995), plants create an effect that reduces mental fatigue and renews attention in individuals. This effect contributes to increased employee productivity, especially in office environments where intensive cognitive tasks are performed.

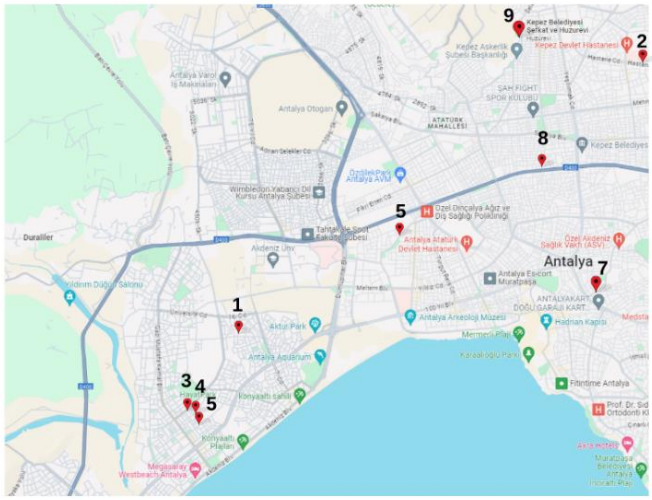
A study conducted in Denmark reported that the use of plants in office environments increased job satisfaction among employees, reduced absenteeism, and contributed positively to overall productivity (Dravigne et al., 2008). Similarly, Shibata and Suzuki's (2002) experimental study found that having plants on desks increased employees' creativity and problem-solving performance. Thus, it is known that the effects of indoor plants on employee productivity are multidimensional and not limited to visual and aesthetic perception; they are directly related to factors such as psychological relaxation, renewed attention, reduced stress, and increased cognitive performance. Therefore, the use of indoor plants in contemporary office design should be seen as a scientifically based strategy aimed at increasing both employee well-being and work productivity.

Within the scope of this research, one-on-one interviews were conducted with a total of 100 people who receive services and work at 9 nursing homes and retirement homes located in the Konyaaltı, Kepez, and Muratpaşa districts of Antalya province. The aim was to determine the presence of indoor plants in the environments where they live/work, the psychological and physiological effects of the existing plants, and the care practices applied.

1. Materials and Methods

1.1.Materials

The list of 9 Nursing Homes and Retirement Homes visited in the districts of Konyaaltı, Kepez, and Muratpaşa in Antalya Province for the survey questions within the scope of the research is as follows (Figure 1).



1-Asmali Konak Nursing and Care Home

2-Private Antalya Nursing and Elderly Care Center

3-Private Emir Çalkuşu Nursing Home

4-Private Four Seasons Palliative Care Center

5-Doğan Güneş Nursing Home

6-Private Öz-İlgi Assisted Living Care Center

7-Private Tutku Care Center

8-Akdeniz Nursing and Elderly Care Center

9-Kepez Compassion Nursing Home

Figure 1. Information and locations of elderly care and nursing homes

1.2.Methods

In this study, a semi-structured questionnaire form was used as the data collection instrument. The questionnaire aims to reveal the preferences, usage habits, and maintenance practices related to indoor plants among staff members and service recipients in elderly care and rehabilitation centers located in the Konyaaltı, Muratpaşa, and Kepez districts of Antalya. The form was administered face-to-face, following the ethical framework of the study and after providing participants with the necessary information.

The questionnaire form is a comprehensive data collection tool containing both quantitative and qualitative features. By enabling the simultaneous evaluation of indoor plant preferences, usage behaviors, maintenance practices, and emotional perceptions, it generates multidimensional data appropriate to the objectives of the research.

The questionnaire consists of four main sections:

2.2.1. Demographic Information Section

This section includes questions designed to determine the socio-demographic characteristics of the participants. Data collected include whether the participant is a care recipient or an employee, the job status and years of experience of employees, place of residence, marital

status, age, educational level, occupation, and monthly income range. The purpose of this section is to define the participant profile and to relate plant preferences to demographic variables.

2.2.2. Information on Indoor Plant Use

This section examines participants' ownership, usage, and preference patterns regarding indoor plants. Questions address whether the participant cultivates indoor plants; if so, the types of plants grown (decorative flowering species, succulents/cacti, decorative foliage plants); methods of plant acquisition (purchasing, online ordering, propagation via cuttings, receiving as gifts); and the locations where these plants are placed within indoor spaces. Additionally, detailed information is gathered on the number of plants owned and the specific species cultivated. This section also includes questions about purchasing cut flowers and preferred types.

2.2.3. Emotional State and Attitude Analysis

In this section, a 5-point Likert scale (1 = Strongly Disagree, 5 = Strongly Agree) is used to assess participants' emotional responses and attitudinal evaluations toward the idea of growing indoor plants. The items address the positive and negative emotions evoked by indoor plants (e.g., happiness, tranquility, calmness, tension, fatigue, monotony) as well as cognitive evaluations related to plant characteristics (e.g., presence of flowers, color preferences, pot selection, ease of maintenance, fragrance, morphological form). This structure allows for a comprehensive analysis of the effects of indoor plants on user psychology and perception.

Furthermore, participants' aesthetic preferences are explored through questions regarding preferred plant forms (round, columnar, trailing, or spreading) and preferred colors of indoor plants. This section provides extensive data on users' aesthetic and functional expectations within indoor landscape design.

2.2.4. Information on Indoor Plant Maintenance Practices

This section aims to reveal participants' habits and practices related to plant maintenance. The questions are structured around the following themes:

- **Watering:** Whether watering is performed, the type of water used, and watering frequency.
- **Pot Replacement:** Whether pots are changed and the frequency of replacement.
- **Pot Material Preference:** Preference for pot materials such as plastic, glass, ceramic, or wood.
- **Growing Medium:** Preference for substrates such as peat, perlite, garden soil, vermiculite, or sand.
- **Pruning:** Whether pruning is conducted, its frequency, and its purpose (removal of dry branches, stimulating growth, pest control, etc.).
- **Propagation:** Methods used for plant propagation, including leaf cuttings, stem cuttings, root cuttings, eye cuttings, or seed propagation.
- **Fertilization:** Whether fertilization is applied, its frequency, the form of fertilizer used (organic/chemical; liquid/solid), and the content of the fertilizer.

- **Pests and Diseases:** Presence of plant pests or diseases, types encountered (insects, flies, ants, fungi), and the methods used for control (chemical treatment, manual removal, etc.).

This section provides a holistic perspective on the maintenance practices that influence the sustainable use of indoor plants within elderly care institutions.

3. Findings and Discussion

The research was conducted in nine different nursing homes located in the districts of Kepez, Muratpaşa, and Konyaaltı in Antalya, and a survey was carried out with a total of 100 participants. Thirty-nine of the participants were individuals receiving care, while 61 were employees working in the nursing homes.

3.1. Demographic Characteristics

Of the individuals receiving care, 21 were female and 18 were male, while 41 of the employees were female and 20 were male. Looking at the age distribution, 53.8% of those receiving care were aged 80 and over, while 49.2% of the employee group were aged 20–29. In terms of educational status, high school graduates constituted the highest percentage (41%) among those receiving care, while associate degree graduates constituted the majority (49.2%) among employees.

3.2. Occupational and Socioeconomic Characteristics

In terms of job distribution among employees, nurses have the highest share at 42.6%, followed by nursing assistants at 37.7%. When examining the participants' residential addresses, it is seen that 49.2% of employees live in the Kepez district. In terms of income level, 43.6% of individuals receiving care earn a monthly income between 10,000 and 19,999 TL, while 60.7% of employees have an income between 20,000 and 29,999 TL.

3.3. Plant and Ecology Education

The percentage of participants who have received plant science education is 2.6% among caregivers and 1.6% among employees.

3.4. Findings Related to Indoor Plants

61.5% of individuals in care settings and 70.5% of employees grow indoor plants. The percentage of those who own plants is 53.8% in care settings and 54.3% among employees. When plant preferences are examined, elderly individuals in care settings prefer decorative flowering plants (33.3%), while employees prefer decorative foliage plants (38.4%).

In terms of plant procurement methods, 45.8% of care recipients purchase plants directly, while this rate is 52.8% among employees. When gift-giving situations are evaluated, the most common plant gift among care recipients is received during patient visits (52%), while among employees it is received during new job visits (31.3%).

When examining the areas where indoor plants are kept, plants are most often placed in rooms (55.8%) among caregivers, while 90% of plants among employees are located in “other areas.” The number of pots owned by plant growers is concentrated between 1 and 5 at a rate of 53.8% in care settings and 46.7% among employees. The study comparatively examined the preferences of individuals in care settings and nursing home employees regarding cut flowers and indoor plants, their emotional states, and their assessments of plant characteristics.

The rate of cut flower purchases among individuals receiving care was 53.8%, while among working individuals, this rate was determined to be 55.7%. The most preferred type of cut flower in both groups was the rose, with a rate of 52.9% among those receiving care and 50% among working individuals.

3.5. Emotional State Analysis Regarding Indoor Plants

The emotional responses of participants who grow indoor plants are quite positive.

- When asked, "Do indoor plants make you feel happy?", 97.4% of caregivers and 98.4% of employees answered "Yes."

- To the question, "Do indoor plants make you feel peaceful?", 100% of caregivers and 98.4% of employees answered "yes".

- To the question, "Do indoor plants make you feel relaxed?", 97.4% of caregivers and 98.4% of employees answered "yes".

- In terms of negative emotions, the vast majority of participants stated that plants are tense (94.9% and 100%), unhappy (97.4% and 98.4%), monotonous (94.9% and 96.7%), sad (92.3% and 95.1%), tiring (79.5% and 96.7%), suffocating (97.4% and 98.4%), boring (92.3% and 95.1%), and ordinary (92.3% and 93.5%).

- When other emotional responses were examined, the rate of plants being found "attractive" was the same in both care areas (59%) and among employees (59%). However, employees showed a higher rate of participation (83.6%) in terms of feeling "unique," while this rate remained at 48.7% in care areas. The percentage of respondents who found them "interesting" was low, with more than half of both groups (51.3% and 50.8%) stating that they did not agree with this statement. Similarly, the perception of plants as "lively" was also weak, with the percentage of respondents who disagreed measured at 46.2% in the care areas and 50.8% among employees.

3.6. Evaluations Based on Plant Characteristics

Opinions differ on whether flowers should be fragrant; 43.6% of caregivers disagree, while 45.9% of employees agree. Those who believe that pots or soil should be changed once a year account for 92.3% of caregivers and 93.4% of employees. Those who consider low water requirements to be important account for 87.2% of caregivers and 85.2% of employees. The percentage of those who believe that the soil should be fertilized once a year is 82.1% among caregivers and 90.2% among employees.

Regarding plant size, 48.7% of those in maintenance areas and 65.6% of employees stated that plant height is important. Those who think that plants should not be too tall are 76.9% in the care areas and 80.3% among employees. Those who think that plants should be flowering are 59% in the care areas and 49.2% among employees. On the other hand, the percentage of those who do not find it appropriate to prefer only species with beautiful leaves is 46.2% in the care areas and 54.1% among employees. Those who stated that both flower and leaf beauty should be considered accounted for 69.2% of caregivers and 88.5% of employees. The criterion of being thornless was considered less important in both groups (46.2% and 55.7% disagreed), while the criterion of being non-poisonous was accepted by 100% of both groups. The percentage of those who stated that it is important for plants to be easy to care for was 97.4% among caregivers and 90.2% among employees. The percentage of those who disagreed that

rare species should be preferred was 66.7% among caregivers and 57.4% among employees. Those who thought that very showy plants should be preferred were 46.2% among caregivers and 42.6% among employees. The percentage of those who prefer simple plants is 53.8% among caregivers and 65.6% among employees. The percentage of those who disagree that flowers should have a pleasant scent is approximately 39% in both groups. Those who think the form of plants is important are 53.8% among caregivers and 44.3% among employees. Looking at preferences regarding plant form and flower colors, the most preferred plant form among individuals in care settings is round at 33.3%, while among employees it is columnar at 32%. The most preferred flower color in both groups is red (24.2% in care settings, 23% among employees).

3.7. Plant Care Practices

All participants (100%) stated that they watered their indoor plants regularly. Tap water was the most commonly used water source (89.7% in care areas; 86.9% among employees). The frequency of watering is every 2–3 days in 74.4% of care areas and every 2–3 days in 63.9% of employees. The rate of those who change pots is 51.3% in care areas and 55.7% in employees. The frequency of pot changes is reported as once a year in 70% of care areas and 83.6% of employees. In terms of pot preferences, 54.3% of caregivers prefer porcelain/ceramic pots, while 45.1% of workers prefer plastic pots. In terms of potting soil preference, garden soil was preferred by both groups (76.4% of caregivers; 81.5% of workers). The study compared pruning, propagation, fertilization, and disease/pest control practices for indoor plants among care recipients and nursing home employees.

A significant portion of participants do not prune regularly. The percentage of those who reported not pruning is 53.8% among care recipients and 59% among employees. Among those who prune, the frequency is generally reported as once a year (77.8% among residents; 76% among staff). The main reason for pruning in both groups is “removing dead branches” (41.2% among residents; 40.5% among staff).

Participants who propagate plants most frequently prefer the stem cutting method. This rate is 75% among individuals in care settings and 56.3% among working individuals.

Fertilization habits are low. The percentage of those who stated they do not fertilize is 61.5% in care settings and 68.9% among working individuals. Those who fertilize generally do so once a year (86.6% of those in care areas; 73.7% of workers). In terms of fertilizer form, all of those in care areas (100%) and 84.2% of workers use solid fertilizer. In terms of content, both groups prefer to use organic fertilizer (100% in maintenance areas; 94.7% among workers). However, the percentage of those who are unaware of the type of fertilizer used is quite high (86.6% in maintenance areas; 68.4% among workers).

Approximately half of the participants stated that they did not encounter diseases or pests in their plants (56% in care areas; 56.4% among workers). Among the pests encountered, insects stand out (54.5% in care areas; 46.7% among workers).

The most common method of pest control is the use of chemical pesticides. 64.7% of individuals in care settings and 76.2% of employees prefer this method. However, when asked about the type of pesticides used, 100% of both groups responded “unknown.”

4. Discussion

The findings from this study shed light on the attitudes and practices of elderly individuals residing in nursing homes and the staff working there toward indoor plants. The data reveals that indoor plant cultivation rates are quite high in both groups (61.5% and 70.5%). This situation shows that plants serve important functions not only as aesthetic elements but also in terms of individuals' quality of life, psychosocial well-being, and sense of belonging to the space.

Environmental psychology literature has repeatedly shown that interaction with nature is effective in reducing stress, renewing attention processes, and helping individuals achieve a positive mood (Kaplan, 1995; Ulrich, 1984). It is emphasized that contact with nature is critically important, especially for older adults, in terms of supporting cognitive functions and increasing life satisfaction (Detweiler et al., 2012). Research findings indicate that the fact that individuals residing in nursing homes mostly place indoor plants in their own rooms suggests that plants can be considered an element that strengthens the sense of individual belonging and privacy. From the perspective of employees, the fact that plants are more commonly found in shared spaces indicates that these elements play a role in supporting spatial aesthetics and social interaction. Furthermore, employees' preference for decorative foliage plants may be related to ease of maintenance and the long-lasting visual contribution they provide to the space (Lohr et al., 1996). This difference in preference shows that the functional and symbolic meanings of plants vary according to user groups.

Furthermore, the use of natural elements in nursing homes should be considered one of the fundamental principles of biophilic design. Kellert (2018) states that biophilic design creates positive effects on health, well-being, and performance by strengthening individuals' connection with nature. Indeed, the fact that nursing home residents largely obtain indoor plants directly through purchase or gifts reveals that these plants serve not only as decoration but also as tools that strengthen social relationships and emotional bonds.

However, the literature also indicates that there are some limitations to the use of plants in nursing homes. For example, in the study by Rappe and Lindén (2004), nurses working in dementia care homes acknowledged the calming effects of plants but also pointed out the difficulties in caring for them (playing with soil, picking plants, hygiene issues). In this context, plant species selection, care plans, and staff training are critical for the effective and sustainable use of indoor plants in nursing homes.

In conclusion, the data obtained from this study shows that indoor plants are a powerful tool for improving both individual well-being and spatial quality in elderly care centers. However, for this effect to be sustainable, user characteristics, spatial design, and care possibilities must be evaluated holistically.

The findings show that both individuals receiving care and nursing home staff generally have a positive attitude toward indoor plants. The vast majority of participants associate indoor plants with happiness, peace, and relaxation, while not associating them with negative emotions. However, the difference in the rates at which plants are found to be “unique” and “interesting” suggests that staff are more inclined to approach plants with an innovative or creative perspective, while older individuals tend to evaluate plants more as familiar, soothing elements.

The low maintenance requirements of plants emerge as a critical criterion for both elderly individuals and staff members. This finding supports the importance of selecting low-

maintenance plant species in nursing homes. Furthermore, the higher importance placed on arrangement among staff members indicates that plants carry greater significance for staff in terms of aesthetic arrangement and professional presentation.

The findings reveal significant similarities between the preferences and care practices of residents and employees regarding indoor plants. Both groups agree on issues such as the appropriate placement of plants according to their ecological needs, their easy maintenance, and their non-toxicity. However, partial differences are observed between the groups regarding the form of the plants, the colors of the flowers, and their aesthetic characteristics. In particular, the fact that caregivers place greater importance on plant arrangement and both leaf and flower beauty suggests that they approach plants from a professional aesthetic perspective. Among the elderly, the preference for round-shaped plants and red flowers indicates that traditional and familiar plant forms are associated with emotional bonds and habits. In terms of care practices, both groups maintain basic care habits such as regular watering and changing the pot/soil once a year, which indicates that indoor plants can be sustained in the nursing home environment over the long term.

The data obtained from the research reveals that both residents and staff in nursing homes show a high level of interest in indoor plants, but knowledge and practice levels in care applications remain limited. Most participants regularly perform basic care tasks such as watering and repotting, but their practices in pruning, fertilizing, and pest control are more superficial.

Particularly regarding fertilization, while the majority of participants stated that they used organic and solid fertilizers, it is noteworthy that they were unaware of the type of fertilizer used. This situation parallels studies in the literature showing that experiential knowledge-based plant cultivation is common in institutional care settings such as nursing homes (Rappe & Lindén, 2004). Similarly, the prominence of pesticide use in pest control poses risks in terms of ecological sustainability, highlighting the importance of educational programs promoting biological and mechanical methods (Han & Ruan, 2020).

The primary objectives of pruning and propagation practices being the removal of dead branches and propagation using stem cuttings indicate that older individuals are more concerned with maintenance care, while employees adopt a similar practical approach. These findings suggest that plant cultivation in elderly care settings is evaluated more in terms of ease of care and continuity.

The literature on environmental psychology and biophilic design emphasizes that the connection with nature not only provides psychological and physiological benefits but also supports individuals' feelings of control, belonging, and responsibility (Kaplan, 1995; Kellert, 2018). In this context, encouraging the active participation of individuals living in nursing homes in care processes such as watering, pruning, or propagation can increase their physical activity levels and contribute to their quality of life and sense of self-efficacy (Detweiler et al., 2012).

The higher level of regularity exhibited by employees in their care practices may be related to their sense of professional responsibility. However, knowledge gaps regarding plant care, particularly concerning fertilizer and pesticide use, are evident in both groups. Therefore, practical training programs for both elderly individuals and staff are recommended to enable indoor plants in nursing homes to be cultivated using more conscious and sustainable methods.

This research shows that indoor plants in nursing homes are not merely an aesthetic or decorative element, but also a multidimensional design component that affects individual well-being, social interaction, and ecological sustainability. However, in order to fully realize this potential, care practices must be supported by an approach that is knowledge-based, sustainable, and encourages user participation.

5. Results

This study, based on survey findings conducted in nine nursing homes in Antalya, shows that indoor plants are highly accepted by elderly individuals and staff and generate strong positive emotions. A significant proportion of participants grow plants; perceptions of happiness, peace, and relaxation are almost unanimously confirmed. Plants, positioned more in rooms for residents, support feelings of privacy/belonging, while in common areas for staff, they support spatial aesthetics and social interaction. The preference of staff for decorative foliage types and that of elderly individuals for traditional forms and red flowers indicates the existence of different functional and symbolic expectations according to user groups.

In contrast, knowledge and practice depth in care practices are limited: Pruning is mostly limited to removing dry branches; fertilization is infrequent and mostly done with “unknown” solid/organic products; and in pest control, the widespread but “unknown content” use of chemical pesticides is prominent. This picture highlights the need for systematic guidance and training for the sustainable and safe management of indoor plants at the nursing home level.

In such spaces, priority should be given to species that tolerate low light and irregular care, are non-toxic, thornless, and require minimal maintenance. A balance should be struck between species with high ornamental leaf value (to meet employee expectations) and species that satisfy the demand for flowers/color (to meet the expectations of older individuals), taking user preferences into account. Species requiring easy maintenance should be preferred. For example, Spathiphyllum (peace lily), Chlorophytum comosum (spider plant), Sansevieria trifasciata (snake plant), and Dracaena species stand out for their tolerance to low light and irregular watering (Wolverton, Johnson & Bounds, 1989). Flowering species can be used especially in individual rooms because they elicit positive emotional responses in older individuals (Rappe & Lindén, 2004). Allergenic and toxic plants (e.g., Dieffenbachia) should be avoided. Small plants that are easy to care for personally should be preferred in individual rooms, thereby strengthening the sense of belonging and control. Decorative foliage plants and species with a high volumetric effect can be used in common areas (lounges, dining areas). This practice enhances the aesthetics of the space while also supporting social interaction. Window sills and atriums contribute to the longevity of plants thanks to the advantage of natural light. Small to medium-sized, round/easy-to-control forms should be preferred in individual rooms; column/narrow forms that do not obstruct circulation should be preferred in common areas. Plants should be placed according to their ecological requirements (light/humidity/heat), and “care” should be taken for each location. The active participation of older adults in plant care should be encouraged. Activities such as simple watering or leaf cleaning provide physical activity and increase psychosocial benefits (Collins & O'Callaghan, 2009). Involving employees in plant care can strengthen their sense of belonging to the space. In terms of care practices: the tendency to water every 2–3 days should be verified with a sensor or simple finger test according to pot volume/ambient temperature; drainage pots and tray use should be standardized to prevent the risk of overwatering. Pot/soil replacement should be linked to an annual cycle protocol; ready-made peat+perlite mix or sterile contents should be preferred.

Pruning/propagation of plants: Not only maintenance but also health and form pruning should be scheduled; simple step-by-step guides should be prepared for propagation using stem cuttings. Fertilization of plants: Following the principle of "low dose, infrequent application," species-specific, labeled products should be used; application records should be kept. For pest and disease management, an Integrated Pest Management (IPM) protocol should be adopted, which includes cultural/mechanical (cleaning, ventilation, isolation), then biological (natural oils/soaps, biocontrol), and finally targeted chemical approaches; the products used and dates should be recorded.

Short workshops should be organized for both employees and elderly individuals (watering, lighting, fertilizer literacy, IPM basics). The active participation of elderly individuals in daily/weekly micro-tasks (watering control, leaf cleaning) should be encouraged; this supports self-efficacy and quality of life indicators. Both plant health and user experience should be monitored using a simple "plant care card" (watering/fertilizer/pest observation) and a satisfaction-mood survey every three months; species and placement should be revised based on findings. Regular cleaning, leaf dust control, and pot positioning measures should be standardized to prevent soil spillage, allergens/pollen, and slip-and-fall risks.

It is recommended that plants be evaluated not only for decorative purposes but also within therapeutic horticulture programs. Such applications can contribute to stress reduction, cognitive vitality preservation, and quality of life improvement in older adults (Detweiler et al., 2012). Furthermore, considering the finding that plants received as gifts strengthen social bonds, plant gifting can be encouraged in institutional events. In conclusion, indoor plants are a widely accepted, low-cost design tool that enhances individual well-being, spatial quality, and social interaction in nursing homes. The continuity of the effect is possible through the selection of the right species, placement appropriate to ecological requirements, simplified maintenance protocols, IPM-based pest management, and structured training/participation programs. In this context, the preparation of internal guidelines that translate biophilic design principles into operational maintenance standards will ensure that research findings are permanently transferred into daily practice.

Thanks and Information Note

The article complies with national and international research and publication ethics. Ethics Committee approval was not required for the study. All authors contributed equally to the article.

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Evaluation of Children's Playgrounds in Terms of Plant Species, Construction Materials, and Landscape Maintenance Practices: The Case of Antalya

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Abstract

This study examines the design and maintenance criteria of children's playgrounds in four central districts of Antalya (Muratpaşa, Kepez, Döşemealtı, and Konyaaltı), focusing on planting design, landscape maintenance, and construction materials. Twenty playgrounds were selected according to age and size, and evaluated through on-site observations. Parameters included plant presence and care, suitability for age groups, play equipment and maintenance, safety, accessibility, flooring, and supporting urban furniture. Findings show that while all playgrounds feature some plant presence, maintenance is generally insufficient. Play equipment is available but lacks variety for different age groups. Safety and cleanliness are mostly ensured, whereas accessibility for disabled users is the weakest aspect. Flooring and supporting elements vary: some parks employ safe rubber surfaces, others rely on unsafe soil or hard materials. Species diversity also differs: Muratpaşa parks provide shade trees, Kepez parks emphasize shrubs, Döşemealtı relies on durable but limited species, and Konyaaltı stands out with greater richness and aesthetic quality. Overall, results indicate that playgrounds are relatively strong in natural assets and equipment availability but need significant improvements in maintenance, accessibility, and age-specific organization. Recommendations highlight enhancing shade with appropriate planting, standardizing safe flooring, ensuring universal accessibility, and adopting sustainable maintenance to improve ecological balance and user satisfaction.

Keywords: Children's playgrounds, planting design, Antalya, landscape maintenance, plant selection

1. Introduction

Open spaces are one of the most important fundamental elements of urban structure and are defined as clearings and vacant areas outside of architectural structures and traffic areas. In other words, open spaces are seen as areas without any development, where recreational opportunities are sufficient (İşçi 2017).

In the planning process carried out in our country, free and open spaces accepted as active green areas are open to the public; parks, gardens, beaches, and children's playgrounds are areas other than passive areas. Passive green areas are separated by strips, green refuges intended to separate residential buildings, and green areas. Furthermore, forest reserves and similar areas on private or public land that are not open to the public should also be considered passive green spaces. Debates have not yet brought the standard measurements in line with the conditions in

our country. The standards are related to the phenomenon of urbanization. It is emphasized that they should be used according to the intensity of urbanization pressures for the incoming or incoming population (Ayaşlıgil 1995). The open and green space standard is generally expressed as the number of square meters of open and green space per person. It is obtained by dividing the total green space of the city by the number of city residents. However, this expression is a quantitative approach. The scope of open and green spaces is as important as their equipment, functionality, and aesthetic qualities. The level of open and green spaces varies from country to country. Just as the age, culture, profession, and financial status of each city dweller differs, so do their green space needs.

Green spaces provide privacy by psychologically developing children's sense of comfort, privacy, and freedom. They can be designed for different purposes such as climbing, sitting on tree trunks, providing shade, protection from climatic factors, sitting and reading a book, or sleeping. Bright materials, geometric arrangements, and sharp lines are necessary to break monotony and add liveliness and movement. The selection of plants to be used should take into account the prevailing soil conditions, light and shade, climate, and dendrological factors (Uluğ 2008).

One of the general rules applied to determine open space and green space standards is that the larger the area, the larger the open space and green space (in hectares) should be, and the more equipped the necessary equipment should be (Ergin 1989).

City parks, which occupy an important place within urban open green spaces, often include children's play areas. Children and young people are the target group most affected by urbanization in Turkey. Therefore, there is a need for spaces and spatial organizations that will relax children, especially in city centers. Children's play areas are open spaces where children spend their free time, contributing to their physical and mental development. Since play areas and the materials used form the basis of children's games, the place where the game is played is of great importance.

The importance of children's playgrounds cannot be denied for children to participate in urban life through play activities and to raise developed generations. Children's playgrounds are places where children encounter nature in an urban environment consisting of buildings and perform exercises that develop their physical, psychological, and physiological structures with various elements. Children's playgrounds are one of the first places outside the home where a child, who is new to social life, can feel a sense of belonging and acceptance (İşçi 2017). In our country, the number of studies evaluating the plant design of children's playgrounds is quite limited (Cevher Kalburan 2014). It emphasizes that the areas where children often play outside are playgrounds close to their homes.

Research shows that children are interested in trees, flowers, and natural objects while playing; they enjoy moving freely on the grass (Özgüner and Şahin 2009). However, the following should be considered when selecting plants for playgrounds: The concept of space creation should be taken into account when selecting plants. Broad-leaved trees should be planted as much as possible. Planting should be done in a way that takes advantage of the autumn and spring sun. Fast-growing, mechanically damage-resistant, evergreen plants of various colors, weights, and sizes should be used. Plants with poisonous leaves, fruits, and flowers should not be used. For example, plants such as *Nerium oleander* L. (oleander) and *Ilex aquifolium* L. (holly) should not be placed in the playground (Türkan and Önder 2011).

Plants of appropriate height and density used in children's play areas not only control noise but also absorb harmful gases and eliminate dust and dirt particles; they purify the air by absorbing polluted air. Despite their limited characteristics, they also provide significant psychological benefits. They are also used as security fencing around some playgrounds. Therefore, the functions of plants should not be overlooked. The presence of small flower beds in the playground is also important for the happiness of children because of their interest in flowers (Uluğ 2008).

The aim of this study is to examine the existing plant life in children's playgrounds located in 20 neighborhood parks in the central districts of Antalya, namely Döşemealtı, Kepez, Muratpaşa, and Konyaaltı, and to evaluate them in terms of botanical design criteria, landscape maintenance practices, and construction materials.

1.1. Children's play areas

According to research by Bühler and Hetzer (1935), children's play period lasts from 2 months to school age. When basic learning begins, the time spent playing decreases at around 7 or 8 years of age. However, as children grow older, the nature of their play changes from indoor games to outdoor games. Children's games are divided into two categories based on location: outdoor games and indoor games. Based on game type, they are divided into action games, money games, logic games, and board games. It is also possible to divide games into those played with tools and those played without tools (Duman and Koçak 2013). Age, gender, health, economic status, climate, child development level, media, and the culture in which they live play a major role in the games children choose and play. The games chosen affect different aspects of a child's development at different important points. The area where the game will be played and the materials available in that area are also important when choosing a game (Bal 2005).

One of the areas children use regularly is playgrounds. Today's physical plans focus on natural play areas for children. In a study where a small forest, a natural area, was selected as a play area for children, the role of these areas in identifying the disadvantages of children in traditional play areas was investigated. The result of the research accepted that natural landscape areas are play areas that meet children's needs. It was emphasized that sloped, spacious grassy areas and planted play areas are beneficial for children's physical (motor) development. Play environments are the best and only ‘official’ outdoor spaces designed for children where the child-environment relationship can be observed in terms of child behavior (Aksoy 2011). For children to become spatially aware, they need to learn different concepts such as up-down, inside-outside, open-closed, right-left, near-far. The repetition of shapes, textures, colors, patterns, and sounds is important for children's learning. In reality, every area and environment has educational potential. Playgrounds provide children with information on shapes, sizes, numbers, relationships between parts, etc. (Alqudah 2003).

When selecting locations for children's playgrounds and gardens, the following should be considered: (Gökok et al. 1990; Alqudah 2003).

- Age distribution of the population within the planned area,
- Socio-economic characteristics of the population,
- Number of school playgrounds,
- Extent to which school playgrounds are open to the public outside of school hours,

- Local trends and habits,
- Climate characteristics,
- City size and proximity to nature—physical and psychological,
- Health characteristics of the population,
- Housing and population densities within the city

1.1.1. Plant Design Criteria for Children's Play Areas

The professional discipline of landscape architecture, which focuses on the protection, development, and organization of the natural and cultural environment in both urban and rural areas, undoubtedly plays an important role in plants and plant design. The use of plants is also very important in children's play areas. Research shows that playing in natural areas has a positive impact on child development. Natural elements such as climbing areas, sloping terrain, trees and shrubs, soil or sand surfaces, water, and large green spaces support children's physical development. At the same time, they help children learn about their bodies and limits and discover their abilities, playing a major role in developing their cognitive and creative skills. It has been found that symptoms of attention deficit disorder decrease in children after spending time in nature (Tandoğan 2020).

The extensive use of botanical elements in children's playgrounds provides rich opportunities for strengthening children's social relationships and developing their play skills and imagination. In this context, botanical designs for children's playgrounds should take climate and environmental conditions into account and consider the concept of space creation. The species to be used in planting should be selected from among those that are resistant to human damage, different from each other, and have attractive features for examination. They should be different from the tree and shrub species preferred in the design of open green spaces in city centers or generally used by adults (Ayaşlıgil 2005).

When planting, broad-leaved trees should be used as much as possible, taking into account the climatic conditions of the region. Trees with large fruits, seeds, branches, or other elements that could pose a danger when they fall, and plants that are the size of children should not be used. Considering the functional characteristics of plants, thorny and poisonous plant species should not be preferred. In addition, the presence of small flower beds within the children's play area will allow children to recognize flowers, making them happy (Muhacir 2016).

When selecting plant species, the existing soil conditions, light, shade, and climate conditions in the area should be taken into account (Uluğ 2007). According to Sorkun (1996), the criteria to be considered in the green spaces to be designed in these areas are as follows:

- Cut flowers and rare flowers should not be used in flower beds,
- Trees, shrubs, and bushes should not create situations that hinder various games,
- Trees should be located in areas where quieter games are played,
- The entrance area should be made attractive,
- Especially in areas for active games, children's need for sunlight should not be obstructed by large plants with broad canopies.

According to Acar (2003), in order to prevent noise from playgrounds located very close to schools or other residential areas, the plants selected for these areas must have the following characteristics:

- Plants with high noise reduction effects should be selected.
- Umbrella-shaped, scaly-leaved trees and shrubs that grow gradually from ground level to the crown should be planted in such a way that there are no wide gaps around them.
- Plants should be selected from species that show foliage and branching from the lower part of the trunk to the crown in their inner parts,
- Opportunities for the inner parts to benefit from sunlight should be provided as described above,
- The selected leafy plants should be evergreen species.

The area designated as a children's play area should receive sunlight for as long as possible during the winter season, especially during and after midday, and should provide shade and coolness in the afternoon during the summer season. An area that is too rugged is not highly preferred. The area should have good drainage and should generally be visible from many parts of the park. The area should be spacious and located at a certain distance from the sea, lakes, and rivers. Once the area is determined, the first task is to identify the age groups that will use it. Considering that misuse can lead to serious accidents, this identification must be done correctly (Yılmaz 2002).

1.1.2. Use of Construction Materials in Children's Play Areas

The primary concern in selecting construction materials for children's play areas is child safety. When choosing materials for play elements, hygienic and easy-to-maintain materials should be preferred in order to create a safe, sturdy, and healthy environment. At the same time, it should be considered that the materials should be attractive and fun for children. Raw metals should not be preferred because they carry the risk of producing toxic materials and are prone to rust. For this reason, wood, laminated plywood, polyethylene, steel or aluminum, textiles, and recycled plastics are more commonly used in playgrounds. The main reasons for using these materials are that they are more economical and durable. However, steel and aluminum materials, while strong and durable, have a structure that rusts over time, with welded joints wearing down and becoming sharp. Additionally, they can become quite hot when exposed to the sun in summer, limiting the use of the equipment. Wood is a good alternative to metal. This is because it is natural, easy to use, inexpensive, and creative. If synthetic materials such as plastic are preferred for playground equipment, the material used must be resistant to impacts such as breakage and bending. Beyond the positive and negative characteristics in play areas, the preference for recycled plastic material is important in terms of preventing unnecessary use of natural resources, providing economic savings, and creating environmentally friendly spaces (Tandoğan, 2020).

There is some uncertainty regarding flooring selection in children's play areas. This is because the flooring must be soft enough to protect children from possible injuries, yet durable and hard enough for wheelchairs, walkers, etc. For example, hard surface materials such as concrete, asphalt, artificial turf, gravel, and granite create a surface suitable for all weather conditions, but none of them are recommended for safety reasons. At the same time, sand and small-grained gravel comply with CPSC (United Nations Commission on Consumer Product Safety)

standards but do not comply with ADA standards. Grass surfaces are quite useful in natural recreational areas but are not preferred due to the problems they can cause in rainy weather (Bulut and Yılmaz, 2002).

In their study examining the safety of various playground surfaces and the quality and height of the play elements they contain, Mott et al. (1997) found that the safest surfaces for playgrounds are synthetic materials and wood chips, and that these materials can be used in all cities (Muhacir, 2016).

According to Anonymous (2006), before children are sent to a playground, it must be checked whether the playground is safe for them. When doing so, the following points should be considered:

- Supporting elements in any area of the playground should not be damaged or missing.
- There should be no sharp edges or points on any equipment.
- Wooden playground equipment should not be broken, splintered, or starting to rot.
- The floor coverings should not be made of materials that could cause injury to children if they fall,
- There should be no missing or damaged bolts, nuts, or screws on the play equipment,
- There should be no broken seating units,
- There should be no rust or bending in any of the metal structures,
- Chains, rings, hoop connections, or seating areas on various play equipment should not be damaged,
- There should be no breaks or missing parts on railings and stairs that could cause children to fall.

If any of these are present in play areas, the play area is not sufficiently safe for children and necessary precautions must be taken (Uluğ, 2007).

1.2.3. Landscape Maintenance Practices in Children's Play Areas

The implementation of design and application studies that create the aesthetic, protected, and restored areas resulting from the design of urban and rural landscapes in harmony with nature forms the structure of the management approach in landscaping. Therefore, the management phase following the implementation of children's playgrounds constitutes a fundamental part of this structure. Even the best design, if poorly managed, loses its functionality and, over time, becomes an unused area posing a risk of accidents. For this reason, local governments bear a great responsibility. After the design of children's playgrounds, they must be continuously monitored, broken or rusted playground elements must be maintained, and precautions must be taken against situations that could cause accidents and injuries. Since children are an important part of society, children's playgrounds should be designed in urban and rural landscapes. Children's playgrounds should be planned throughout the city, in every district and neighborhood, adopting a socioeconomically equitable approach.

The design of each planned playground should be carried out by landscape architects, and the children's play elements to be used should comply with safety and ergonomic standards set by experts. Play elements should be placed with safety in mind. Playgrounds should be designed

with plants that are suitable for children's health (without features that could harm children, such as thorns or poisonous fruits) and plants that make play safe. A regulatory body should be established to oversee maintenance and repair work in the designed and implemented area.

In order for children to play safely, all design details of each playground must be preserved, maintained, and updated. If the planning, design, and management flow are ensured to work smoothly, the play system is designed together with the child and establishes a connection between play and the individual's self-confidence. Therefore, ensuring the safety of play areas should be a task that local governments and planning and design experts take seriously (Bulut and Kılıçaslan 2009). Local governments should pay attention to quality and quantity when constructing and installing playgrounds and play elements. Regular maintenance of play elements helps children spend their playtime more efficiently (Memiş and Gülcan 2020).

Playground design ideas that support children's physical, mental, social, and environmental development, that include areas where children with disabilities can also play, and that feature not only artificial materials but also natural materials should be researched, and children's expectations of playgrounds should be met (Arslan 2023).

Accordingly, we can say that landscape maintenance practices in children's playgrounds involve various processes carried out to ensure that playgrounds are safe, healthy, and attractive to children. The basic elements of landscape maintenance practices in children's playgrounds can be listed as follows:

-Ground Maintenance:

- Playground surfaces are usually made of soft and safe materials. Regular maintenance of these surfaces is important to prevent injuries in the event of a fall.
- This includes removing irregularities in the ground, repairing cracks, and cleaning stones.

-Plant and Tree Maintenance:

- Maintaining the plants and trees that make playgrounds attractive is important. Regular pruning should be performed, and measures should be taken against harmful insects and diseases.
- It is important to check tree branches for the risk of falling and, if necessary, prune them for safety purposes.

- Play Equipment Maintenance:

- All play equipment in the playground should be regularly inspected and maintained. This includes replacing broken or dangerous parts and sanding down boards.
- Metal equipment should be regularly maintained to prevent freezing and rusting.

- Safety Inspections:

- Playgrounds should undergo regular safety inspections. These inspections should verify compliance with safety standards to prevent children from encountering potential hazards.

- Playground Cleaning:

• Keeping playgrounds clean and tidy is important for children's health. Regularly cleaning up trash generated by activities ensures children play in a clean environment.

-Water and Drainage Systems:

• The drainage of playgrounds should be checked regularly, and any problems should be addressed immediately. Puddles and areas that frequently accumulate water can be breeding grounds for mosquitoes, so water management is important.

- Safety Markings and Instructions:

• The markings necessary for safety in playgrounds should be checked and updated regularly. Appropriate instructions and markings are important to prevent children from entering dangerous areas.

These practices are important to ensure that children's playgrounds are safe and attractive to use. Regular maintenance ensures that playgrounds are durable and that children can play healthily. The purpose of this study is to examine the existing plant life in children's playgrounds located in 20 neighborhood parks in the central districts of Antalya, namely Döşemealtı, Kepez, Muratpaşa, and Konyaaltı, and to evaluate them in terms of botanical design criteria, landscape maintenance practices, and construction materials.

2. Material and Methods

2.1 Material

The research material consists of 20 children's parks located in the four major districts of Antalya province (Muratpaşa, Konyaaltı, Kepez, and Döşemealtı). The Parks and Gardens Directorates of each of the four districts were consulted, and information on the size, year of construction, and availability of children's play areas in the parks listed in the existing zoning plans was obtained. When selecting the parks, five parks were chosen from each district based on their being at least 10 years old and having an area of 2,000 square meters or more, resulting in a total of 20 parks being studied. The parks and the districts they are located in are indicated in Figure 1.

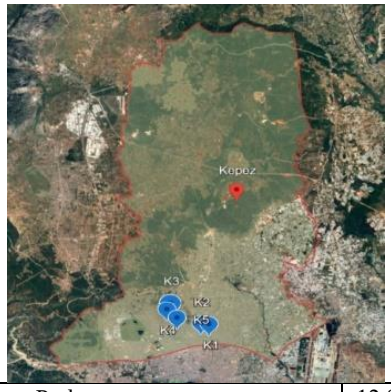
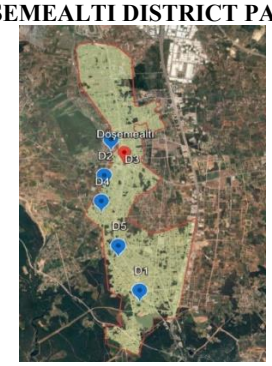
MURATPAŞA DISTRICT PARKS		KEPEZ DISTRICT PARKS	
			
M1: Büyüklüdere Park	5.586 m²	**K1:** Sakarya Park	12.824 m²
M2: Aydın Kanza Park	8.724 m²	**K2**: Şehitler Park	3.800 m²
M3: Öner Bozkurt Park	10.740 m²	**K3**: Seyir Terası Park	15.000 m²
M4: Beşşehitler Park	9.094 m²	**K4**: Yavuz Sultan Selim Park	2.033 m²
M5: Köy Enstitüleri Park	5.530 m²	**K5:** Atatürk Park	4.690 m²
DÖŞEMEALTI DISTRICT PARKS		**KONYAALTI DISTRICT PARKS**	
			
D1: Atalan Park	7.782 m²	**Ko1:** Kaymazlar Park	4.930 m²
D2: Atatürk Park	5.209 m²	**Ko2**: Expo 2016 Park	5.106 m²
D3: İbrahim Kolak Park	2.088 m²	**Ko3**: Kavaklar Park	4.930 m²
D4: Mevlana Park	8.855 m²	**Ko4**: 23 Nisan Ulusal Egemenlik Park	46.183 m²
D5: Gazi Ramazan Sarıyar Park	4.234 m²	**Ko5:** Şehit Akil Demiral Park	3.660 m²

Figure 1. Locations and sizes of parks included in the study area

2.2 Methods

The research method is summarized under eight main headings, as indicated in the method flow chart in Figure 2. (1) Identification of the research topic: Defining the central focus of the study based on the overarching research problem and objectives. (2) Determination of the study area: Selection of a representative geographic or contextual site that aligns with the research scope and objectives. (3) Formulation of research objectives: Establishing specific, measurable, and theoretically grounded aims that guide the study. (4) Comprehensive literature review: Domain-Specific Literature Review: Examination of prior studies, theories, and conceptual frameworks directly related to the selected study area. Topic-Oriented Literature Review: Systematic evaluation of scholarly work and empirical evidence pertinent to the broader research theme. (5) Field Data Collection: Direct Observations: On-site examination of spatial, environmental, and functional characteristics. Visual Documentation: Systematic photographic recording to support spatial and qualitative analysis. (6) Synthesis and Critical Assessment of Existing Child Playgrounds: Comparative and evaluative analysis of current playground conditions based on

collected field data and literature. (7) Data Analysis: Employing both qualitative and quantitative analytical techniques to identify patterns, deficiencies, and strengths. (8) Formulation of Recommendations: Developing evidence-based proposals and design guidelines, informed by analytical results and aligned with best practices in urban design, environmental psychology, and child development theory.

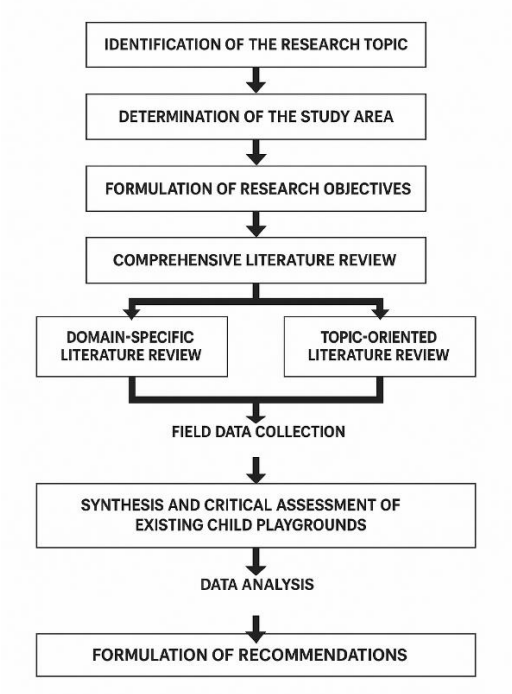


Figure 2. Methodological framework

3. Findings and Dissusion

The parks examined in the study were evaluated in terms of existing plant life and maintenance, suitability for different age groups, existing play equipment and maintenance, safety, accessibility for people with disabilities, presence of ground cover materials, and fixtures (Table 1).

Although plant life was observed in all parks in the Muratpaşa district, plant maintenance practices were found to be inadequate. Play equipment was present in all parks, but the variety suitable for different age groups was limited. Safety and cleanliness criteria were generally met. However, there were very few arrangements for disabled access. Although ground materials and fixtures were adequate in some parks, a comprehensive standard could not be achieved. This situation reveals that central parks are strong in terms of natural assets but weak in terms of accessibility and maintenance.

All parks examined in the Kepez district have plant life, but maintenance activities have been carried out to a limited extent. Although playground equipment is widely available, it has been observed that safety conditions are not fully met. Regulations regarding disabled access are quite limited. There are various deficiencies in terms of ground materials and fixtures. In the vast majority of parks, areas have not been arranged according to age groups. In general, Kepez parks stand out for their play equipment, but need improvement in terms of maintenance, fixtures, and accessibility.

All parks in the Döşemealtı district have vegetation, but maintenance practices are inadequate. Play equipment is mostly available, and safety and cleanliness criteria are largely met. However, regulations for disabled use are quite limited. Floor materials were found to be suitable in some parks, while deficiencies were identified in others. Furnishings are partially available. These results show that Döşemealtı parks are adequate in terms of basic furnishings but problematic in terms of accessibility and regular maintenance.

While all parks in Konyaaltı district have vegetation, the lack of maintenance activities is noteworthy. Playground equipment is more diverse compared to other districts, and safety criteria are largely met. However, accessibility features for people with disabilities remain limited. Ground surfaces and fixtures are generally in better condition. Expo 2016 Park, in particular, stands out from other parks in terms of equipment and scope. Arrangements according to age groups have only been made in a limited number of parks. Although Konyaaltı parks are generally better equipped than those in other districts, they have significant shortcomings in terms of accessibility.

Table 1. Evaluation of the current status of work area parks according to design criteria

Design criteria	**Working Areas (Park No)**																			
	M1	M2	M3	M4	M5	K1	K2	K3	K4	K5	D1	D2	D3	D4	D5	KO1	KO2	KO3	KO4	KO5
Plant inventory	+	+	-	-	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+
Plant maintenance	+	+	-	-	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+
Type of play equipment	+	-	-	+	+	+	+	+	+	+	+	+	+	-	-	--	+	+	+	--
Safety	-	+	+	+	-	+	-	+	-	+	+	+	-	+	+	+	+	+	+	+
Playground cleaning	+	+	-	+	+	+	+	+	-	+	+	+	+	-	+	+	+	+	+	+
Accessibility for disabled users	+	+	-	-	+	+	+	+	-	+	+	+	-	+	+	+	+	+	+	+
Ground cover materials	+	+	-	+	-	+	-	-	+	+	+	+	+	+	+	+	+	+	+	+
Analysis of parks by age group	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Furnishings	+	-	-	-	-	+	-	+	-	+	-	+	-	-	-	+	+	--	+	+
Analysis of plant species	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+

The examination of the study areas revealed that all parks have vegetation, but plant maintenance is mostly inadequate. Although playground equipment is widely available, there are noticeable deficiencies in terms of suitability for age groups. Safety and cleanliness criteria are generally met, but accessibility for people with disabilities emerged as the weakest criterion

in all areas. Although ground materials and fixtures were adequate in some parks, a standard consistency could not be achieved across the districts. Consequently, the parks examined were found to be strong in terms of natural features and play equipment, but areas for improvement were identified in maintenance, accessibility, and age-group-specific design criteria.

Although there are differences between districts according to the findings, some common trends in the structural and botanical design features of children's play areas are noticeable. In terms of furnishing elements, it was determined that a significant portion of the parks have seating units, trash cans, and lighting elements, but these elements are insufficient in number or irregularly distributed. While the fixtures in some parks are considered positive in terms of maintenance and functionality, deficiencies are particularly noticeable in small-scale parks. When examining the ground materials, it was found that grass, soil, and rubber surfaces are used, but soil and hard ground applications pose safety risks. Examples using rubber flooring were positively evaluated in terms of child safety. In terms of play equipment, it was observed that maintenance and repairs were carried out regularly in some parks, but in some parks, the equipment was old, neglected, and potentially dangerous. The variety of play equipment was limited. In terms of botanical design, while all parks had a certain level of plant life, the lack of shade-providing trees and the fact that some plants posed a risk to child safety were among the negative features. In most parks, plants were used for restrictive or functional purposes rather than for aesthetic purposes. In terms of safety criteria, while some parks are located away from vehicle roads and are accessible, risks such as lakes, hard surfaces, or unkempt fences have been identified in others. This situation reveals that safety varies between parks. In terms of accessibility, most parks are located in easily accessible locations, but it has been determined that arrangements for disabled access are quite limited.

Overall, the large-scale, well-maintained parks in Konyaaltı district serve as positive examples. In contrast, many parks in Muratpaşa, Kepez, and Döşemealtı districts have various deficiencies in terms of maintenance, safety, ground coverings, and fixtures. This situation highlights the need to improve children's play areas in terms of safety, functionality, and aesthetics.

In addition, the existing plant life in the parks has been identified and is presented in Table 2. While plant diversity is relatively high in the park areas in the Muratpaşa district, shade-providing and aesthetically valuable tree species such as Pinus pinea, Jacaranda mimosifolia, Morus alba, and Olea europaea stand out. In the shrub group, Bougainvillea spectabilis, Hibiscus syriacus, and Nerium oleander are frequently used. However, species diversity is limited in small-scale parks, creating park-specific differences rather than a homogeneous plant distribution.

In the parks of Kepez district, *Platanus orientalis*, *Quercus cerris*, and *Gleditsia triacanthos* stand out among tree species. These species are notable for their resilience. *Ligustrum vulgare, Duranta erecta,* and *Pittosporum tobira* are commonly preferred shrub species. Although there is relatively high shrub diversity in Kepez parks, tree species diversity is limited. This situation creates deficiencies in terms of shading and microclimate formation and indicates that the parks need to be improved in terms of user comfort.

Tablo 2. Distribution of tree and shrub species identified in park areas in the districts of Muratpaşa, Kepez, Döşemealtı and Konyaaltı

	Working Areas (Park No)																			
Parks	M 1	M 2	M 3	M 4	M 5	K 1	K 2	K 3	K 4	K 5	D 1	D 2	D 3	D 4	D 5	KO1	KO2	KO3	KO4	KO5
Trees																				
Pinus pinea	--	--	- -	- -	+	- -	- -	- -	- -	- -	+	+	- -	+	- -	--	--	--	--	--
Washingtonia robusta	+	--	- -	- -	- -	+	+	- -	+	- -	- -	+	- -	+	- -	--	+	+	+	--
Jacaranda mimosifolia	--	+	+	+	- -	+	- -	+	- -	+	+	+	- -	+	+	+	+	+	+	+
Salix babylonica	+	+	- -	+	- -	+	+	+	- -	+	+	+	+	- -	+	+	--	--	+	+
Populus alba	+	+	- -	+	- -	+	- -	- -	+	+	- -	+	- -	+	- -	+	+	--	+	+
Olea europaea	+	+	+	- -	+	+	- -	+	- -	+	+	- -	+	+	- -	+	--	--	--	+
Melia azedarach	--	--	- -	- -	- -	+	+	- -	- -	- -	- -	- -	+	- -	- -	--	--	--	+	--
Morus alba	+	--	- -	- -	- -	+	- -	+	- -	+	- -	+	- -	- -	- -	+	--	--	--	+
Platanus orieantalis	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Cupressus sempervirens	+	+	- -	- -	- -	+	+	+	- -	+	+	+	+	+	- -	--	--	+	+	--
Citrus aurantium	--	--	- -	+	- -	- -	+	- -	- -	+	- -	+	+	- -	+	+	--	--	--	+
Shrubs																				
Lantana camara	+	+	- -	- -	- -	+	+	- -	+	- -	+	+	- -	- -	- -	+	--	--	+	--
Buxus sempervines	+	+	+	+	- -	+	+	- -	- -	+	+	+	- -	+	+	+	--	--	+	+
Viburnum opulus	+	+	+	- -	- -	+	+	+	- -	- -	+	+	+	+	+	--	--	+	+	+
Laurus nobilis	+	+	+	- -	+	+	- -	- -	+	+	- -	+	- -	+	- -	+	+	+	+	--
Nerium oleander	+	--	+	+	- -	- -	+	+	+	- -	- -	+	+	- -	+	+	+	--	--	---
Thuja orientalis pyramidalis	--	--	+	+	+	- -	- -	- -	- -	+	+	- -	+	- -	- -	--	+	+	--	--
Photinia red robin nana	--	+	+	- -	- -	- -	- -	- -	- -	+	+	- -	- -	- -	+	---	--	--	+	+
Callistemon citrinus	+	--	+	- -	- -	- -	+	+	- -	- -	- -	+	+	+	- -	--	--	+	--	--

Parks in Döşemealtı district are characterized by *Pinus pinea* and *Cupressus sempervirens*, which are species resistant to climatic conditions. In the shrub group, *Nerium oleander* and *Bougainvillea spectabilis* stand out. However, the parks have a limited structure in terms of species diversity. In particular, the scarcity of plants that provide aesthetic value and seasonal color diversity limits the landscape quality of these parks. Therefore, the parks in Döşemealtı need to be enriched in terms of plant material.

The parks in the Konyaaltı district exhibit a stronger profile in terms of plant diversity compared to other districts. Expo 2016 Park (KO2) is particularly noteworthy for its extensive collection of species. This park features a balanced use of both shade-providing tree species *(Jacaranda mimosifolia, Olea europaea, Platanus orientalis*) and shrub species (*Hibiscus syriacus, Bougainvillea spectabilis, Callistemon citrinus*). Therefore, Konyaaltı parks stand out in terms of landscape aesthetics, plant diversity, and functionality.

An analysis conducted on a district basis revealed that Muratpaşa parks are rich in shade trees, Kepez parks are strong in shrub diversity, Döşemealtı parks are limited to more resilient species, and Konyaaltı parks are the most developed areas in terms of plant diversity and aesthetics. These results indicate that there are district-based differences in the selection of plant material for parks. Improvements are needed in all districts, particularly in terms of maintenance practices, aesthetic concerns, and diversity.

4. Discussion

Research findings indicate that children's playgrounds in four different districts of Antalya have various structural and botanical deficiencies. Although the presence of plants in all parks is considered a positive development, inadequate maintenance practices limit the functionality of this presence. The literature (e.g., Erdoğan, 2019; Korkut and Yılmaz, 2021) also emphasizes that playgrounds gain quality not only through fixtures and equipment but also through regular maintenance and ecological continuity. In this context, the current findings are consistent with the literature and reveal that maintenance deficiencies directly affect the quality of use of children's playgrounds.

In terms of play equipment, it was determined that most of the parks examined had basic equipment, but the variety according to age groups was limited. This situation shows that the physical and social needs of children in different age groups are not sufficiently met. Similarly, Çelik et al. (2020) drew attention to the importance of play designs that appeal to different age groups on child development. In this context, the findings reveal that existing play areas are lacking in terms of inclusivity.

When safety criteria were evaluated, accessible location, distance from vehicle roads, and lighting elements stood out as positive features in some parks, while hard surface applications, unmaintained fences, and locations near lakes were identified as risk factors. Although research on child safety (Fjortoft, 2004; Herrington & Brussoni, 2015) indicates that encountering natural risks may have positive contributions to child development, ensuring safety standards in urban playgrounds is considered a priority requirement. Therefore, the findings of the study emphasize the need for improvement in terms of child safety.

When examined in terms of accessibility for people with disabilities, accessibility was found to be the weakest criterion in all districts. This contradicts universal design principles. The literature (Preiser & Ostroff, 2001; Moore & Cosco, 2010) also states that playgrounds should

be designed to be equally accessible to all children. This finding shows that existing parks are far from inclusive and require urgent improvements.

Differences were observed between districts in terms of plant diversity. Muratpaşa parks are strong in terms of shade trees, Kepez parks stand out for their shrub diversity, and Döşemealtı parks are characterized by more resilient but limited species. Konyaaltı parks, on the other hand, exhibit a more developed profile in terms of plant diversity and aesthetics. This situation shows that the selection of plant species in urban playgrounds depends not only on ecological conditions but also on aesthetic and functional concerns. Previous studies (Kendle & Forbes, 1997; Çelikyay, 2018) have also emphasized that plant diversity not only creates aesthetic value but also increases user satisfaction through its microclimate-regulating effect.

Overall, common problems identified across all study areas include lack of maintenance, absence of designs suitable for disabled access, non-standardized ground coverings, and insufficient variety of play equipment. While large-scale and well-maintained parks in the Konyaaltı district provide positive examples, parks in the Muratpaşa, Kepez, and Döşemealtı districts are seen to be in need of significant improvements. These findings highlight the need to re-evaluate children's play areas in terms of safety, accessibility, plant diversity, and maintenance criteria, producing results consistent with sustainable, inclusive, and functional play area approaches in the literature.

5. Results

Findings regarding the current state of parks point to deficiencies, particularly in maintenance, inadequate accessibility for people with disabilities, and a lack of play areas tailored to different age groups. Therefore, it is recommended that regular maintenance programs be established in park management and that practices ensuring the continuity of plant health be increased. Adding equipment that caters to different age groups in play areas will increase user diversity. Ensuring accessibility standards for individuals with disabilities will support the inclusive use of parks. Furthermore, ensuring that ground materials meet safety criteria, standardizing the placement of fixtures (seating areas, trash cans, lighting, etc.) in all parks, and ensuring the continuity of cleaning activities will be important steps in increasing the functionality of parks and user satisfaction.

In the 20 parks we examined in 4 districts of Antalya province, woody species were generally used. The 20 parks examined in the study featured 19 plant species, including trees and shrubs. The research showed that the parks need to be improved in terms of plant material. It is important to establish regular pruning, watering, and maintenance programs to protect existing plants. In addition, adding new species to parks with limited species diversity and using flowering trees and shrubs that provide seasonal color changes will add aesthetic value. Preferring local and resilient species that are compatible with Antalya's climatic conditions will reduce maintenance costs while contributing to biological diversity. Increasing shade-providing trees, especially in Kepez and Döşemealtı parks, will enhance user comfort. It is recommended that shrub groups be used more consciously for boundary demarcation, guidance, and visual integrity. Furthermore, the widespread use of drip irrigation systems for water conservation and the adoption of xeriscape principles will contribute to the sustainable management of parks.

In the botanical design of children's play areas, it is crucial that plants provide functional contributions. However, care should be taken to select plant taxa that are non-toxic, non-prickly, and non-allergenic for functional purposes. Shrub taxa that are toxic, prickly, or allergenic and

could harm children, and that are small enough for children to easily touch and reach, should not be used in children's play areas. However, plant taxa with minimal harmful effects can be used in children's play areas to provide specific functional contributions at distances away from play areas and at points where the likelihood of direct contact by children is very low. This is because when plant taxa are evaluated according to their poisonous, allergenic, or toxic properties, it is seen that almost all plants possess these toxic properties to a greater or lesser extent.

Considering that plants stimulate the senses of touch, sight, smell, taste, and hearing (Kiper, 1999), it is important to use plant taxa with different colors, textures, forms, and sizes, provided they are harmless, and to create botanical designs that emphasize seasonal changes. In children's play areas, considering that children will come into contact with plants and may use them as play materials, the selection of plant taxa that may be harmful to health should be avoided. Plants, which play an important role in defining natural areas, should be diverse in terms of color, texture, form, and size in the compositions of botanical designs in children's play areas. in terms of color, texture, form, and size, positively affect children's mental and psychological development. They also provide benefits such as highlighting different play areas, directing children to different points, providing shade in some areas, delimiting areas, screening views and noise, and creating spaces.

Within the scope of this study, it was determined that suitable plants were not used in 60% of the parks in the Muratpaşa district, 80% of the parks in the Kepez and Döşemealtı districts, and 50% of the parks in the Konyaaltı district. The *Nerium oleander* (oleander) plant, whose leaves are poisonous, is found in 11 parks in the districts of Muratpaşa, Kepez, Döşemealtı, and Konyaaltı, which is approximately 60% of the parks studied. The fruits of the Melia azedarach (johannes tree) are also dangerous for children. It is also found in 4 of the 20 parks in the districts we researched.

Within the scope of this study, 20 children's playgrounds located in the districts of Muratpaşa, Kepez, Döşemealtı, and Konyaaltı were evaluated in terms of their structural and botanical characteristics. The findings revealed that all playgrounds had a certain level of plant life, but that shade-providing trees were mostly insufficient. In terms of fixtures, seating, trash cans, and lighting elements were found to be adequate in some parks, while these elements were lacking in others. When examined in terms of ground materials, grass, soil, and rubber surfaces were used, but soil and hard surfaces were observed to pose a risk to child safety. While playground equipment is regularly maintained and repaired in some parks, it was found to be neglected and outdated in many others. In general, parks in the Konyaaltı district serve as positive examples, while many parks in the Muratpaşa, Kepez, and Döşemealtı districts have deficiencies in terms of maintenance, safety, and fixtures.

Based on the findings, several recommendations have been developed to make children's play areas safer, more functional, and more aesthetically pleasing. First, play equipment must be regularly maintained and repaired, and hard surfaces that pose a safety risk must be replaced with suitable materials such as rubber. The number and quality of fixtures in parks should be increased, and lighting, seating, and trash cans, in particular, should be standardized throughout all areas. Increasing the number of shade-providing trees in the botanical design and using species with high aesthetic value will improve user comfort and landscape quality. Furthermore, it is important to remove plant species that could pose a danger to children from parks. The inclusive use of parks can be supported by making arrangements suitable for disabled access.

Finally, adopting sustainable landscaping principles in all arrangements will increase functionality and user satisfaction in the long term while preserving ecological balance.

Thanks and Information Note

The article complies with national and international research and publication ethics. Ethics Committee approval was not required for the study. All authors contributed equally to the article.

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Geotourism Activities in Geoparks and Their Relationship with Nature Conservation Areas

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Abstract

Geoparks are designated conservation areas that combine scientific, educational, and touristic functions with the overarching aim of safeguarding and sustainably utilizing natural and cultural heritage. Distinguished geological features such as fossil beds, volcanic formations, caves, fault lines, and diverse geomorphological elements form the foundation of geoparks, offering opportunities for nature-based learning and experiences. Through geotourism, geoparks contribute to the promotion and preservation of geological heritage while also fostering local economic development and job creation. The relationship between geoparks and protected areas holds strategic importance for achieving holistic conservation. While protected areas generally focus on maintaining biodiversity, ecosystems, and landscape integrity, geoparks introduce a multilayered conservation and promotion model that encompasses both geological formations and cultural-historical elements. Consequently, many geoparks overlap with or complement national parks, nature parks, and biosphere reserves, thereby enhancing the overall effectiveness of conservation networks. This paper explores cooperation mechanisms between geoparks and protected areas and evaluates their impact on heritage conservation, sustainable use, and geotourism development. It highlights how geoparks advance education, awareness, and local development strategies within the frameworks of ecotourism and geotourism, while integrating with protected area management and sustainable tourism policies. The findings suggest that geoparks represent more than geological conservation zones. They serve as dynamic models of sustainable development, simultaneously contributing to the protection of natural and cultural heritage, the socio-economic empowerment of local communities, and the enhancement of environmental awareness. In this respect, geoparks not only safeguard geological heritage but also strengthen the resilience and sustainability of broader conservation and tourism systems.

Keywords: Geopark, geological heritage, geotourism, nature conservation

1. Introduction

In recent years, the conservation and sustainable use of natural and cultural heritage have become increasingly significant on a global scale. Throughout human history, the value of natural and cultural heritage has been recognized, and various efforts have been undertaken to ensure its transmission to future generations. However, factors such as rapid urbanization, industrialization, environmental degradation, and tourism pressure pose a threat to both natural and cultural heritage, putting them at risk of disappearance. In response to these threats, the concept of geoparks has emerged with the aim of protecting geological formations

and natural landscapes, and passing them on to future generations by integrating them into educational and tourism activities.

The concept of a geopark was officially defined and announced for the first time in 2000 by the United Nations Educational, Scientific and Cultural Organization (UNESCO). Geoparks are special areas where landscapes and sites of international geological significance are managed with an integrated understanding of conservation, education, and sustainable development (UNESCO National Commission of Türkiye, 2025). Containing rare geological formations, fossil beds, volcanic structures, caves, and other geomorphological features, geoparks play a critical role in the conservation of geological heritage (Brilha, 2016). They also support biodiversity, contribute to the continuity of ecosystems, and serve the protection of the natural environment (UNESCO Global Geoparks Network, 2025). Through the preservation of the geosites they contain, the dissemination of knowledge about the natural environment through educational activities, and the social and cultural contributions they provide to local communities, geoparks enable the safeguarding of geological heritage within a sustainable model (Karataş, 2023). Furthermore, these areas offer visitors opportunities to directly observe and learn about geological processes and the history of the Earth.

In this context, geotourism stands out as a type of tourism that focuses on visiting geological formations and aims to experience and learn about geological processes (Gümüş, 2008). Geotourism makes significant contributions to the protection of the natural environment, the promotion of geological heritage, the support of scientific education, and the encouragement of sustainable tourism (Yıldız, 2017; Vural & Külekçi, 2021). It also supports the local economy, contributes to regional development, and enhances community well-being. Through geotourism activities carried out in geoparks, visitors are provided easier access to geological heritage; this process creates a dual benefit that supports both educational engagement and environmental conservation.

The International Union for Conservation of Nature (IUCN) defines protected areas as “areas of land or sea especially dedicated to the protection and maintenance of biological diversity and of natural and associated cultural resources, and managed through legal or other effective means” (IUCN, 1994). Although geoparks emerged with the primary purpose of conserving and educating about geological heritage, they also offer a conservation approach that encompasses biodiversity, which places them in close relation to nature conservation areas. Indeed, many geoparks can be evaluated as structures that overlap with or complement protected area statuses such as national parks, nature parks, or biosphere reserves.

For an area to be designated as a geopark, it must meet the scientific, managerial, and sustainability-oriented criteria set by UNESCO. Today, there are a total of 213 UNESCO Global Geoparks in 48 countries that fulfill these criteria, and this number continues to increase each year (UNESCO Global Geoparks Network, 2025). China, with 47 Global Geoparks, is the country with the highest number of registered geoparks worldwide.

Türkiye ranks among the countries with high geotourism potential due to its rich geological structure and diverse natural landscapes. In recent years, many areas have been proposed as

geopark candidates for the protection of geological heritage and the development of geotourism; however, the only site currently registered in the UNESCO Global Geoparks Network is the Kula–Salihli Geopark. This demonstrates that Türkiye holds significant potential for promoting its geological heritage at the international level, supporting the local economy through geotourism, and contributing to sustainable development goals.

2.Geoparks

Geoparks are special areas where rare geological formations are found, containing numerous geosites of the same or different types within a space that exceeds walking scale, and possessing both scientific and economic value (Akbulut & Ünsal, 2012; JEMİRKO, 2025). The geological heritage that forms the basis of these areas refers to the set of natural elements that reflect the Earth's geological history, formation processes, and evolution, and therefore require protection (Ekiz, 2015). The conservation and development of sites containing geological heritage hold strategic importance for advancing scientific research, increasing societal awareness of natural processes, sustaining education and cultural heritage, and supporting economic development. These areas shed light on human history while preserving traces of the past and unique natural landscapes.

Global awareness regarding the protection of geological heritage became more visible with the Digne Declaration, published in 1991 in the city of Digne, France. Signed by more than thirty countries, this declaration emphasized that the Earth is the fundamental source of humanity's existence and future and established at the international level that geological values must be protected and used sustainably (Digne Declaration, 1991).

Geoparks, which stand out with their scientific and cultural richness, not only provide significant data on the geological past but also attract attention as centers of interest with strong geotourism potential (Özcan Selçuk, 2019). Among the primary objectives of geoparks are the conservation of geological heritage, the support of nature conservation activities, the encouragement of education and scientific research, the creation of awareness at local and global scales, the strengthening of sustainable development, and the enhancement of international cooperation (Tunçay, 2011; Gürsay, 2014; Türk, 2021). In addition, geoparks contribute to maintaining biodiversity by protecting various ecosystems; they offer visitors opportunities for education, recreation, and relaxation in natural environments while also creating avenues for acquiring knowledge about the past.

For an area to be recognized as a UNESCO Global Geopark, it must meet certain criteria (European Geoparks Network, 2025):

• It must have clearly defined boundaries and a sufficiently large surface area.

• A significant portion of the area must contain elements of geological heritage.

• It must formally participate in the UNESCO Global Geoparks Network.

• It must possess an effective management structure capable of implementing conservation, development, and sustainable development policies.

It must engage in interaction and cooperation with other sites within the UNESCO Global Geoparks Network.

These criteria ensure that geoparks establish a holistic model of conservation and management not only from a scientific perspective but also in terms of local development, tourism, environmental education, and international cultural interaction.

2.1. UNESCO Global Geoparks Network

The global recognition of geoparks and their attainment of an institutional structure gained momentum when UNESCO began working on geoparks in 2001. With the meeting held in Paris in 2004, the Global Geoparks Network (GGN) was established, and in 2015, during the 38th General Conference of UNESCO, the authority for the official designation and certification of geoparks was granted to UNESCO, thereby strengthening their status (UNESCO National Commission of Türkiye, 2025). As of 2024, a total of 213 UNESCO Global Geoparks have been designated in 48 countries, and this number continues to increase each year (UNESCO Global Geoparks Network, 2025).

The UNESCO Global Geoparks Network undertakes three main functions for the conservation, promotion, and sustainable management of geoparks, namely conservation, education, and geotourism (Bayram, 2014). This network is an important institutional mechanism that contributes to the protection of natural and cultural heritage on a global scale by increasing the international recognition and interaction of geoparks. It also serves as a strategic platform that supports the development of geoparks, promotes local development, and enhances public awareness of geological heritage.

Among the core objectives of the Global Geoparks Network are ensuring the fair designation of geoparks and promoting their professional management; enhancing knowledge and understanding of the nature and functions of geoparks; encouraging local communities to take ownership of their natural and cultural heritage; contributing to the preservation of world heritage for future generations; and educating society about the relationship between the geological sciences and natural hazards. In addition, supporting the socio-economic and cultural development of communities through nature-based systems, strengthening ties among different cultures through participatory management models, and promoting research activities are also among the network's priority goals (Global Geoparks Network, 2025). UNESCO Küresel Jeopark Ağı, bu amaçlara ulaşabilmek için on temel odak alanı üzerinde çalışmalar yürütmektedir (UNESCO Global Geoparks, 2025):

1. Natural Resources: It supports the sustainable use of natural resources and fosters a societal awareness that respects environmental and landscape integrity.

2. Geological Hazards: It raises awareness of geological disasters such as earthquakes, volcanic eruptions, and tsunamis, and increases society's resilience in disaster management and risk preparedness.

3. Climate Change: It provides information on the impacts of climate change and contributes to the promotion of renewable energy resources and green tourism.

4. Education: It organizes educational programs that highlight the relationship between geological heritage and humans, culture, and nature, carrying out awareness activities for all age groups.

5. Science: It supports scientific research through cooperation with academic institutions and promotes the production of knowledge about the Earth's geological processes.

6. Culture: By focusing on the interaction between nature and humans, it contributes to the preservation of local and global cultural values.

7. Gender Equality and Women's Empowerment: It conducts training programs and activities aimed at strengthening the role of women in economic and social life.

8. Sustainable Development: It develops plans that support not only the protection of geological heritage but also the economic and social development of local communities.

9. Local and Indigenous Knowledge: It preserves the traditional knowledge and cultures of local and indigenous communities and integrates this knowledge into geopark management.

10.Geo-Conservation: It implements effective conservation strategies for the protection, promotion, and sustainable use of geological heritage.

These focus areas demonstrate that UNESCO Global Geoparks contribute in a multidimensional way not only to the conservation of geological heritage but also to global priorities such as combating climate change, reducing disaster risks, supporting sustainable development, and fostering cultural interaction.

2.1.1. Criteria for Joining the UNESCO Global Geoparks Network

Specific international criteria have been defined for candidate areas seeking to join the UNESCO Global Geoparks Network. These criteria require geoparks to demonstrate a holistic approach not only in geological terms but also in governance, education, conservation, and sustainable development (UNESCO Global Geoparks Network, 2025). The main criteria are summarized below:

1. Size and Delineation: The geopark area must possess a clearly defined boundary and be large enough to support local, economic, and cultural development. Its size should enable the effective conservation of geological heritage while allowing educational and tourism activities to be carried out sustainably.

2. Management and Local Participation: A strong management system and a clear implementation plan are required for the effective establishment and long-term administration of geoparks. The mere presence of geological features is not sufficient; the cultural heritage elements within the area must also be protected and made accessible to visitors. Local community support and stakeholder cooperation are essential conditions for ensuring the secure preservation of the geopark and fostering community ownership.

3. Economic Development: One of the primary goals of geoparks is to promote economic activities in line with the principles of sustainable development. UNESCO-supported geoparks contribute to improving living conditions in both rural and urban areas by supporting socio-economic development that is culturally and environmentally sensitive.

4. Education: Geoparks must organize educational activities that enhance geological knowledge, environmental awareness, and cultural understanding for local communities and visitors. Within this scope, activities such as museum visits, guided tours, nature walks, workshops, and seminars aim to disseminate scientific knowledge and environmental awareness.

5. Conservation: Geoparks must ensure the protection of representative rocks, minerals, fossils, natural formations, and geological landscapes in accordance with national legislation.

This conservation constitutes one of the fundamental pillars of sustainable geopark management and UNESCO certification.

6. Global Network: Geoparks are required to participate actively in the UNESCO Global Geoparks Network and to cooperate with other geoparks. This network provides an important platform for promoting geological heritage, sharing knowledge and experience, advancing sustainable development practices, and disseminating good examples worldwide.

These criteria ensure that geoparks function not only as natural heritage sites but also as multifunctional conservation areas that support local development, promote education and scientific research, and strengthen international cooperation.

2.2. European Geoparks Network

The idea of international cooperation among geoparks was first introduced during the International Geological Congress held in China in 1997. At this congress, two scientists proposed the creation of a network among geoparks, and this initiative materialized in 2000 with the establishment of the European Geoparks Network (EGN) under the leadership of four pioneering European geoparks (Gümüş, 2008; Frey, 2001; Zouros & Ramsey, 2007; Ekiz, 2015). The EGN was developed within the framework of the European Union's LEADER IIC Program, and the network's administrative center is located in France (Zouros, 2005; Gümüş, 2008; Ekiz, 2015).

The founding objectives of the European Geoparks Network are grouped under three main headings (European Geoparks, 2025):

• To ensure the conservation of the geological heritage in their regions and to manage this heritage in accordance with the principles of sustainable development.

• To establish a strong European cooperation group among countries contributing to sustainable development goals.

• To implement new European projects by fostering dialogue and developing joint programs among member geoparks.

The EGN strengthens coordination among its members through biannual meetings organized to develop and support joint activities at local and regional scales (UNESCO National Commission of Türkiye, 2025). These meetings serve as an important platform for sharing experience and knowledge related to the conservation of geological heritage, the development of geotourism activities, and the promotion of sustainable development.

Today, the European Geoparks Network has expanded into a broad structure encompassing 94 geoparks across 28 European countries (European Geoparks, 2025). This network stands out as one of the most comprehensive and effective institutional frameworks that promotes the conservation of geological heritage and the implementation of community-based sustainable development strategies across the European continent (Figures 1, 2).



Figure 1. Spatial Distribution of Geoparks in European Countries (European Geoparks, 2025)

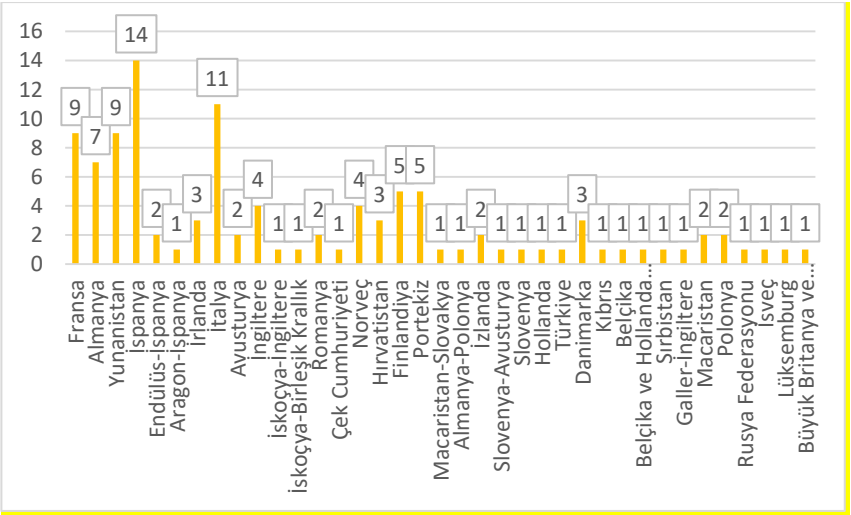


Figure 2. Distribution of European Geoparks by Country

3. Geotourism

Today, the rise in education levels and the increasing accessibility of information have led to significant transformations in the understanding of tourism (Yıldız, 2017). Individuals now travel not only for rest, entertainment, or health-related purposes but also to gain educational and scientific experiences. In this context, educational-scientific tourism involves the recognition of different cultures and the visitation of historical sites, natural formations, and areas of scientific significance. Geotourism has emerged as a growing and prominent subfield among these types of tourism, directly associated with geological heritage.

Geotourism is a specialized form of tourism in which individuals seek to explore the natural environment and geological riches (Gümüş, 2008; Kazancı, 2010; Koçan, 2012). Aiming to experience the natural landscapes, cultural values, and heritage sites of regions with geographical and geological characteristics from a scientific and educational perspective, geotourism is also practiced within the framework of sustainable tourism principles (Stokes, Cook & Drew, 2003; Özcan Selçuk, 2019). This form of tourism offers a multidimensional travel and learning experience in which geological structures, landforms, and cultural values are integrated with scientific research and educational activities.

Within the scope of geotourism, visitors have the opportunity to explore unique geological formations such as volcanic terrains, caves, geothermal resources, and tectonic areas (Gürsay, 2014). In addition to geological features, the natural environment and biodiversity are also key components of geotourism. Activities such as nature walks, cave explorations, mountaineering, rock climbing, and geological observation tours enrich the tourism experience by offering participants the chance to interact directly with nature (Ekiz, 2015).

Geotourism is not only a recreational activity but also a platform for nature education and scientific research. Geoparks and geological sites function as open-air laboratories for schools, universities, and research groups, providing visitors with opportunities to gain direct knowledge about fossils, geological processes, volcanic activities, and the evolution of the Earth. In this way, geotourism raises public awareness of geology and the natural sciences and contributes to the dissemination of scientific knowledge.

Geotourism provides benefits that extend beyond educational and cultural dimensions. This form of tourism supports economic development, enhances the welfare of local communities, and contributes to the growth of environmental awareness. By promoting the conservation of geological heritage, geotourism offers sustainable income sources for the local economy while ensuring the transmission of natural and cultural values to future generations.

In summary, geotourism stands out as a strategic form of tourism that contributes both to the protection of natural and cultural heritage and to a deeper public understanding of nature. It achieves this through the conservation of the natural environment, the promotion of scientific research, the support of educational activities, and the development of sustainable tourism practices.

4. The Relationship Between Geoparks, Geotourism, And Nature Conservation

Geoparks are special conservation areas established to protect geological heritage, promote scientific and educational research, and support sustainable tourism. These areas provide a unique framework for integrating geological and natural riches with society by enabling the development of geotourism, which is one of the alternative types of tourism. Geotourism aims to explore and experience natural and cultural heritage by visiting geological formations such as volcanic areas, caves, high-altitude mountains, waterfalls, fossil beds, and various landforms.

Geoparks create an effective model for the planning and management of geotourism activities. In this way, the conservation of natural and cultural heritage, the promotion of sustainable tourism, and the support of the local economy become possible. Directing geotourism activities within geopark boundaries ensures both the transmission of geological heritage to future generations and the development of public awareness and environmental consciousness toward nature. In addition, geoparks serve as open-air laboratories for scientific research and educational activities; they contribute to understanding the formation of the Earth by offering researchers, natural scientists, and educators the opportunity to study geological processes and the sustainability of natural resources.

Geoparks aim to ensure the protection and sustainable use of geological heritage. These areas are not limited only to geological values; they also encompass regions that are rich in ecological and cultural terms and aim to transmit these values to future generations. In addition to protecting the geological formations, fossils, and landforms they contain, geoparks support the continuity of biodiversity and ecosystems by providing natural habitats

for rare and endangered species. In this way, they contribute to the joint conservation of both geological and biological values.

The geotourism activities carried out in geoparks strengthen nature conservation awareness and provide significant benefits in terms of environmental education. Informing visitors about the geological and ecological importance of the region allows sustainable tourism practices to become widespread and enables tourism activities to be conducted without harming ecosystems. At the same time, the active participation of the local community enables tourism to directly contribute to the socio-economic development of the region.

Geoparks also offer ideal observation and research areas in terms of scientific studies. Researchers can monitor geological processes in these protected areas, conduct studies on biodiversity, and develop strategies for the conservation of rare species. These studies strengthen the production of knowledge aimed at protecting the natural and cultural heritage of geoparks and supporting their sustainable use, contributing both to the scientific literature and to local conservation policies.

5. Geoparks in the World and in Turkey

5.1. Brezilya Quarta Colonia UNESCO Global Geopark

The geopark, located in southern Brazil within the transition zone between the Pampa and Atlantic Forest biomes, is an area of exceptionally rich geological and biological diversity. Covering a total surface area of 2,923 km², it comprises nine municipalities and is home to a population of approximately 62,000. Situated in the central region of Rio Grande do Sul, the area is one of the regions with the highest cultural diversity in the state, and this diversity is strongly reflected in traditional forms of expression such as gastronomy, music, dance, and handicrafts. The boundaries of the geopark overlap with the Mata Atlantica Biosphere Reserve, designated by UNESCO in 1991, which reinforces the geological and ecological significance of the region (Figure 3).



Figure 3. Images from the Quarta Colonia UNESCO Global Geopark, Brazil

The geopark also attracts global attention for its rare paleontological heritage. Visitors can encounter significant evidence regarding the emergence of dinosaurs, one of the most iconic animal groups in the science of paleontology. Fossil records, dating back approximately 233 million years and exceptionally preserved within sedimentary rocks, constitute a unique archive reflecting critical evolutionary processes in the history of life on Earth.

The geopark's topography offers noteworthy features from both scientific and touristic perspectives. Supporting paleontological discoveries, this landscape is characterized by mountainous ranges surrounded by extensive cliffs composed of sandstone and basaltic rocks. Formed over thousands of years of geological processes, the area features extraordinary natural landscapes shaped by deep valleys, waterfalls, river beaches, and navigable rivers. This geomorphological diversity provides strong potential for both scientific research and nature-based tourism activities (Figure 4).



Figure 4. Images from the Quarta Colonia UNESCO Global Geopark, Brazil

5.2. Yunanistan Lavreotiki UNESCO Global Geopark

The Lavreotiki UNESCO Global Geopark, located approximately 60 km southeast of Athens, Greece, encompasses a region extremely rich in geological, geomorphological, and cultural features. Covering a total area of 176.87 km², the geopark has a population of approximately 25,102 and has historically experienced dense settlement due to its underground resources, a characteristic it continues to preserve today.

The geopark is internationally recognized particularly for its sulfur ore deposits, silver mining, and rare mineral diversity. The Lavrion deposit, with 48 different mineral species identified to date, is one of the regions with the highest known elemental diversity in the world, effectively serving as a natural mineralogy museum. This unique mineralogical and geological richness makes the geopark an important attraction not only for scientific research but also for nature-based education and geotourism activities (Figure 5).



Figure 5. Images from the Lavreotiki UNESCO Global Geopark, Greece

The Lavreotiki UNESCO Global Geopark presents a unique landscape where mining and archaeological heritage are intertwined. The region bears traces of mining activities spanning

from prehistoric times to the present, while also preserving tangible evidence of the cultural and economic development shaped by these processes. One of the geopark's significant cultural heritage elements, the Monastery of Saint Paul the Apostle, stands out with its traditional fresco technique and architecture reflecting Orthodox monasticism (Figure 6).



Figure 6. Images from the Lavreotiki UNESCO Global Geopark, Greece

The Lavrion Environmental Education Center in the region is one of the most important institutions supporting the conservation and educational functions of the geopark. The center focuses particularly on the protection of Posidonia oceanica seagrass meadows and offers rich educational programs aimed at raising awareness among young people regarding the importance of marine–coastal ecosystems. These educational activities contribute both to the conservation of marine biodiversity and to increasing the environmental awareness of society.

With its integrated management of geological, mineralogical, mining, and cultural values, the Lavreotiki UNESCO Global Geopark is regarded as one of the leading exemplary sites not only in Greece but also worldwide in terms of geotourism and nature conservation.

5.3. Kula – Salihli UNESCO Global Geopark

The Kula–Salihli UNESCO Global Geopark, located in Turkey's Manisa province within the boundaries of the Kula and Salihli districts, covers a vast area of 2,320 km². Geologically highly complex, the geopark exhibits remarkable geological diversity with a 200-million-year geological history and is distinguished by its rich geomorphological features.

As one of Turkey's youngest volcanic regions, the Kula–Salihli Geopark holds great significance for geotourism not only nationally but also internationally, due to the coexistence of natural, geological, cultural, and archaeological values. Its status as Turkey's first and only UNESCO Global Geopark places the area in a strategic position for both scientific research and nature-based tourism (Figure 7).



Figure 7. Volcanic scoria cones

Within the geopark boundaries, there are 80 volcanic scoria cones and 5 maars (maar craters). Typically, the miniature scoria cones do not exceed 150 meters in height. The area draws attention for containing characteristic products of recent volcanism and hosts a variety of geological formations, including lava flows, lava caves, lava tubes, fairy chimneys, volcanic canyons, dykes, and basalt columns. This geomorphological diversity provides the geopark with a unique natural laboratory for both scientific observation and geotourism activities (Figure 8).



Figure 8. Volcanic caves and tunnels

The Kula–Salihli Geopark is significant not only for its geological features but also for its cultural geosites and geoarchaeological areas. The geoarchaeological heritage in the region reveals the relationship of past civilizations with the geological environment, offering visitors the opportunity to observe the interaction between geological processes and human settlement. This integrated structure enables the geopark to serve as a model area for both nature conservation and sustainable tourism (Figure 9).



Figure 9. Fairy chimneys

6. Conclusion and Recommendations

Geoparks and nature conservation areas represent two complementary protection strategies for the preservation and sustainable use of natural and cultural heritage. While nature conservation areas aim to protect biodiversity and ecosystems, geoparks prioritize the promotion and conservation of geological heritage alongside cultural values. The interaction and collaboration between these two protection models provide significant opportunities for both scientific research and sustainable development.

The integration of geoparks with nature conservation areas contributes to the holistic preservation of natural and cultural heritage. Geoparks can encompass not only geological elements but also biodiversity and ecosystems, sharing similar conservation objectives with

nature protection areas. This allows for the development of a multi-layered protection model in which both geological and biological elements are safeguarded together. Consequently, protected areas can be managed with a more comprehensive approach to environmental and cultural sustainability.

Geotourism activities conducted in geoparks serve as a powerful tool for the preservation and promotion of natural and cultural heritage. Visitors have the opportunity to directly observe and learn about nature and geology by exploring geological formations, rare fossils, volcanic activities, and other unique geological features within geoparks. These tourism activities contribute to the local economy by generating employment and supporting sustainable development. However, the planning and regulation of geotourism are of critical importance. Excessive or uncontrolled tourism can place pressure on natural and cultural heritage, leading to the degradation of ecosystems. Therefore, robust policies and practices must be developed to ensure the sustainable management of both geoparks and nature conservation areas.

In conclusion, the collaboration between geoparks and nature conservation areas plays a crucial role in the protection and sustainable use of natural and cultural heritage, as well as the responsible implementation of ecotourism activities. Strengthening this collaboration, adopting effective management models, and applying sustainable tourism principles will not only secure the transmission of natural and cultural heritage to future generations but also provide a foundation for a livable environment and regional economic development.

Thanks and Information Note

The article complies with national and international research and publication ethics. Ethics Committee approval was not required for the study. All authors contributed equally to the article.

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The Role of Cultural Routes in the Conservation of Cultural Heritage and the Advancement of Sustainable Tourism

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Abstract

This paper explores the significance of cultural routes in safeguarding cultural heritage while fostering sustainable tourism. Cultural heritage is understood as a multidimensional construct that encompasses both tangible remains—such as monuments, archaeological sites, and landscapes—and intangible values, practices, and traditions that define the collective identity of societies. Within this context, cultural routes are increasingly regarded as innovative mechanisms for preserving, interpreting, and transmitting heritage to future generations, while simultaneously enabling platforms for intercultural dialogue and exchange. The study traces the historical development of cultural routes and outlines their essential components, including historic cities, rural settlements, traditional living environments, individual monuments, natural landscapes, and wildlife areas. Drawing upon the framework of the Council of Europe Cultural Routes Program, it evaluates national and international examples that demonstrate the role of cultural routes in linking heritage with sustainable development. In Turkey, initiatives such as the Lycian Way, the Phrygian Way, and the St. Paul Trail illustrate how cultural and natural assets can be integrated through holistic approaches. These examples show how cultural routes stimulate local development, encourage community participation, and contribute to the dynamic preservation of heritage. The findings reveal that cultural routes can be made more effective through enhanced local participation, integrated management models, and greater investment in awareness-raising and educational initiatives. Ultimately, cultural routes extend beyond their function as physical pathways: they operate as strategic tools that strengthen cultural continuity, foster identity formation, and advance long-term regional sustainability.

Keywords: Culture, cultural heritage, cultural route, conservation, sustainable tourism.

1. Introduction

Culture is a distinctive construct that differentiates one society from another, continually evolving and transforming throughout history while shaping belief systems, artistic expressions, customs, traditions, and modes of thought and life (TDK, 2025). This structure, which defines the identity of societies, encompasses both tangible and intangible values that strengthen solidarity and a sense of belonging among individuals, thereby ensuring the continuity of social order (URL-1, 2025). In tourism literature, culture is described as "the world's greatest performance," a phenomenon fundamentally rooted in the concept of heritage. Heritage refers to the collection of values transmitted from one generation to the next (TDK, 2025), while cultural heritage encompasses both its tangible and intangible dimensions—enabling individuals and communities to connect with their past, preserve their identity, and establish continuity toward the future (ISMEP, 2014).

The concept of cultural heritage has undergone a substantial evolution in both meaning and scope over time. Initially confined to monumental structures and architecturally significant physical remains, it has gradually expanded to include examples of vernacular architecture,

urban and rural settlements, traditional lifestyles, and the intangible dimensions of culture and art (Negiz, 2017). In this context, cultural heritage is understood as a product of the historical interaction between people and place, encompassing not only tangible components—such as historic urban fabrics, monumental buildings, archaeological sites, and cultural landscapes—but also intangible expressions including language, music, dance, rituals, crafts, and oral traditions (ICOMOS, 1999). These elements play a crucial role in maintaining the continuity of knowledge, experience, and traditions accumulated by humanity throughout history and in transmitting them to future generations. Cultural heritage, therefore, should not be regarded merely as a relic of the past but as a living reflection of the ever-evolving values, beliefs, and collective wisdom of societies.

In the contemporary context, the concept of cultural heritage is defined in a more systematic manner through international organizations and legal instruments, and it is classified under various categories. In particular, the conventions and recommendations developed by UNESCO and ICOMOS have provided both national and international legal frameworks that establish the scope of cultural heritage. According to UNESCO's classification, cultural heritage is categorized under four main groups:

1. Tangible Cultural Heritage, encompasses physical assets, subdivided into movable (such as paintings, sculptures, manuscripts, and archaeological artifacts) and immovable (such as monuments, historic buildings, archaeological sites, and traditional urban fabrics) elements.
2. Underwater Cultural Heritage, includes submerged shipwrecks, underwater settlements, and archaeological remains located on the seabed or lakebed.
3. Intangible Cultural Heritage, refers to the oral traditions, expressions, performing arts, rituals, festivities, and craftsmanship knowledge that constitute the living expressions of communities.
4. Natural Heritage, comprises cultural landscapes, unique ecosystems, geological formations, and natural sites of cultural and aesthetic value (UNESCO).

One of the most significant milestones in the preservation of cultural heritage is the adoption of the Convention Concerning the Protection of the World Cultural and Natural Heritage at the UNESCO General Conference held in Paris from October 17 to November 21, 1972. This convention established the principle of global cooperation for the protection of both cultural and natural heritage and imposed a range of obligations on the signatory states. Türkiye decided to accede to the convention through Law No. 2658, dated April 14, 1982, and completed the ratification process with the Council of Ministers' decision on May 23, 1982. Following its publication in the Official Gazette on February 14, 1983, and the submission of the required documents to the UNESCO Headquarters, Türkiye officially became a State Party to the Convention on March 16, 1983.

Under this convention, the World Heritage List was established, which currently includes a total of 1,223 sites of cultural, natural, and mixed character. These sites are recognized as universal heritage assets that must be preserved as part of humanity's shared values (UNESCO). The cultural and natural heritage sites in Türkiye inscribed on the UNESCO World Heritage List are presented in Table 1.

Table 1. Cultural and Natural Heritage Sites of Türkiye Inscribed on the UNESCO World Heritage List

No	Heritage Site	Year	City/Province
1	Great Mosque and Hospital of Divrigi	1985	Sivas
2	Historic Areas of Istanbul	1985	İstanbul
3	Göreme National Park and the Rock Sites of Cappadocia	1985	Nevşehir
4	Hattusha: The Hittite Capital	1986	Çorum
5	Mount Nemrut	1987	Adıyaman
6	Hierapolis–Pamukkale	1988	Denizli
7	Xanthos–Letoon	1988	Antalya and Muğla
8	City of Safranbolu	1994	Karabük
9	Archaeological Site of Troy	1998	Çanakkale
10	Selimiye Mosque and its Social Complex	2011	Edirne
11	Neolithic Site of Çatalhöyük	2012	Konya
12	Bursa and Cumalıkızık: The Birth of the Ottoman Empire	2014	Bursa
13	Pergamon and its Multi-Layered Cultural Landscape	2014	İzmir
14	Diyarbakır Fortress and Hevsel Gardens Cultural Landscape	2015	Diyarbakır
15	Ephesus	2015	İzmir
16	Archaeological Site of Ani	2016	Kars
17	Aphrodisias	2017	Aydın
18	Göbekli Tepe	2018	Şanlıurfa
19	Arslantepe Mound	2021	Malatya
20	Gordion	2023	Ankara
21	Wooden Hypostyle Mosques of Medieval Anatolia (Great Mosque of Afyon, Sivrihisar Great Mosque, Ahi Şerafettin Mosque, Eşrefoğlu Mosque, Mahmut Bey Mosque)	2023	Afyon, Eskişehir, Ankara, Konya, Kastamonu

These developments have transformed the preservation of cultural heritage from being merely a local responsibility into an international obligation. The recognition of the universal value of cultural heritage underscores the importance of sustainable conservation strategies and

integrated management models, while also demonstrating that conservation efforts lacking the support of local community participation, legal regulations, and awareness initiatives struggle to achieve permanence. Therefore, the preservation of cultural heritage goes beyond the act of remembering the past; it represents a strategic necessity for safeguarding the identity and collective memory to be transmitted to future generations.

The Convention Concerning the Protection of the World Cultural and Natural Heritage, adopted by UNESCO in 1972, provided a comprehensive framework for heritage conservation by classifying cultural heritage under three main categories (ICOMOS, 1999). This classification highlights that cultural heritage should not be evaluated solely through its physical assets but also in terms of historical continuity, collective memory, and identity formation.

The first category, Monuments, includes architectural works, sculptures, wall paintings, archaeological discoveries, inscriptions, caves, and various structural components. These assets, which possess universal historical, artistic, or scientific value, represent the most visible and symbolic expressions of cultural heritage.

The second category, Groups of Buildings, refers to collections of structures that exhibit functional or historical unity and architectural coherence. Such ensembles, through their relationship with their surrounding environment, contribute to the preservation of collective identity and social memory by reflecting cultural, aesthetic, and historical integrity.

The third category, Sites, encompasses areas that have been constructed by human hands, formed through natural processes, or created through the interaction of both. These sites embody values of universal importance from aesthetic, ethnological, and anthropological perspectives.

This classification emphasizes the multidimensional nature of cultural heritage and points to the necessity of an interdisciplinary, holistic, and sustainable approach to conservation. Consequently, the preservation process should not be confined to the physical restoration of structures; it must also ensure the safeguarding of the meanings, social functions, and cultural contexts embodied in these assets (Üstündağ & Özer, 2021). Such an approach guarantees not only the survival of tangible heritage but also the continuity of the historical and cultural memory it represents for future generations.

1.1. The Relationship Between Conservation and Utilization of Cultural Heritage

Cultural heritage is a multilayered phenomenon that reflects the collective memory, identity, and value systems of humankind. It derives meaning through both tangible and intangible elements—such as historical buildings, archaeological sites, traditional handicrafts, music, and oral cultural expressions—and contributes to the continuity of social identity (Özdemir, 2024). The preservation of cultural heritage extends beyond safeguarding traces of the past; it enables societies to establish a meaningful connection with their historical roots and transmit this bond to future generations, thus facilitating the continual reconstruction of identity (Çatalbaş & Kılıç, 2021).

In this context, the conservation of cultural heritage is not limited to maintaining the physical integrity of tangible elements; it also encompasses the safeguarding and revitalization of the historical, aesthetic, and social values they embody. Physical conservation requires scientific interventions to prevent deterioration, deformation, or destruction of monumental structures, archaeological sites, and movable cultural assets, whereas maintaining cultural integrity

involves ensuring the sustainability of the symbolic meanings, traditional functions, and positions this heritage elements hold within collective memory (Oktay et al., 2020). This perspective transforms the conservation process from a purely technical restoration activity into a multilayered process of intervention and management that operates on both physical and symbolic levels.

Therefore, conservation policies should not only focus on the physical preservation of movable and immovable cultural properties but also include the safeguarding of intangible cultural heritage—such as traditions, handicrafts, oral narratives, and folk dances. The protection of such cultural expressions is crucial for the continuity of collective memory and the construction of social identity, reinforcing individuals' and communities' attachment to their historical roots and contributing to the preservation of cultural diversity (Çakmak, 2020).

Moreover, the conservation of cultural heritage is not solely an effort to keep the traces of the past alive but also serves as a strategic instrument for enhancing economic development and sustainable tourism potential. Historic urban fabrics and heritage sites that preserve their authentic identity act as centers of attraction for visitors seeking cultural experiences, thereby generating direct economic benefits through tourism revenues and creating a positive cycle that further encourages heritage preservation (Henderson, 2019).

Within this framework, the conservation of cultural heritage necessitates a multilayered and interdisciplinary approach at both physical and conceptual levels. By establishing a strong link between the preservation of historical identity and economic sustainability, it constitutes one of the fundamental pillars of contemporary conservation policies.

1.2. The Concept of Cultural Routes

Throughout history, transportation routes used for military, religious, commercial, and social purposes have been reinterpreted in contemporary times primarily for tourism-related functions. These routes have emerged as significant instruments for the preservation and promotion of cultural and natural heritage. Having entered the agenda of international organizations, such routes are defined in the literature as "cultural routes" (ÇEKÜL, 2015). A cultural route is considered a local, regional, or national pathway—either historically utilized or conceptually developed in the present day—that derives meaning from the cultural and natural heritage elements it encompasses. It serves multiple objectives such as conservation, rural development, and the promotion of tourism (ÇEKÜL, 2015).

Cities function as living organisms undergoing constant change and transformation, the interaction between the past, present, and future forms the foundation of their shared cultural heritage. In the historical development of cities, numerous factors—such as individuals' and communities' livelihood needs, religious pilgrimages, trade activities, livestock-related mobility, and seasonal migrations—have shaped human movement patterns. These journeys contributed to the preservation and transmission of historical traces by enriching the cultural identity of stops and routes along the way. In this sense, roads have not only served as physical infrastructures facilitating movement but have also played a vital role as tangible and symbolic carriers of civilization, shaping social life and fostering interaction among diverse cultures.

Among the historical examples, the Silk Road and the Spice Route stand out as the most prominent networks that enabled cultural interaction and knowledge exchange (Berk, 2020). These routes facilitated communication between different communities, laying the groundwork for cultural diversity. Over time, they evolved into cultural routes that hold both physical and

symbolic significance within collective memory. Such routes have served as key conduits for transmitting new ideas, belief systems, cultural values, and artistic movements across generations (Toraman, 2022).

The preservation of cultural heritage contributes to the continuity of collective memory by enabling societies to connect with their histories, traditions, and identities. Sustaining this heritage is strategically important for understanding the past and transmitting it to future generations. One of the most significant initiatives developed within this framework is the establishment of cultural routes programs. The approach introduced by the Council of Europe, aimed at promoting cultural heritage conservation and enhancing public awareness, was initially designed to highlight Europe's shared historical themes. Over time, it gained international recognition and expanded to different geographical regions.

Today, cultural routes are regarded as innovative tools that go beyond being mere physical pathways or transportation corridors. They serve as mechanisms for preserving, promoting, and transmitting historical, artistic, and social values to future generations. Accordingly, efforts to refine the conceptual framework of cultural routes, establish effective management models, define promotion strategies, and embed sustainability principles underline their growing significance in both heritage conservation policies and sustainable tourism planning.

1.3. The Historical Development of Cultural Routes

Systematic studies on cultural routes gained institutional significance in 1984, when the Council of Europe invited its member states to participate in the establishment of the European Cultural Routes Program. Within the scope of this initiative, the Santiago de Compostela Pilgrim Route in Spain was designated as the first cultural route highlighting Europe's shared historical and spiritual values, and in 1993 it was inscribed on the UNESCO World Heritage List by the World Heritage Committee. Following this development, at the 1994 meeting of the World Heritage Committee held in Madrid, the concept of the "cultural route" was officially discussed for the first time, and a foundational reference document titled "Routes as Part of Our Cultural Heritage" was published (Baştemur, 2009; ÇEKÜL, 2015) (Figure 1).



Figure 1. Santiago de Compostela Pilgrim Route (URL-1)

Building on these pioneering steps, the European Institute of Cultural Routes (EICR) was established in 1997 through a protocol signed between the Council of Europe and the Grand Duchy of Luxembourg to ensure the effective implementation of the European Cultural Routes

Program. Subsequently, in 1998, with contributions from ICOMOS members representing diverse regions, the ICOMOS International Committee on Cultural Routes (CIIC) was founded. The shared objectives of these two institutions include researching and documenting cultural routes, conserving and valorizing the cultural heritage located along them, and enhancing their social and economic impacts (ÇEKÜL, 2015).

In 2005, UNESCO officially recognized cultural routes as one of the four core heritage categories within the framework of the World Heritage Convention, marking a pivotal step in the global dissemination of the concept. Following this momentum, a series of meetings organized under the leadership of the ICOMOS International Committee on Cultural Routes led to the publication of the ICOMOS Charter on Cultural Routes in 2008. The charter defines the principles and methodologies related to the research and documentation of cultural routes and promotes the establishment of institutional mechanisms that facilitate knowledge exchange and cooperation in their conservation, management, and evaluation (ÇEKÜL, 2015).

In the subsequent period, a significant international meeting was held in 2012 in Colmar, France, with the participation of UNESCO, the European Union, the United Nations World Tourism Organization (UNWTO), the Organisation for Economic Co-operation and Development (OECD), non-governmental organizations, local authorities, and universities. This platform focused on developing innovative tools to strengthen the educational, participatory, and visibility dimensions of cultural routes. As a result of this meeting, the "Colmar Declaration: 25th Anniversary of the European Cultural Routes" was adopted, and the "Crossroads of Europe" initiative was launched to promote cultural routes among private sector actors, tourism enterprises, local and national governments, and other stakeholders—aiming to enhance awareness and foster cooperation (ÇEKÜL, 2015).

During this process, in 2013, UNESCO launched the VeRoTour Project (Venetian Routes: Enhancing a Shared European Multi-Cultural Sustainable Tourism). The project aimed to promote and protect the cultural heritage distributed along the historical Venetian maritime routes on an international scale. Implemented within a multi-stakeholder framework aligned with Europe's shared cultural values, the initiative was supported by institutions such as the World Tourism Organization, the Council of Europe Venice Office, and the UNESCO Regional Bureau for Science and Culture in Europe (UNESCO, 2013). The VeRoTour project is regarded as a strategic step toward diversifying heritage-based tourism and strengthening cultural cooperation across Europe (Table 2).

Table 2. Historical Development of the European Cultural Routes

Year	Development
1984	The Council of Europe invited member states to launch the European Cultural Routes Program.
1987	The Santiago de Compostela Pilgrim Route was declared the first European Cultural Route. The route was later expanded to form the European Migration Routes.
1994	The first meeting was held in Madrid with the participation of UNESCO and ICOMOS representatives; "Routes as Part of Our Cultural Heritage" was adopted.
1997	The European Institute of Cultural Routes was established by the Council of Europe.

1998	The ICOMOS International Committee on Cultural Routes (CIIC) was founded.
2002	The European Institute of Cultural Routes launched the web portal "A Shared Heritage: Cultural Routes and Landscapes."
2005	Cultural routes were recognized by UNESCO as one of the four major heritage categories.
2008	The ICOMOS Charter on Cultural Routes was published.
2012	The Council of Europe adopted the Colmar Declaration on the 25th Anniversary of the European Cultural Routes.
2013	The Council of Europe detailed the aims, definitions, activities, and rules of the Cultural Routes Project.

This chronological development demonstrates that cultural routes have evolved not merely as a revival of historical pathways but also as a significant global policy instrument promoting international cooperation, cultural exchange, and sustainable tourism.

Cultural routes are thematic itineraries that aim to connect and present historical, cultural, and natural assets located across different geographical regions in a meaningful and coherent framework. Türkiye, with its rich cultural heritage and diverse geography, holds remarkable potential in this regard.

Council of Europe Cultural Routes Involving Türkiye

- Viking Route
- Winter Corridor
- Faith Tourism Corridor
- Silk Road Tourism Corridor
- Western Black Sea Coastal Corridor
- Highland Corridor

The chronological information about the historical development of Cultural Routes in Turkey is shown in Table 3.

Table 3. Historical Development of Cultural Routes in Türkiye

Year / Period	Development / Event	Description
Late 1980s – Early 1990s	Popularization of nature walking and trekking concepts	The concept of cultural routes began to gain recognition in Türkiye.
1990	Establishment of the ÇEKÜL Foundation	Marked an important institutional step toward the protection of natural, historical, and cultural heritage.
1996	The Lycian Way project was submitted to a competition and received an award	Prepared by Kate Clow, the project won a prestige award in the "Lights of the Future" competition.
1999	Opening of the Lycian Way	Recognized as Türkiye's first long-distance walking route, stretching 760 km.
Early 2000s	Creation of the St. Paul Trail	Marked and developed by Kate Clow, the route extends from Perge to Yalvaç, incorporating numerous cultural and natural sites.
2012	Establishment of the Culture Routes Society	Founded to promote, protect, and standardize cultural routes across Türkiye.
2012	Launch of the ÇEKÜL Regional Road Maps Program	Planning initiatives began in regions such as Thrace, the Golden Triangle, the Lakes Region, and Cappadocia.
2013	Preparation of regional vision plans	Conducted in regions including Thrace, Çukurova, Muğla, Southern Marmara, and the Lake Van Basin.
2014	Publication of Spatial Planning Guidelines	Included cultural route planning for Çukurova, Kelkit, Niksar, Yeşilırmak, and Gaziantep regions.
2015	Publication of the Cultural Routes Planning Guide	Outlined principles, processes, and methods for the planning of Anatolia's cultural heritage.
2015	Identification of Tourism Development Corridors	Defined Olive, Winter, Faith, Silk Road, Western Black Sea, Highland, and Thrace Cultural Corridors.
2020	Academic evaluation of the Lycian Way	Recognized as one of the world's longest trekking routes.
2021	The Culture Routes Society reached 23 registered routes	The association included a variety of natural, historical, and thematic routes.
2023	Update of routes under the Culture Routes Society	Featured prominent routes such as the Lycian Way, St. Paul Trail, Evliya Çelebi Way, and Carian Trail.

1.4. Components of Cultural Routes

The fundamental components of cultural routes generally consist of tangible and intangible elements of cultural heritage, together with natural environmental formations. These

components vary depending on the main theme, function, and geographical characteristics of the route, with each element contributing to the deepening of its historical and cultural meaning (ÇEKÜL, 2015). The main components that constitute cultural routes can be classified as follows:

Historic cities: Urban settlements that have preserved their traditional fabric, maintain a strong sense of historical continuity, and stand out with their distinctive identities.

Rural settlements: Villages and small towns that reflect traditional production methods, architectural character, and lifestyles.

Traditional ways of life: Intangible cultural practices such as local cuisine, music, belief systems, language, handicrafts, and rituals.

Ancient settlements: Prehistoric or classical sites containing remains of cities, sanctuaries, or other archaeological structures.

Individual historic buildings: Architectural examples located in urban or rural settings, such as churches, castles, bridges, mills, inns, or industrial structures.

Natural environment: Unique geomorphological features and natural landscapes, including valleys, mountain peaks, canyons, lakes, and coastal zones.

Wildlife areas: Natural habitats that host high levels of biodiversity and rare species of flora and fauna.

A cultural route may sometimes be shaped around a single dominant component, while in other cases, it emerges as a holistic cultural network encompassing multiple elements. For instance, the route followed by Alexander the Great in 334 BCE during his conquest of Anatolia and the eastern territories can be regarded as a historical corridor characterized by ancient settlements and military outposts. In contrast, a gastronomy-themed route may highlight rural settlements and historic city centres as key locations where local culinary traditions can be experienced.

Regardless of its thematic focus, the primary function of a cultural route is to integrate diverse cultural and natural heritage elements into a coherent system and to present them to visitors within a network of meanings that reveals historical continuity, cultural identity, and spatial context (ÇEKÜL, 2015). In this respect, cultural routes are not merely travel pathways but multilayered cultural experience spaces that serve as bridges between the past and the present.

2. The Contribution of Cultural Routes to the Conservation of Cultural Heritage

2.1. Conservation Strategy for Cultural Routes

The conservation of cultural routes requires a multilayered process that not only ensures the preservation of physical heritage but also safeguards social memory, local identity, and cultural continuity. Therefore, any conservation strategy to be developed must adopt a multidimensional, participatory, interdisciplinary, and sustainable framework.

First, the holistic conservation approach advocates for considering cultural routes not merely as collections of monumental structures but as entities inseparable from their environmental, historical, and social contexts. According to this perspective, cultural heritage should be assessed together with historical urban fabrics, natural landscapes, and traditional lifestyles (Kadıköy Akademi, 2023). The Council of Europe Cultural Routes Program also embraces this

approach, emphasizing the simultaneous protection of cultural diversity and environmental values.

Second, local participation and stakeholder collaboration constitute a fundamental prerequisite for the ownership and long-term sustainability of cultural routes. The active involvement of local communities, non-governmental organizations, and local authorities in decision-making processes transforms these routes from being mere touristic attractions into cultural instruments that reinforce collective memory (Union of Historical Towns, 2023).

The third strategy is based on thematic and regional planning principles. Designing cultural routes around themes consistent with the historical and socio-cultural fabric of a region strengthens regional identity while generating unique values for cultural tourism (Sönmez & Özdemir, 2023). In this regard, the four-phase route planning implemented in the Menteşe Urban Conservation Area serves as a model for integrating conservation and tourism within a local context.

Finally, education and awareness-raising activities play a critical role in the conservation of cultural routes. Educating society—particularly younger generations—about cultural heritage not only enhances long-term conservation awareness but also supports the social sustainability of routes (ÇEKÜL, 2023).

In conclusion, conservation strategies for cultural routes should encompass more than the physical restoration of heritage assets; they must also ensure cultural continuity, foster community ownership, and promote management approaches aligned with the goals of sustainable development. Implementing these strategies through a locally responsive, interdisciplinary, and inclusive framework produces lasting and effective outcomes for both the preservation of heritage and its transmission to future generations.

3. Examples of Cultural Heritage Conservation Through Cultural Routes

3.1. Major Cultural Routes in Türkiye

The recognition and adoption of the concept of cultural routes in Türkiye emerged in the late 1980s and early 1990s, in parallel with the growing popularity of outdoor activities such as nature walking and trekking. During this period, the increasing public interest in the natural environment led to new forms of engagement with cultural landscapes, paving the way for the creation of routes that integrated both natural and cultural values.

One of the most significant milestones in this process was the Lycian Way Project, developed in 1996 by British author and mountaineer Kate Clow, based on the ancient roads of the Lycian civilization. The project received the Prestige Award in Garanti Bank's "Lights of the Future" competition and is regarded as the first systematic initiative in Türkiye to create a long-distance walking route that integrates natural and cultural heritage within a holistic framework. The strong national and international interest in the Lycian Way accelerated the development of thematic walking routes centered on cultural heritage (Figure 2).



Figure 2. Lycian Way (URL-2)

Following the creation of the Lycian Way, public awareness of cultural routes in Türkiye increased rapidly, and the active involvement of non-governmental organizations and local associations became more evident. Various civil initiatives were launched to plan and promote walking routes aligned with the principles of sustainable tourism and the conservation of cultural heritage. These efforts strengthened the understanding that cultural routes should be supported not only through individual initiatives but also within institutional and policy frameworks.

An important institutional advancement in this regard was the establishment of the Culture Routes Society in 2012, supported by the Ministry of Culture and Tourism. The society has played a crucial role in the development, marking, and promotion of cultural routes across Türkiye. To date, it has contributed to the creation and official recognition of 28 marked and promoted routes, representing a strategic step toward developing a sustainable national model for the joint preservation and experience of Türkiye's natural and cultural heritage.

The information about the Cultural Routes of Türkiye is shown in Table 4.

Table 4. Cultural Routes in Türkiye

No	Route Name	Type	Theme	Region	Length / Route Count	Year
1	Lycian Way	Hiking	History, Nature	Fethiye–Antalya (Teke Peninsula)	600 km	1999
2	St. Paul Trail	Hiking	History, Nature, Faith	Antalya–Isparta	500 km	2004
3	Yenice Forest Trails	Hiking, Cycling	Nature	Yenice, Karabük	210 km	2007
4	Independence Route (İstiklal Yolu)	Hiking, Cycling	History, Nature	İnebolu–Kastamonu	105 km	2007
5	Abraham's Path (Hz. İbrahim Yolu)	Hiking	History, Faith	Şanlıurfa	170 km	2008
6	Kaçkar Trails	Hiking	Nature	Artvin, Rize, Erzurum	40 routes	2008

7	Sultans Trail	Hiking	History, Nature	Thrace Region	285 km	2009
8	Ephesus–Mimas Route	Hiking, Cycling	History, Nature	İzmir	709 km (hiking), 773 km (cycling)	2009
9	Küre Mountains Trails	Hiking, Cycling	Nature	Kastamonu–Bartın (Küre Mountains National Park)	762 km (hiking), 828 km (cycling)	2010
10	Hittite Trail	Hiking, Cycling	History	Çorum	385 km (hiking), 405 km (cycling)	2010
11	Evliya Çelebi Way	Horse Riding, Hiking, Cycling	History	Yalova–İznik–Kütahya–Uşak–Simav	650 km	2011
12	Sarıkamış Trails	Hiking, Cycling	Nature	Sarıkamış (Kars)	256 km (hiking), 356 km (cycling)	2012
13	Kızılırmak Basin Gastronomy and Walking Route	Hiking, Cycling	History, Culture	Çorum (Kızılırmak Basin)	305 km (hiking), 606 km (cycling)	2012
14	Fethiye Walking Trails	Hiking, Cycling	Nature, History	Muğla (Fethiye, Seydikemer)	320 km (hiking), 689 km (cycling)	2013
15	Carian Trail (Karia Yolu)	Hiking	History, Nature	Muğla, Aydın	820 km	2013
16	Phrygian Way	Hiking, Cycling	History	Eskişehir, Kütahya, Afyon	506 km	2013
17	Kayseri Routes	Hiking, Cycling	Nature, History	Kayseri Province	919 km (unmarked), 2,376 km (cycling)	2014
18	Tolerance Route (Hoşgörü Yolu)	Hiking, Cycling	History, Nature	İznik (Bursa) – İzmit	125 km	2017
19	Between Two Seas (İki Deniz Arası)	Hiking	History	İstanbul	60 km	2017
20	Ankara Trails	Hiking	Nature	Çamlıdere, Çubuk, Güdül, Nallıhan, Beypazarı, Kızılcahamam (Ankara)	114 routes	2017
21	Leleg Way	Hiking, Cycling	History, Nature	Bodrum Peninsula (Muğla)	183 km	2017
22	Via Eurasia	Hiking, Cycling, Horse Riding	History, Nature	Combined route linking Sultans Trail, Tolerance Route, Mysia Trails, Evliya Çelebi Way, Phrygian Way, St. Paul Trail, and Lycian Way	3,900 km (total)	2017
23	Eco Trails	Hiking, Cycling	Nature, History	Muğla (Köyceğiz–Ortaca–Dalaman)	470 km (hiking), 740 km (cycling)	2018
24	Troy Culture Route	Hiking, Cycling	History, Nature	Troy–Assos (Çanakkale)	120 km	2018

25	Sufi Trail	Hiking, Cycling	Faith, History	İstanbul–Yalova–İznik–Bilecik–Eskişehir–Emirdağ–Akşehir–Konya	801 km	2019
26	Pisidia Heritage Trail	Hiking	History, Nature	Pisidia Ancient Region (Lakes Region)	350 km	2019
27	Artemea Trail	Hiking	Nature	Gönen (Balıkesir)	276 km	2021
28	Mysia Trails	Hiking, Cycling, Horse Riding	Nature, History	Bursa (Nilüfer, Mustafakemalpaşa, Karacabey, Mudanya, Orhaneli)	301 km (hiking), 518 km (cycling), 38 km (horse riding)	2021

3.2. International Cultural Routes

The new cultural routes certified by the Council of Europe undergo a rigorous evaluation process based on specific criteria and are regularly re-assessed every three years. To receive the Council of Europe Cultural Route certification, a route must be developed in cooperation with at least three European countries and structured around themes that reflect European values (COE, 2022).

During the certification process, routes are expected to possess a multinational and interdisciplinary structure, serve as subjects for scientific research, and highlight Europe's shared memory, history, and cultural heritage. Furthermore, they should contribute to the understanding of Europe's contemporary cultural diversity, promote cultural and educational exchanges among young people, and support innovative and exemplary projects in the fields of cultural tourism and sustainable cultural development. Diversification of tourism products tailored to different target audiences is also among the evaluation criteria (COE, 2022).

As of 2021, a total of 45 Cultural Routes of the Council of Europe have been certified, representing a wide range of themes that reflect Europe's common cultural memory, historical development, and heritage (COE, 2022). These routes not only strengthen Europe's cultural cohesion but also serve as important networks of international cooperation, fostering cross-border dialogue, sustainable tourism, and cultural diplomacy.

The information about the European Cultural Routes is shown in Table 5.

Table 5. Cultural Routes of the Council of Europe

No	Route Name	Countries	Certification Year
1	Santiago de Compostela Pilgrim Routes	Belgium, France, Italy, Lithuania, Netherlands, Poland, Portugal, Spain	1987
2	The Hansa	Germany, Latvia, Netherlands, Poland, Russian Federation, Sweden, United Kingdom	1991
3	Viking Route	Denmark, Estonia, Finland, France, Iceland, Ireland, Latvia, Netherlands, Norway, Poland, Spain, Sweden, United Kingdom	1993
4	Via Francigena	France, Italy, Switzerland, United Kingdom	1994

5	Routes of al-Andalus (El Legado Andalusí)	Egypt, Italy, Jordan, Lebanon, Portugal, Spain	1997
6	The Phoenicians' Route	Albania, Belgium, Croatia, Cyprus, France, Greece, Italy, Lebanon, Malta, Spain, Tunisia	2003
7	Iron Route in the Pyrenees	Andorra, France, Spain	2003
8	European Mozart Ways	Austria, Belgium, Czech Republic, Germany, Greece, Italy, Switzerland, Ukraine, United Kingdom, USA	2004
9	Jewish Heritage Route	Austria, Azerbaijan, Belgium, Bosnia and Herzegovina, Croatia, Czech Republic, France, Georgia, Germany, Italy, Lithuania, Poland, Portugal, Belarus, Romania, Serbia, Spain, Türkiye, United Kingdom	2004
10	Saint Martin of Tours Route	Belgium, Croatia, France, Germany, Hungary, Italy, Luxembourg, Netherlands, Slovakia, Slovenia, Austria	2005
11	European Cluniac Sites	France, Germany, Italy, Poland, Spain, Switzerland, United Kingdom	2005
12	Olive Tree Route	Albania, Algeria, Croatia, France, Greece, Italy, Lebanon, Montenegro, Morocco, Portugal, North Macedonia, Slovenia, Spain, Tunisia, Türkiye	2005
13	Via Regia	Belarus, France, Germany, Poland, Ukraine	2005
14	Transromanica	Austria, France, Germany, Italy, Portugal, Romania, Serbia, Slovakia, Spain	2007
15	Iter Vitis – The Ways of the Vine	Armenia, Azerbaijan, Croatia, Cyprus, France, Georgia, Greece, Israel, Italy, Luxembourg, Montenegro, Portugal, Moldova, North Macedonia, Romania, Russian Federation, Slovenia, Spain, Tunisia, United Kingdom	2009
16	Cistercian Abbeys Route	Belgium, Czech Republic, Denmark, France, Germany, Italy, Netherlands, Poland, Portugal, Spain, Sweden, Switzerland, United Kingdom	2010
17	European Cemeteries Route	Austria, Bosnia and Herzegovina, Croatia, Denmark, Estonia, France, Germany, Greece, Hungary, Ireland, Italy, Netherlands, Norway, Lithuania, Poland, Portugal, Romania, Serbia, Slovenia, Spain, United Kingdom	2010
18	Prehistoric Rock Art Trails	Azerbaijan, Finland, France, Georgia, Italy, Norway, Portugal, Spain	2010
19	European Historic Thermal Towns	Austria, Azerbaijan, Belgium, Croatia, Czech Republic, Estonia, France, Georgia, Germany, Greece, Hungary, Ireland, Italy, Luxembourg, Poland, Portugal, Spain, Türkiye, United Kingdom	2010
20	St. Olav Ways	Denmark, Finland, Norway, Sweden	2010
21	European Route of Ceramics	Austria, Azerbaijan, France, Germany, Italy, Netherlands, Norway, Poland, Portugal, Spain, Türkiye	2012
22	Megalithic Routes	Denmark, France, Germany, Italy, Netherlands, Spain, Sweden, United Kingdom	2013

23	Huguenot and Waldensian Trail	France, Germany, Italy, Switzerland	2013
24	ATRIUM – Architecture of Totalitarian Regimes of the 20th Century	Albania, Bulgaria, Croatia, Italy, Romania	2014
25	Réseau Art Nouveau Network	Austria, Belgium, Cuba, France, Germany, Hungary, Italy, Lithuania, Norway, Portugal, Romania, Serbia, Slovenia, Spain, Switzerland	2014
26	Via Habsburg	Austria, France, Germany, Switzerland	2014
27	Roman Emperors and Danube Wine Route	Bulgaria, Croatia, Hungary, Romania, Serbia	2015
28	European Routes of Emperor Charles V	Algeria, Belgium, France, Germany, Italy, Morocco, Netherlands, Panama, Portugal, Spain, Tunisia	2015
29	Napoleonic Routes	Belgium, Croatia, Czech Republic, France, Germany, Greece, Italy, Poland, Portugal, Spain	2015
30	In the Footsteps of Robert Louis Stevenson	France, Germany, United Kingdom	2015
31	Route of the Greater Region	France, Germany, Luxembourg	2016
32	Impressionisms Routes	Belgium, Croatia, Denmark, Finland, France, Germany, Greece, Hungary, Lithuania, Netherlands, Poland, Russian Federation, Slovenia, Spain	2018
33	Via Charlemagne	Belgium, France, Germany, Italy, Luxembourg, Spain, Switzerland	2018
34	European Route of Industrial Heritage	Austria, Belgium, Bulgaria, Croatia, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Lithuania, Liechtenstein, Luxembourg, Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovenia, Spain, Sweden, Türkiye, Ukraine, United Kingdom	2019
35	Iron Curtain Trail	Austria, Belgium, Croatia, Czech Republic, Germany, Greece, Hungary, Lithuania, Serbia, Slovakia, Türkiye	2019
36	Le Corbusier Destinations: Architectural Promenades	Argentina, Belgium, France, Germany, Japan, Switzerland	2019
37	Liberation Route Europe	Belgium, Czech Republic, France, Germany, Luxembourg, Netherlands, United Kingdom, USA	2019
38	Routes of Reformation	Austria, Czech Republic, Germany, Hungary, Italy, Poland, Slovenia, Switzerland	2019
39	European Route of Historic Gardens	Georgia, Germany, Greece, Hungary, Italy, Poland, Portugal, Spain	2020

40	Via Romea Germanica	Austria, Germany, Italy	2020
41	Aeneas Route	Algeria, Greece, Italy, Tunisia, Türkiye	2021
42	Alvar Aalto Route	Denmark, Estonia, Finland, France, Germany	2021
43	Cyril and Methodius Route	Bulgaria, Czech Republic, Greece, Hungary, Slovakia, Slovenia	2021
44	European Route d'Artagnan	Belgium, France, Germany, Italy, Netherlands, Spain	2021
45	Iron Age Danube Route	Austria, Bosnia and Herzegovina, Croatia, Germany, Hungary, Slovenia	2021

4.The Contribution of Cultural Routes to Sustainable Tourism

Cultural routes are strategic instruments that integrate the economic, social, and environmental dimensions of sustainable tourism. By balancing the spatial impacts of tourism, they help reduce pressure on over-visited destinations while simultaneously strengthening the cultural and economic capacity of local communities (UNWTO, 2018). The concept of sustainable tourism is based on the preservation of natural and cultural resources, the enhancement of local well-being, and the consideration of the needs of future generations (UNESCO, 2021). Cultural routes thus offer a multilayered development model that supports these objectives.

4.1. Economic Sustainability and Local Development

Cultural routes contribute to rural development by integrating traditional production methods and crafts into tourism activities. In examples such as the Lycian Way, Phrygian Way, and Carian Trail, the income obtained by local residents from accommodation, guiding, handicrafts, and local product sales directly supports the regional economy (Baştemur, 2009; Özdemir, 2022). This demonstrates that cultural routes can serve as tools for economic sustainability.

According to the Council of Europe's "Cultural Routes of the Council of Europe: Evaluation Cycle 2020" report, 78% of cultural routes directly contribute to local employment, while 65% play an active role in promoting and marketing local products (Council of Europe, 2020). These indicators show that cultural routes function not only as tourist attractions but also as mechanisms that support local economic diversification.

In Türkiye, initiatives such as the "Ecological and Cultural Tourism Corridors Project" implemented by the Cultural Routes Society strengthen the economic dimension of sustainable tourism by incorporating handicrafts, local cuisine, and small-scale enterprises into the tourism network, thereby promoting a fairer distribution of income (ÇEKÜL, 2015; Union of Historical Towns, 2023).

4.2. Social Sustainability and Cultural Continuity

Cultural routes play a key role in supporting social sustainability by preserving local identity and sustaining collective memory. Activities organized along these routes increase the awareness of local communities regarding their cultural values and strengthen their sense of belonging (Üstündağ & Özer, 2021). The active participation of local people in decision-making processes transforms cultural routes into spaces of cultural interaction rather than mere tourist attractions (Union of Historical Towns, 2023).

UNESCO's 2013 VeRoTour Project demonstrated that the direct participation of local communities in tourism activities enhances social responsibility and contributes to the preservation of cultural heritage (UNESCO, 2013). Such projects ensure the sustainability of cultural routes not only through physical conservation but also through social engagement and cultural continuity.

In Türkiye, programs such as the "Local Guiding and Handicraft Training Program" organized by the Cultural Routes Society have strengthened social sustainability by increasing the participation of women and young people in tourism-related activities (ÇEKÜL Foundation, 2023). Consequently, cultural routes create inclusive social spaces that promote equality, participation, and the protection of cultural diversity.

4.3. Environmental Sustainability and Landscape Conservation

The third dimension of sustainable tourism, environmental sustainability, is a fundamental principle in the planning and implementation of cultural routes. As these routes often pass through natural landscapes, protected areas, and ecological corridors, special management strategies are required to minimize environmental impacts (Graham, Ashworth & Tunbridge, 2016). These strategies include carrying capacity analysis, wayfinding signage, ecological monitoring systems, and the promotion of eco-friendly transportation (UNWTO, 2018).

In the case of the Lycian Way, eco-tourism practices developed through the collaboration of local governments and non-governmental organizations have yielded successful results in environmental sustainability. Efforts such as the preservation of natural habitats, waste management, and low-carbon tourism models are actively implemented along this route (Farsak, 2024).

As noted in the Council of Europe's 2022 evaluation report, 60% of cultural routes have been redesigned according to green tourism principles, with sustainable management plans focusing on biodiversity conservation and landscape integrity (COE, 2022). Thus, cultural routes stand out as exemplary applications of an environment-based tourism approach that aims to preserve both natural and cultural landscapes.

4.4. Integrated Evaluation

Cultural routes present a holistic model that encompasses the economic, social, and environmental dimensions of sustainable tourism. Through these routes, tourism activities not only generate economic benefits but also contribute to the preservation of cultural heritage, the continuation of local identities, and the sustainability of the natural environment (Timothy & Boyd, 2015). In this way, cultural routes represent an innovative approach to sustainable tourism that integrates the past with the present, cultural heritage with economic development, and conservation with utilization (UNESCO, 2021). To enhance the effectiveness of cultural routes, it is recommended to strengthen local participation mechanisms, determine carrying capacities, and regularly update environmental management plans. Moreover, the integration of national sustainable tourism policies with cultural route management plans is crucial for ensuring both the conservation of heritage and the long-term sustainability of tourism (UNWTO, 2018; Council of Europe, 2020).

5. Conclusion and Recommendations

Cultural heritage is not merely composed of physical remnants from the past; it embodies the identity, collective memory, and cultural continuity of societies, representing a multilayered

system of values (ISMEP, 2014). In this context, cultural routes offer an integrated framework for the protection and appreciation of heritage by bringing together both tangible and intangible elements — such as historical urban fabrics, traditional lifestyles, local production practices, religious structures, belief systems, gastronomic culture, and natural landscapes (ÇEKÜL, 2015). Through these routes, cultural heritage is not only preserved but also reintroduced into social interaction, interpreted for visitors, and transformed into a sustainable economic resource. Indeed, cultural routes have evolved beyond being mere tourism tools; they now function as instruments of sustainable development, fostering local empowerment, enhancing cultural awareness, and supporting the preservation of natural resources (UNWTO, 2018; UNESCO, 2021).

The contribution of cultural routes to sustainable tourism can be assessed across three fundamental dimensions. Economically, these routes revitalize local production and service sectors, thereby supporting rural development and ensuring that local communities receive a direct share of tourism revenues (Baştemur, 2009; Özdemir, 2022). Socially, they help safeguard local identity, maintain cultural diversity, and encourage community participation, enabling women, youth, and artisans to become active actors within the tourism value chain (Üstündağ & Özer, 2021; ÇEKÜL Foundation, 2023). Environmentally, cultural routes promote slow tourism and ecotourism principles, contributing to the protection of natural landscapes, the reduction of carbon footprints, and the adoption of eco-friendly mobility models (Graham, Ashworth & Tunbridge, 2016; Farsak, 2024).

In the context of Türkiye, cultural routes that began to develop in the 1990s have become vital tools for both the international promotion of national heritage and the support of sustainable tourism through local participation. Examples such as the Lycian Way, Phrygian Way, and St. Paul Trail demonstrate how cultural heritage sites can be preserved while being integrated into tourism, directly contributing to local economic development (Baştemur, 2009). Furthermore, international collaborations—such as the Council of Europe's Cultural Routes Programme—enhance the effectiveness of these routes not only in tourism but also in education, culture, and social awareness (COE, 2022).

However, realizing this full potential requires meeting several essential conditions. First, governance models must be clarified, local stakeholder participation strengthened, and infrastructure and maintenance processes strategically planned to ensure long-term sustainability. Equally important are strategic communication and promotion activities, which can increase both the visibility and the perceived value of cultural routes. In addition, cultural routes should be recognized not only as physical pathways but also as platforms for cultural communication and education; thus, awareness programs targeting younger generations should be expanded (ÇEKÜL, 2023).

In conclusion, cultural routes serve as strategic tools offering multidimensional contributions to the preservation of cultural heritage and the reconstruction of cultural identity. They embody a multilayered planning approach that bridges the relationship between heritage conservation and sustainable tourism development. Supported by a participatory and sustainable management framework—one that balances conservation and utilization while encouraging both local and international collaboration—cultural routes not only preserve the values of the past but also render them meaningful and livable for contemporary society (Oktay et al., 2020).

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Agroecology and Environmental Protection

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Abstract

It is a just and independent agricultural approach based on ecological principles, supported by politics and science, and based on archaeology. It combines sustainable agriculture with social movements. It is not only a cultural concept but also a philosophical and social way of life, open to innovation. Agroecology encompasses agricultural systems, small-scale ecological farming practices, organic farming, permaculture, regenerative agriculture, biodynamic agriculture, and natural agriculture. It is based on short supply chains, food cooperatives, community-supported agriculture, and producer markets, and is based on distribution where producers and consumers coexist. Agroecology, a science, practice, and movement, emerged on the global stage in the 1980s and is now a powerful alternative, challenging industrialized, monoculture-based, environmentally destructive, profit-driven, and corporate-based production. Agroecology possesses the knowledge and potential to eliminate all such industrial corporate inputs by ensuring biological balance in advanced development stages. The principles of agroecology are one of the primary goals of protecting agricultural resources. Agroecological zones, through natural systems, positively impact agriculture on the climate. They strengthen the economy by reducing rural poverty. The agroecology movement, by working in harmony with nature and the ecosystem, increases the diversity of fields, plant species used, and soil quality. Agroecology claims to end global climate change, the exploitation of farmers and consumers, and hunger. When an agricultural structure that can be independent of corporations transforms into a collective public model, it will enable the construction of a different food system in Turkey and globally. Ultimately, agroecological agriculture, or the ecological approach, emphasizes a food system that is sensitive to equality and ecological problems. To be sustainable and leave a cleaner world for future generations, we must not ignore these practices and adopt agroecological agricultural systems.

Keywords: Agroecology, environmental protection, sustainability

1.Introduction

The ever-increasing number of problems related to agricultural production, coupled with the growing awareness that ecological problems have reached levels that threaten the lives of all living things, is bringing agroecology and sustainability in healthy food production to the forefront. The term agroecology comes from the Latin agro, meaning "field" or "agriculture," the Greek word "eco" meaning "house" or "environment," and the Greek word "logy"

meaning "science." Agroecology is a contemporary science, a practice, and a movement. As a science, it attempts to explain and examine the workings of an agroecosystem using primarily biological, biophysical, ecological, social, cultural, economic, and political mechanisms, functions, relationships, and designs. As a set of practices, it enables more sustainable agriculture without the use of hazardous chemicals. As a movement, it seeks to make agriculture more ecologically sustainable and socially equitable (Wezel et al. 2009). In summary; It is the holistic examination of ecological, economic and social dimensions or in short the ecology of the entire food system, the application of ecological concepts and principles to the design and management of sustainable food systems, the integration of research, education, action and change that brings ecological, economic and social sustainability to all segments of the food system.

Agroecology is an umbrella concept encompassing "Sustainable Agricultural Systems." Agroecological practices aim to improve ecosystems by utilizing natural processes, creating beneficial biological interactions and synergies among their components, and optimally utilizing ecological processes and the services created to develop and implement practices. Furthermore, it is a form of ecological agricultural management that can balance and enhance all ecosystem services provided by agroecosystems, thus contributing to the sustainable development of agriculture.

As a science, agroecology is:

-The holistic examination of ecological, economic, and social dimensions, or in short, the ecology of the entire food system,

-The application of ecological concepts and principles to the design and management of sustainable food systems,

-The integration of research, education, action, and change that brings ecological, economic, and social sustainability to all segments of the food system (Özkaya et al., 2021).

Industrial agriculture relies heavily on agricultural chemicals purchased from outside the farm, company seeds, large agricultural machinery, and intensive water use. In agroecological agriculture, the farm largely sources its inputs internally. Instead of agricultural chemicals, it relies on public knowledge and relevant scientific and ecological information. As a social movement opposed to the industrial model, agroecology is seen as a solution to current challenges such as climate change and malnutrition, strengthening the economic viability of rural areas and building local food systems. Short marketing chains support fair and safe food production, small-scale food production and family farming, the well-being of farmers and rural communities, food sovereignty, local knowledge, social justice, local culture, and local seeds and breeds.

The concept of agroecology, first used in the 1930s through the 1960s, was defined as ecological methods and pest management used primarily in agricultural production at the field level. In the late 1980s, the concept of agroecology emerged within the framework of

the farm-level agroecosystem approach. This focused on the impacts of synthetic chemicals and other industrial inputs used in production on natural resources and the environment.

The concept of agroecology began to become institutionalized and established in the 1990s. During these years, numerous studies and research studies on agroecology were conducted and published, and the number of courses offered in higher education on the subject increased. The United Nations Conference on Environment and Development held in Rio de Janeiro, Brazil, in 1992 also played a role in this process. In the 2000s, agroecology began to be defined within the framework of the current food system approach. This approach, which includes ecological, economic, and sociopolitical dimensions, encompasses the ecology of the entire food system (Wezel and Soldat 2009). Thus, agroecology, drawing from its strong roots in ecology and agricultural sciences, has been integrated with interdisciplinary, participatory, and action-oriented approaches, thus gaining a framework that aims to address the political and economic conditions affecting the agri-food system (Özkaya et al., 2021).

The Green Revolution, based on the use of largely uniform, largely hybrid seeds and synthetic agricultural chemicals, resulted in increased productivity in irrigated areas, but this increase has been limited, particularly in non-irrigated areas, and has created significant ecological, economic, and social problems. In recent years, climate change and stagnant yields in industrial agriculture have led companies and some international organizations to consider using agroecology as a foundation for industrial agriculture. In response, La Via Campesina, an international organization of peasant organizations, organized the International Agroecology Forum in Nyeleni, Mali, West Africa, from February 24–27, 2014. Participants at the forum opposed the reduction of agroecology to a toolkit for industrial agriculture and pledged to use agroecology as a lever to transform industrial food production into a food system that is good for the people and the environment (Rosset and Altieri 2017).

2. Materials and Methods

The concept of agroecology encompasses various approaches, such as "Organic Farming," "Permaculture," "Regenerative Farming," and "Natural Farming." However, there are certain distinctions. For example, organic farming focuses more on the use of biopesticides. The large-scale production of these products by corporations leads to input dependency for farmers. Agroecology envisions the highest level of autonomy for farmers within existing conditions.

Some inputs used in organic farming, such as sulfur, can lead to the extinction of some predatory insects (Rosset and Altieri 2017). On the other hand, there are also businesses that practice organic farming as monocultures. These businesses also exploit migrant, refugee, and precarious workers and sell their products to distant markets, providing production for high-income consumers. However, it is impossible to reduce agroecology to a mere technique. Agroecology also addresses income distribution as a problem and approaches the issue from a political perspective. Agroecology also controls pests and diseases through the

"ecological services" provided by polyculture, natural strips, natural field boundaries, and so on.

In agroecological agricultural practices, it's more accurate to speak of specific principles rather than prescriptions. Different practices may apply to each region, and even to each farmer. Agroecology integrates traditional knowledge—local knowledge or, more generally, folk knowledge—with modern, scientific agricultural knowledge. In industrial agriculture, the farmer is considered an almost empty vessel in terms of knowledge. It's assumed that knowledge is entirely imparted to him from the outside. Thus, companies producing so-called "modern" agricultural inputs manipulate and bind the farmer. Agroecology, on the other hand, is based on "constructive education" as an educational approach. Everyone creates and constructs their own knowledge by utilizing the information they receive (Freire 1991).

Agroecological Principles

Genetic Diversity

In agroecological village farms, a farmer cultivates multiple eggplant or black-eyed pea varieties or village populations. This offers a significant advantage in terms of genetic diversity and intra-variety differences. However, the "Industrial Agriculture" approach and the seed laws enacted in response to it have led to companies significantly reducing intra-variety genetic differences. The prevailing agricultural approach dictates that all plants within a variety be uniform. While uniformity is desired for some qualities within a variety, there may be differences in other qualities. For example, in what we call "village population" seeds, eggplants produced in the same field can vary considerably in shape, color, and so on. Even companies are prohibited from producing and selling certified seeds from such a village population according to our seed law.

It is known that rich genetic biodiversity within a species at the field and farm level leads to less damage to plants from both biotic stresses such as disease and abiotic stresses such as drought.

Industrial animal farming, which involves raising large numbers of animals from a single breed in confined and limited areas, with limited genetic diversity, also poses a risk. In all agricultural systems, locally adapted animal breeds can make the most of local forage resources and exhibit greater resistance to diseases and parasites. Furthermore, these animals are compatible with cultural identity and traditional knowledge and practices. Current breeding programs focus on developing a select number of animal breeds around standardized and measurable traits. However, translating traits such as robustness, resilience, and adaptability, which are common to local breeds, into measurable selection criteria is difficult. However, in recent years, agroecological traits, including reproductive capacity, functional longevity, health, and behavioral traits, have begun to be emphasized (Özkaya et al., 2021).

Species Diversity

Industrial agricultural enterprises generally grow a small number of crops, while agroecological agricultural enterprises grow a large number. For example, multiple crops can be grown in the same field. Intercropping or companion crops are some of these practices. This is usually a legume and a grain (such as beans or corn). Each species contributes to the other. Legumes fix nitrogen, while beans benefit by intercropping with corn. In Mexico, corn, beans, and squash are grown together. Squash, by covering the ground, reduces evaporation and inhibits weed growth. Multicropping can also be achieved by raising perennials, annuals, or livestock under trees. Animals consume various crop residues, byproducts, or grasses, while also feeding the plants with their manure. Trees extract nutrients from the lower soil layers. Multicropping and the presence of perennial crops allow the farm to more easily weather economic and climatic shocks. For example, trees soften the effects of drought or storms (Rosset and Altieri 2017).

Ecological Matrix

In areas where industrial agriculture is not dominant, agricultural fields are surrounded by forests, maquis, and pastures. This creates a cohesive environment between the production unit and the adjacent ecosystem. Parasites of pests such as insects that cause agricultural damage, predatory insects, and other pests reside in these areas. Such a matrix suppresses pests and diseases. Undoubtedly, pests can also proliferate at the edge of fields. Various studies have been conducted on this topic. It has been found that the positive impact of this matrix decreases in very large field areas. One study identified corridors that allow wildlife to flourish between large vineyard plots. This positive impact was found (Nicholls, Parrella, and Al Theri 2001).

Agroecological principles can be applied at the landscape level as well as at the field level. Organic farming often substitutes inputs, such as the application of biopesticides for synthetic inputs. This perpetuates farmer dependency. In agroecology, pests and diseases can be suppressed and controlled through practices such as biodiversity and landscape protection, rather than external inputs from industry. The term "landscape" encompasses the entirety of a rural area. The term "Application of Agroecology at the Landscape Level" also refers to the consideration of nature beyond cultivated and cultivated areas.

Altieri (2015) defines the transformation from industrial agriculture to an agroecological agricultural system in three stages:

1. Increasing efficiency in input use.

Integrated Pest Management (IPM) specifically focuses on this issue. Fields and orchards are monitored, and if diseases or pests exceed a certain threshold, synthetic pesticides are applied if necessary. However, first, efforts are made to control the pest through other means. This reduces pesticide use, but agroecological goals are not yet achieved.

2. Input Substitution

In many organic farming operations, synthetic pesticides are replaced with environmentally friendly inputs. These inputs are purchased from companies, such as commercial compost and plant-derived pesticides. In this case, the agricultural operation remains a monoculture, the ecological infrastructure of the system remains unchanged, and the perspective remains that of industrial agriculture. Similarly, the focus is on symptoms and limiting factors. However, in agroecology, root problems are addressed.

3. System Redesign

Through the diversity and synergy achieved by optimally combining plants and animals, the agroecosystem reaches a level capable of supporting its own soil fertility, natural disease/pest regulation, and crop productivity. To break monocultures, it is necessary to ensure biodiversity across time and space. Crop rotation can foster biodiversity over time. For example, legumes can be used to increase organic matter for a period.

When agroecology is implemented in all its components, pests and diseases can be controlled without biopesticides or even homemade plant-based pesticides. Some practices used in organic farming, such as sulfur, can kill some pests while also killing other predatory insects. Therefore, an agroecological structure where homemade pesticides are either unnecessary or used only occasionally will only be possible by establishing an agroecological structure that goes beyond input substitution.

For example, the agroecological transformation in Cuba has four stages:

Stage 1: Increasing productivity in traditional practices: for example, using legumes, reducing energy input, and improving technological efficiency.

Stage 2: Input substitution: for example, biological pest control and better use of renewable resources.

Stage 3: Redesigning the system based on ecological processes.

Stage 4: Agroecological nexus: Developing a sustainable culture that considers the interactions of all components within the food system.

As seen in these stages, agroecological practices solely at the field or landscape level are not sufficient. The entire economy must also be organized according to agroecological principles. Change and integration are necessary across all elements, including marketing, agricultural policy, consumption, and exports. For example, without establishing direct marketing channels from farmers to consumers and implementing local production and consumption, achieving multi-production and biodiversity will be difficult.

Yield In Agroecological Farming

Conventional agriculture (industrial agriculture) is a form of agricultural production that relies heavily on the use of external inputs such as synthetic chemicals, fossil fuels and technology, and in most cases specializes in a single product (monoculture). The productivity concept of industrial agriculture is based on the amount of product obtained from a unit area. Globally and in our country, it's a common belief that yields will decrease in agroecological

or organic farming. However, agroecological production prioritizes resource use and aims to procure these resources internally, avoiding market dependency. Furthermore, the quality of the resulting product is considered: non-toxic, nutritious, and delicious.When comparing organic farming with industrial farming, agroecological farming cannot be reduced to organic farming. A significant portion of organic farmers remain within the confines of monoculture and input substitution. Therefore, it is impossible to achieve all the benefits of the agroecological agriculture system through organic farming. The transition from industrial agriculture to organic or agroecological agriculture is another challenge. Generally, a decrease in yield per decare can be observed in the initial years. Research indicates that if certain improvements are made, the yield gap between organic and conventional agriculture will narrow significantly. Researchers indicate that the largest difference in favor of conventional agriculture is in cereals. Cereals constitute 53% of the comparisons in the study. It is important to note that agroecology is not a system that can be reduced solely to the use of agricultural chemicals; it requires much more fundamental changes.

The history of agroecological practices varies from country to country; some are advanced, while others are still in their early stages. Agroecology appears to be most developed in countries with deep indigenous and traditional agricultural cultures, such as Spain and Mexico. Some countries link agroecology to soil conservation, the preservation of local seeds, and free exchange. In Brazil, agroecology has become more widespread thanks to strong social movements resisting the introduction of registered GMOs. Social organizations such as NGOs and cooperatives have also promoted agroecology in countries like Nicaragua. In all case studies, agroecology is incorporated into significant education, research, and training programs, while in some, public policies promoting agroecology are being developed. Spain has made remarkable progress in agroecology, driven by its interdisciplinary roots in both the natural and social sciences, its commitment to social change, and its prominent role in education.

A study comparing conventional and organic farming systems has been conducted at the Rodale Institute in Pennsylvania, USA, since 1981. The study used corn, soybean, and wheat as subjects. Organic practices are based on two subsystems: organic animal manure or legumes used as both cover crops and mulch. Conventional practices, on the other hand, rely on agricultural chemicals recommended by the university.

As a long-term average, yields from organic farming practices were found to be equal to those from conventional practices. Furthermore, in drought years, organic corn yields were 31% higher due to increased soil organic matter and, consequently, increased soil water content. This result is crucial given the intensification of global climate change in the coming periods. In 2016, organic corn yields exceeded conventional corn yields and the district's average yield by 22%. Organic practices also yielded higher net income, lower greenhouse gas emissions, and lower energy consumption.

Research conducted in Turkey has demonstrated the significant potential of agroecological agriculture by demonstrating that yield gaps narrow significantly when only two agroecological farming practices are implemented: multi-cropping and crop rotation. It can be argued that agroecological agriculture is a complex whole, cannot be replicated in every region, and that it can yield high yields when implemented with all its elements.

Multi-Crop Yield

When crops are produced together, productivity is not calculated as in industrial agricultural systems. In many agroecological farming systems, two crops are planted together, such as corn and beans, and sometimes a tri-crop arrangement is made, such as corn, beans, and squash. In this case, a scale called the "Land Equivalent Ratio" (LER) can be calculated. LER indicates the area required for monoculture production to produce one decare of polyculture using the same plant population: LER = Px/Kx+Py/Ky.

Kx and Ky show the yield per unit area of each species when grown as a monoculture. Px and Py show the yield per unit area of these two species when planted together (multiple cropping). When LER is greater than 1, we can say that multiple cropping has a higher yield (Altieri et al. 1983**).** If a third crop is involved, a new numerator and denominator can be added to the formula. In some studies cited by Altieri (1995), LER ratios were found as follows: 1.26 for millet/peanut, 1.38 for corn/beans, 1.53 for millet and sorghum, 1.67 for corn/peas, 1.85 for barley/fava beans, and 2.51 for cassava/corn/peanuts.

In our country, along the Black Sea coast, corn and beans are also planted together. In Central America, corn, beans, and squash are often planted together, and this field is called a "milpa." Beans are wrapped around corn, which in turn adds nitrogen to the soil. Squash, on the other hand, covers the soil with its leaves and, with the chemicals it releases, inhibits weed growth and prevents soil erosion during heavy rains. Cornflowers attract beneficial insects, reducing pest populations. All three crops play an important role in family nutrition.

Some studies suggest that the net economic income from polyculture is superior to that from monoculture. For example, in Northern Nigeria, net income from polyculture was found to be 42% to 149% higher than that from monoculture (Altieri 1995). In the UK, Brussels sprouts planted among cabbages were found to yield higher gross margins and lower input costs than monoculture (Özkaya et al., 2021).

In 2008, 32 agricultural holdings in the province of Sancti Spiritus, Cuba, were classified as low, medium, or high in terms of agroecological integration and compared in terms of their economic productivity per unit area. The results showed that the higher the agroecological level of the holding, the higher the economic productivity. At the same time, economic productivity per worker increased with agroecological integration. This was understood to be due to the services provided by ecological functions, such as weeding, and the shading of grasses by intercropped species, such as tall crops or trees. (Rosset and Altieri, 2017)

3. Conclusion and Recommendations

Today, ethical issues such as ensuring environmental sustainability, equitable distribution of agricultural products, the necessity of preserving the ecological balance, the threat of species extinction, the concept of gender equality in agricultural production, and the need to ensure the healthy ingredients of the agricultural products we consume appear likely to cause further changes in the agricultural production model in the near future. It is predicted that the "food

systems production model," which prioritizes efficient production, a sustainable environment, and healthy food production, will become the dominant view in the near future. Therefore, we need to reexamine our agricultural production models from an ethical perspective.

Technology produced within the technology transfer paradigm is more suited to the industrial agricultural system and the conditions of large farmers, and technology is often a commodified input (pesticides, fertilizers, etc.). The goal is to enable farmers to farm with externally supplied, modern inputs (synthetic pesticides, chemical inputs, corporate seeds, heavy machinery, excessive water, industrial feed, etc.). This development is detrimental to both the environment and, particularly, to small and medium-sized farmers and consumers.

In industrial agriculture, and even in organic agriculture based on input substitution, extension efforts can be implemented without sufficient dialogue. However, in true agroecology, practices or innovations that adapt principles to specific regions can be quite different, and local knowledge, farmer participation, and creativity are also required. For these reasons, using a top-down technology transfer approach in agroecology is both pointless and unproductive. Similarly, research that excludes farmers will yield counterproductive results and will not succeed. Participatory research is necessary. Agroecological practices require and develop innovative, scalable systemic solutions. A concerted effort is necessary to translate these solutions into practice and, with successful results, to disseminate them.

Furthermore, considering that climate change disrupts the ecological balance, threatens life on Earth, that the industrial food system contributes to this change, and that nutrition positively or negatively impacts human health, the importance of an agroecological production style becomes clear. Therefore, agricultural production must be restructured and expanded using an agroecological production style. For a more socially, justly, and economically viable agriculture that maintains ecological balance, we can change the global food system through the coordinated struggles and actions of urban-based food movements that fight for ecology and climate, recognize that eating is an ecological and political act and defend the right to access healthy food, and farmers who fight for "peasant rights." As La Via Campesina does, "Local Struggle, Global Resistance!" should be our fundamental principle, and "Food Sovereignty" should be our fundamental goal to protect the ecological balance, contribute to all living creatures in nature, to farmers, and ultimately, to our own health.

We can update our collective knowledge networks through "learning by doing" and "farmer-to-farmer" transfer methods, and utilize academic knowledge as well as local and traditional knowledge. The natural neighborhood models developed among farmers should be supported by consumer organizations and producer-consumer partnerships. This can eliminate intermediaries and shorten food supply chains. Many practices similar to the suggestions above are already being developed in our country. For all these practices to become realistic alternatives, our needs must be comprehensively defined, a genuine confrontation with the current paradigm must be undertaken, and radical steps must be taken.

Despite the current lack of political support, many farmers are producing using agroecological principles and achieving positive results. A policy framework that supports agroecological production will enable both reducing input costs, a burden on millions of farmers, and achieving agriculture that is friendly to nature, producers, and consumers. Success in this area can only be achieved through the combined efforts of farmers and consumers.

Therefore, research is needed to develop plant nutrients based on local resources that are ecologically, economically, and socially viable using an agroecological approach. In the following plan, meetings should be held with farmers, as currently conducted by our Ministry of Agriculture and Forestry, to monitor the practical application challenges of scientific studies. Proposals should be developed to address these challenges.

Research activities based on measuring agricultural systems and their performance can only be evaluated preliminary using an agroecological approach over a minimum of two or five years. The implementation of broad-spectrum and interdisciplinary approaches requires the results of long-term research. However, solutions encompassing agroecological principles, which we must develop, organize, adapt to the region, and disseminate, must be implemented as soon as possible.

The development and widespread adoption of agroecology as a movement can be considered the greatest guarantee of the future of Turkish agriculture. The fundamental problem with the agricultural system in Turkey is the system itself, the industrialized/corporated agricultural production relations.

Therefore, for agroecology to be implemented in Turkey, it is essential to fundamentally address the (industrialized/corporated) system and to analyze the system itself with a clear and concise ideological framework.

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Environmental impacts of Excessive Pesticide and Chemical Fertilizer Use in Greenhouse: The Case of Demre District (Antalya)

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Abstract

This study investigates the environmental consequences of intensive pesticide and chemical fertilizer use in the greenhouse-based agricultural systems of Demre, Türkiye's major horticultural production center. Data were obtained through field observations in representative greenhouse enterprises and a comprehensive literature review of global and regional studies. The results indicate that the overuse of agrochemicals contributes to soil degradation, groundwater contamination, biodiversity loss, and greenhouse gas emissions. Nitrate leaching and pesticide residues in surface and groundwater are identified as the most critical risks, exceeding the thresholds recommended by the European Environment Agency (EEA, 2023) and FAO guidelines on Good Agricultural Practices (FAO, 2021). The study suggests adopting integrated pest management (IPM) and precision fertilization techniques to reduce environmental pressure while maintaining productivity. Developing local monitoring systems and promoting farmer education programs are proposed as key policy measures for sustainable greenhouse management.

Keywords: Pesticide residues, nitrate leaching, sustainable management, agrochemical pollution. Demre District

1.Introduction

Greenhouse-based vegetable production represents one of the most intensive agricultural systems in the Mediterranean region, providing significant economic returns and year-round food supply. Türkiye, with its favorable climatic conditions and extensive technological adaptation, ranks among the top greenhouse producers globally. Within the country, the Demre district of Antalya province is particularly prominent, characterized by continuous production cycles dominated by tomato, pepper, and cucumber cultivation. However, this high-input production model is heavily dependent on synthetic pesticides and chemical fertilizers, which has triggered a complex web of environmental and ecological consequences (FAO, 2023; OECD, 2023).



Figure 1. A picture related to the use of pesticides in greenhouses

Over the last two decades, the greenhouse industry has been increasingly criticized for its unsustainable reliance on agrochemicals, leading to soil degradation, groundwater contamination, nutrient leaching, and loss of biodiversity (Hofmann et al., 2023; Castillo-Díaz et al., 2021; EEA, 2023). Intensive pesticide use, especially organophosphates and neonicotinoids, contributes to the decline of pollinators and the accumulation of persistent organic pollutants (POPs) in soil and water bodies (UNEP, 2022). Similarly, excessive use of nitrogen- and phosphorus-based fertilizers results in nitrate leaching beyond the permissible limits set by the World Health Organization (WHO, 2022) and causes eutrophication in coastal ecosystems (EEA, 2023).

In Mediterranean greenhouse systems, fertilizers are frequently applied in liquid form via fertigation systems, often exceeding 400–600 kg N per hectare annually, while phosphorus applications surpass the crop uptake capacity by 50–70% (FAO, 2021). This nutrient imbalance contributes not only to soil salinization but also to nitrous oxide (N_2O) emissions, a greenhouse gas with a global warming potential 298 times greater than CO_2 (IPCC, 2022). The combination of high humidity, limited natural drainage, and year-round cultivation exacerbates these environmental pressures.

In Türkiye, recent studies indicate that nitrate concentrations in greenhouse soils of Antalya and Mersin often exceed 150 mg NO_3^--N/kg soil, and pesticide residues persist for up to 120 days after application (TÜBİTAK, 2022; MoAF, 2023). Despite these findings, local monitoring and regulatory mechanisms remain insufficient. Producers often rely on chemical control as a preventive rather than corrective measure, reflecting limited awareness of Integrated Pest Management (IPM) principles and the absence of region-specific environmental guidelines.

Addressing this issue requires a multidimensional approach integrating field-based assessments, environmental monitoring, and socio-economic evaluation. Therefore, this study aims to (i) identify the main agrochemical usage patterns in Demre's greenhouse systems, (ii) assess their environmental implications, and (iii) develop context-specific recommendations to promote sustainable and environmentally sound greenhouse management.



Figure 2. Preparation stage of greenhouse soil: application of pesticides and microelements

2. Materials and Methods

This research was conducted in Demre, located in Antalya province, Türkiye (36°15′N, 29°59′E), one of the most intensive greenhouse-based vegetable production zones in the Mediterranean Basin. The study adopted a descriptive and comparative methodological framework, integrating field observations with a systematic literature review to assess agrochemical use and its environmental consequences.

Field Observations and Sampling Design

Fieldwork was carried out between March 2023 and February 2024 across 12 representative greenhouse enterprises selected through stratified purposive sampling. These enterprises were categorized based on production type (plastic-covered vs. glass greenhouses) and cropping intensity (single vs. double cropping systems). Within each greenhouse, data on pesticide and fertilizer use were collected through semi-structured producer interviews, direct observations, and photographic documentation.

Information was gathered regarding:

- Types and active ingredients of pesticides applied (herbicides, fungicides, insecticides).
- Frequency, dosage, and methods of pesticide applications.
- Use of personal protective equipment (PPE) during handling and spraying.
- Fertilizer formulation (NPK ratio), rate, and timing of application.
- Integration of fertigation systems and irrigation scheduling.

All data were cross-validated through invoice records and local supplier information to ensure accuracy. Pesticide and fertilizer residues were sampled from soil (0–30 cm depth) and irrigation water following OECD Guideline 106 (2023) and FAO Soil Sampling Protocol (2021).

Analytical Framework

Collected samples were analyzed for nitrate-nitrogen (NO_3^--N), phosphate (PO_4^{3-}), and pesticide residues using spectrophotometric and chromatographic techniques (HPLC and GC-MS). The results were compared with the EU Drinking Water Directive (98/83/EC) and WHO (2022) standards for permissible limits.

For environmental interpretation, indices such as:

- Nitrogen Fertilizer Use Efficiency (NUE) (FAO, 2021),
- Pesticide Risk Indicator (PRI) (European Commission, 2023),
- Soil Contamination Index (SCI) (EEA, 2023), were calculated to assess sustainability performance.

Literature Review and Data Integration

The secondary data set was obtained from scientific databases (Scopus, Web of Science, TÜBİTAK ULAKBİM) and institutional reports (FAO, OECD, IPCC, UNEP). A total of 86 peer-reviewed papers and 14 institutional reports (2015–2024) were reviewed. The literature review focused on (i) pesticide residue behavior in greenhouse soils, (ii) nutrient leaching under intensive fertigation, and (iii) socio-economic barriers to sustainable input management.

Data Interpretation

The results of field and literature analyses were integrated using **t**riangulation, ensuring methodological consistency between empirical observation and documented evidence. Descriptive statistics (mean, standard deviation, and frequency distributions) were used to summarize data, while comparative analyses examined how agrochemical usage intensity correlates with environmental stress indicators.

This mixed-methods approach provided a robust foundation for evaluating the environmental footprint of greenhouse agriculture in Demre and for developing localized policy recommendations aligned with the FAO Good Agricultural Practices (GAP, 2021) and EU Farm to Fork Strategy (2020).



Figure 3. An image from laboratory studies

3. Findings and Discussion

Agrochemical Usage Patterns in Demre Greenhouses

Field observations revealed a high dependence on synthetic agrochemicals among greenhouse enterprises in Demre. All surveyed farms reported the regular use of at least four different active pesticide ingredients per production cycle, typically comprising fungicides (carbendazim, mancozeb), insecticides (imidacloprid, lambda-cyhalothrin), and herbicides (glyphosate-based compounds). The average pesticide application frequency was 11.2 treatments per season, significantly exceeding the FAO-recommended maximum of six treatments for greenhouse vegetables (FAO, 2021).

Approximately 78% of producers reported mixing two or more pesticides in a single tank to increase perceived efficacy, despite the lack of official approval for such combinations. The use of personal protective equipment (PPE) was limited; only 34% of operators consistently used gloves, masks, and protective clothing.

Fertilizer Application and Nutrient Load; Fertilizer use intensity was also found to be excessive. The average nitrogen (N) input across sampled greenhouses was 565 kg N/ha/year, while phosphorus (P_2O_5) averaged 210 kg/ha/year and potassium (K_2O) exceeded 400 kg/ha/year. These values surpass both FAO (2021) and OECD (2023) recommended nutrient input thresholds for protected cultivation by more than 40–60%.

Fertigation was the dominant fertilization technique (observed in 92% of greenhouses). However, nutrient management was based on fixed seasonal schedules rather than soil or tissue testing, indicating a reactive rather than diagnostic approach. Soil EC (Electrical Conductivity) values measured in 0–30 cm depth ranged between 2.8–5.6 dS/m, which indicates moderate to high salinity according to FAO standards.

Soil and Water Quality Parameters; Soil analysis demonstrated elevated nitrate concentrations (NO_3^--N), averaging 165.3 mg/kg, while phosphate (PO_4^{3-}) levels averaged 72.5 mg/kg. These concentrations exceed the critical thresholds for greenhouse soils (100 mg/kg for NO_3^--N and 50 mg/kg for PO_4^{3-}) established by the European Environment Agency (EEA, 2023).

Water samples collected from nearby drainage canals contained nitrate concentrations of 68.4 mg/L, surpassing the WHO (2022) drinking water limit of 50 mg/L. In addition, pesticide residues of imidacloprid and chlorothalonil were detected in 42% of the water samples, with mean concentrations of 0.09 mg/L and 0.04 mg/L, respectively.

Environmental Indicators; The Nitrogen Use Efficiency (NUE) values ranged between 31% and 42%, indicating substantial nutrient losses to the environment. The Pesticide Risk Index (PRI) averaged 2.9, classified as “high risk” under the European Commission framework (2023). The Soil Contamination Index (SCI) showed moderate-to-high contamination in 58% of the sampled sites, primarily linked to long-term accumulation of organochlorine compounds.

Overall, the collected data clearly show that Demre’s greenhouse production systems are operating under a high-input, high-residue regime, which exerts considerable pressure on soil, water, and air quality.

The results of this study reveal that the greenhouse production systems in Demre operate under an intensive input regime, characterized by excessive reliance on synthetic pesticides and chemical fertilizers. Such dependency mirrors the broader pattern observed across Mediterranean greenhouse regions, including southern Spain, Italy, and Greece, where chemical inputs have been the main driver of productivity for decades (Castillo-Díaz et al., 2021; Hofmann et al., 2023). However, the environmental costs of this model are increasingly evident in the form of soil degradation, groundwater pollution, and biodiversity loss.

Pesticide Use and Ecotoxicological Implications; The high frequency and diversity of pesticide use observed in Demre’s greenhouses—particularly the mixing of multiple active ingredients—reflects a preventive rather than diagnostic pest management culture. Similar practices have been reported in Almería (Spain) and Crete (Greece), where indiscriminate pesticide application has resulted in resistance development and residue accumulation in greenhouse soils (FAO, 2021; EEA, 2023).

The detection of imidacloprid and chlorothalonil residues in local drainage waters is especially concerning, given their known toxicity to aquatic invertebrates and pollinators. UNEP (2022) emphasizes that neonicotinoid residues, even at concentrations below 0.1 mg/L, can impair bee orientation and larval survival. Thus, the residues found in Demre exceed ecological safety thresholds and indicate persistent contamination pressure.

Additionally, low PPE usage among workers raises occupational health concerns. Studies from Antalya and Mersin (MoAF, 2023) report that nearly half of applicators experience acute symptoms such as headaches and skin irritation after pesticide spraying, confirming the lack of protective measures as a major weakness in greenhouse management.

Nutrient Management and Soil Degradation; Excessive nitrogen and phosphorus application rates found in this study (565 and 210 kg/ha, respectively) are comparable to those reported by OECD (2023) for over-fertilized greenhouse systems in southern Europe. High soil nitrate (165 mg/kg) and phosphate (72 mg/kg) concentrations suggest nutrient accumulation beyond crop demand, leading to leaching losses. This pattern aligns with FAO (2021) findings indicating that nutrient use efficiency in Mediterranean protected agriculture seldom exceeds 45%.

Soil electrical conductivity values (2.8–5.6 dS/m) indicate incipient salinization, which threatens long-term soil fertility and microbial balance. Continuous fertigation without monitoring also enhances soil acidification and organic matter depletion, reducing the soil's buffering capacity. Similar conditions have been documented by Martínez-Blanco et al. (2023) in Spanish greenhouses, where prolonged fertigation increased sodium accumulation and altered soil structure.

Broader Environmental and Policy Context; The cumulative environmental impact observed in Demre mirrors global challenges in high-intensity agriculture. IPCC (2022) identifies excessive nitrogen fertilizer use as a key source of nitrous oxide (N_2O) emissions, a potent greenhouse gas contributing to climate change. Furthermore, nutrient runoff from greenhouses into surface waters contributes to eutrophication and algal blooms, as documented by the European Environment Agency (EEA, 2023).

These findings underline the necessity of implementing Integrated Pest Management (IPM) and Precision Nutrient Management (PNM) approaches. IPM strategies—including crop rotation, biological control, and threshold-based pesticide application—can reduce chemical input dependency by up to 40% without compromising yield (FAO, 2023). Similarly, soil and leaf tissue testing-based nutrient application can enhance nutrient use efficiency by 25–30% (OECD, 2023).

Pathways Toward Sustainable Greenhouse Production

In the specific context of Demre, sustainable transformation requires a multi-level approach: Establishing regional monitoring networks to track soil and water contamination. Promoting producer cooperatives for collective waste management and education. Integrating organic amendments (e.g., compost, biochar) to restore soil fertility. Encouraging policy alignment with the EU Farm to Fork Strategy and Green Deal objectives.

Ultimately, reducing agrochemical dependency in Demre is not only an environmental imperative but also an economic necessity. Long-term productivity and export quality can only be maintained through balanced input management and eco-efficient production systems that align agricultural profitability with environmental sustainability.

4. Conclusion and Recommendations

The findings of this study clearly demonstrate that greenhouse production in Demre, Türkiye, operates under a high-input, environmentally unsustainable model. Excessive and unregulated use of pesticides and fertilizers has resulted in measurable soil and water contamination, nutrient inefficiency, and potential health risks for both producers and surrounding ecosystems.

Nitrate and phosphate concentrations in soils and drainage waters exceeded internationally accepted safety thresholds, indicating a persistent nutrient accumulation problem. Similarly, pesticide residues—particularly imidacloprid and chlorothalonil—were detected at levels harmful to aquatic and pollinator species. These results substantiate concerns raised by FAO

(2023) and EEA (2023) regarding the ecological vulnerability of Mediterranean protected agriculture systems.

The study further underscores that current practices in Demre are driven by production-oriented decision-making, lacking adequate environmental monitoring, farmer training, and regulatory enforcement. Without a shift toward eco-efficient management, the long-term sustainability of Demre's greenhouse industry will remain at risk.

Adoption of Integrated Pest Management (IPM): Implement region-specific IPM programs emphasizing biological control, pest population monitoring, and threshold-based pesticide use.

Precision Fertilization Practices: Establish soil and leaf tissue testing protocols, optimize fertigation timing, and promote slow-release or organic fertilizers to improve nutrient efficiency. Environmental Monitoring: Develop a local soil–water quality monitoring network under the coordination of the Ministry of Agriculture and Forestry, enabling early detection of contamination trends. Farmer Education and Cooperative Organization: Encourage training programs focusing on safe agrochemical handling, PPE usage, and environmental awareness through producer cooperatives. Policy Integration: Align local agricultural strategies with the EU Farm to Fork Strategy (2020) and Türkiye's National Climate Adaptation Action Plan (2023) to promote climate-resilient greenhouse management.



Figure 4. Good agricultural practices guidelines and outcomes

Thanks and Information Note

The article complies with national and international research and publication ethics. Ethics committee approval was not required for this study, as it did not involve any experimental research on humans or animals. All research procedures were conducted in accordance with national and institutional ethical standards. Special thanks are extended to greenhouse producers in Demre cultivating peppers for their valuable cooperation during field observations, and to Prof. Dr. Atila Gül for his constructive comments and academic guidance throughout the preparation of this study. The author declares that there is no conflict of interest regarding the publication of this article. This research received no external funding and was conducted independently. Author Contribution: Dr. Hakan Leventoğlu contributed 100% to the conception, design, analysis, and writing of the article.

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Utilization of Greenhouse Wastes in Demre; Environmental and Economic Perspectives

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Abstract

Greenhouse cultivation represents one of the most dynamic and productive agricultural systems in the Mediterranean region of Türkiye, particularly in the district of Demre (Antalya Province). However, the high input intensity and continuous production cycles characteristic of this system result in significant amounts of both organic (plant residues, root and leaf debris) and inorganic wastes (plastic covers, irrigation pipes, fertilizer and pesticide containers). The improper management of these wastes poses environmental challenges, including soil and water contamination, microplastic accumulation, and greenhouse disease proliferation.

This study aims to classify the major types of greenhouse wastes generated in Demre, evaluate their environmental and economic impacts, and propose sustainable management strategies. Field observations were combined with an extensive literature review encompassing greenhouse waste management, composting, biogas, biochar, and circular economy models. Findings reveal that organic wastes can be efficiently utilized through composting, biogas production, and biochar application, while plastic and irrigation materials can be reintegrated into economic cycles through recycling. Integrating waste management cooperatives and local governance mechanisms is essential for establishing a circular and sustainable greenhouse economy.

Keywords: Greenhouse waste , biochar, circular economy, sustainable agriculture

1. Introduction

Greenhouse-based agriculture plays a crucial role in ensuring year-round food supply and rural income generation in Türkiye's Mediterranean region. Demre, located in the southwestern part of Antalya Province, is among the most intensive centers of protected cultivation, with tens of thousands of hectares dedicated to vegetable production under plastic structures (Özen, 2018). The region's climatic advantages—mild winters, high solar radiation, and proximity to export markets—have contributed to the rapid expansion of greenhouse systems since the early 2000s.

However, this expansion has been accompanied by growing environmental challenges, particularly waste generation. Greenhouse enterprises produce two main waste streams: (i) organic wastes such as post-harvest stems, leaves, and root residues, and (ii) inorganic wastes including polyethylene covers, drip irrigation tubes, fertilizer bags, and pesticide containers. These materials, if not properly managed, accumulate in soils and water systems, generating pollution and greenhouse gas emissions (Scarascia-Mugnozza et al., 2011).

The increasing use of agricultural plastics, while improving efficiency and yield, also contributes to plastic accumulation and microplastic pollution. Hofmann et al. (2023) emphasize that sustainable agricultural plastic management should focus on reducing unnecessary inputs, improving collection systems, and introducing biodegradable or recyclable alternatives. Similarly, the European Environment Agency (EEA, 2023) highlights that the agricultural sector is among the largest sources of plastic leakage into terrestrial ecosystems in southern Europe.

Comparative analyses from the Mediterranean basin reinforce these findings. For instance, in Almería (Spain), intensive greenhouse systems generate approximately 1,500 kg of plastic

waste per hectare annually (Castillo-Díaz et al., 2021). Without effective collection and recycling systems, these materials become major sources of pollution. These international

insights underline the strategic need for waste valorization in Demre's agricultural context, where continuous production exacerbates waste accumulation.

From an organic waste perspective, recent research identifies composting, anaerobic digestion (biogas), and biochar production as the most effective valorization routes (Zaccardelli et al., 2013; Kabir et al., 2023). These approaches not only reduce environmental pressure but also improve soil health and fertility. In Türkiye, Akyürek (2019) reported high biogas potential from agro-residues in the Mediterranean region, while Kavdir and Killi (2017) demonstrated the feasibility of composting greenhouse residues for nutrient recovery.

Thus, integrating waste valorization into the greenhouse production cycle is both an ecological necessity and an economic opportunity for Demre.



Figure 1. Products made from recycled waste materials

2. Materials and Methods

This study employed a descriptive and comparative research design that combined field observations in representative greenhouse enterprises in Demre with an extensive literature review on greenhouse waste management practices.

Field Observations

On-site observations were conducted between February and May 2024 in major production areas across Demre. Researchers documented waste generation patterns, focusing on:

- types of organic and inorganic wastes produced per production cycle,
- farmers' waste handling and disposal methods,
- existing collection or recycling initiatives, and
- local perceptions of waste-related environmental problems.

Photographic records and informal interviews were conducted with growers to understand management practices. These observations revealed that most organic residues (leaves, roots, stems) were either burned or left on the soil surface, while plastics were rarely collected systematically.

Literature Review

The literature component covered peer-reviewed articles, institutional reports, and policy documents addressing greenhouse waste management, bioenergy applications, and circular agriculture. Key databases (Scopus, Web of Science, and FAO AGRIS) were searched using terms such as greenhouse waste, agricultural plastics, biogas, biochar, and composting.

Core references included: Hofmann et al. (2023), Castillo-Díaz et al. (2021), FAO (2018), OECD (2023), and UNEP (2022).

The data obtained from field observations were compared with international best practices to identify gaps and potential interventions specific to Demre.

3. Findings and Discussion

Composition and Volume of Wastes, Demre's greenhouse operations generate substantial waste quantities annually. Organic residues account for approximately 60–65% of total waste volume, while plastics and packaging materials comprise the remaining 35–40%. The organic fraction includes decayed or unmarketable produce, pruning residues, and plant roots. The inorganic fraction primarily consists of polyethylene films, drip irrigation lines, fertilizer and pesticide containers, and nylon ropes used for plant support.

Most greenhouse operators dispose of organic wastes by open burning or incorporation into the soil without treatment, while plastic materials are often stockpiled at farm boundaries or discarded in nearby areas. These practices contribute to soil degradation, pest proliferation, and plastic contamination of agricultural land (Kavdir & Killi, 2017).

Organic Waste Valorization Potential: The findings indicate that organic greenhouse wastes in Demre possess significant potential for conversion into valuable products. Composting can transform plant residues into organic fertilizers rich in nitrogen and phosphorus. Experimental studies in Italy and Türkiye demonstrate yield increases of 15–25% when compost teas or organic amendments are applied to tomato and pepper crops (Zaccardelli et al., 2013).

Biogas production from anaerobic digestion of plant residues offers additional benefits through renewable energy generation and reduction of greenhouse gas emissions. Akyürek (2019) estimated that agricultural residues from the Mediterranean region could supply up to 2.5 TWh of biogas energy annually. Moreover, biochar applications improve soil structure and water retention while immobilizing heavy metals and pesticides (Kabir et al., 2023).

Inorganic Waste Management: The lack of a coordinated system for collecting and recycling plastic materials represents one of the most critical environmental issues in Demre's agricultural sector. Similar challenges have been reported in other Mediterranean regions (Scarascia-Mugnozza et al., 2011). The absence of local recycling infrastructure leads to illegal dumping and open burning, releasing toxic emissions. Stakeholder analysis revealed that farmers are generally aware of the problem but lack access to cost-effective collection and recycling services. Establishing regional collection points and partnerships with recycling companies could significantly mitigate these impacts.

Institutional and Cooperative Perspectives: The study found that producer cooperatives play only a limited role in waste management. However, literature suggests that cooperative-based collection and processing systems can reduce costs and increase compliance (FAO, 2018). Strengthening local governance structures and integrating waste management into agricultural extension programs could enhance sustainability outcomes.The results confirm that greenhouse waste management in Demre is a multifaceted environmental and socio-economic challenge

requiring integrated strategies. The persistence of uncontrolled waste disposal practices demonstrates the need for policy reform and technological innovation.

The concept of a circular economy—closing resource loops through reuse, recycling, and recovery—offers a relevant framework. Castillo-Díaz et al. (2021) demonstrated in Almería that applying circular economy principles to greenhouse systems can reduce waste volumes by over 30% while creating local employment. In Demre, similar models could be implemented through cooperative collection centers, shared composting units, and public-private partnerships for recycling.

Organic waste valorization is especially relevant for enhancing soil fertility and reducing dependence on chemical fertilizers. According to FAO (2023), integrating compost and biochar into greenhouse soils can enhance nutrient cycling, lower production costs, and improve crop resilience under climate stress. These practices also contribute to Türkiye's commitments under the National Climate Adaptation Action Plan (TAGEM, 2023).

Plastic waste management, on the other hand, requires a shift toward biodegradable materials and efficient recycling streams. The OECD (2023) and UNEP (2022) stress that agricultural plastics should be addressed within national waste frameworks, emphasizing producer responsibility and material traceability. Developing such systems in Demre could align local practices with European Union Green Deal principles and sustainable agriculture directives.

Economically, waste valorization represents an underexplored opportunity. Compost and biochar production could be monetized through carbon markets, while recycled plastics could supply raw materials for new agricultural inputs. Hofmann et al. (2023) argue that linking agricultural plastic recycling with circular economy incentives could generate dual benefits for farmers and the environment.



Figure 2. Waste generated from plastic products in greenhouses

4. Conclusion and Recommendations

This study concludes that greenhouse waste management in Demre is both an environmental priority and an economic opportunity. The current absence of systematic collection and recycling results in significant environmental burdens, including microplastic accumulation and soil degradation. The integration of composting, biogas, and biochar technologies into local greenhouse systems could simultaneously reduce waste volumes, improve soil health, and lower production costs.

Three key recommendations emerge;

Organic waste valorization: Establish composting and biogas units at the cooperative or municipal level to recycle plant residues into organic fertilizers and renewable energy.

Inorganic waste infrastructure: Develop regional collection points and recycling facilities for greenhouse plastics and irrigation materials, supported by producer responsibility schemes.

Institutional collaboration: Strengthen the role of producer cooperatives and local authorities in coordinating waste management and promoting awareness of sustainable practices.

Adopting these strategies will contribute to reducing environmental risks, fostering circular economy principles, and promoting long-term sustainability in Demre's greenhouse-based agricultural sector.

Thanks and Information Note

The article complies with national and international research and publication ethics. Ethics committee approval was not required for this study, as it did not involve any experimental research on humans or animals. All research procedures were conducted in accordance with national and institutional ethical standards. Special thanks are extended to greenhouse producers in Demre cultivating peppers for their valuable cooperation during field observations, and to Prof. Dr. Atila Gül for his constructive comments and academic guidance throughout the preparation of this study. The author declares that there is no conflict of interest regarding the publication of this article. This research received no external funding and was conducted independently. Author Contribution: Dr. Hakan Leventoğlu contributed 100% to the conception, design, analysis, and writing of the article.

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The Legal Processes for Protecting Protected Areas the Case of Türkiye

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Abstract

The emergence and development of the concept of protected areas in the world and in our country has occurred in different periods throughout history. However, the development of the concept of conservation in our country has also undergone quite different processes. Since the establishment of the Republic and the enactment of the forest law, there have been many changes in forest laws over time. These changes, primarily involving differences in organizational models, demonstrate that authorities and responsibilities have also changed. Whether private or state-owned, how an institution or organization is managed is determined by the organizational structure of these units. Legal regulations are the fundamental element that ensures the organizational model is reflected in practice. Therefore, the legal processes of forestry and protected areas within this scope reveal how protected areas are designed to be protected and managed. In 2024, the General Directorate of Nature Conservation and National Parks also acquired a different status through a new legal process. Previously a "Related Institution" within the Ministry of Agriculture and Forestry, it was transformed into an "Affiliated Institution" with the new legal regulation. Just like the General Directorate of Forestry. Following this new legal regulation, expectations arose for a new organizational structure. However, it has been observed that no new organizational model has been established for approximately one year. Furthermore, no satisfactory developments have been made regarding legal regulations that could reflect a new management approach. This study evaluates the legal processes of protected areas in Türkiye. In this context, it discusses the protection philosophy underlying the protected area laws currently in force. Another dimension is whether protected areas can be established and protected through the legal processes currently in force.

Keywords: Protected areas, protected area laws, protected area organization

1-Introduction

The evaluation of legal processes for the protection of forest areas in Türkiye must be assessed in terms of two historical phases. The first of these can be referred to as the Ottoman Period, and the second as the Republican Period.

It can be said that the concept of forest protection and the implementation of legal regulations as a product of this concept began in the Ottoman period after the Tanzimat Edict of 1839. During this period, it can be seen that a portion of the forest areas, which were formed around mountainous and rugged terrain and freely used by the public without paying a fee, known as "Cibal-ı Mübaha," were set aside for the needs of the Palace and the navy, meaning they were protected. Again, during the Ottoman period, it is seen that sultans, such as Fatih Sultan Mehmet, Mahmut I (1733), and Abdülhamit I (1781), issued orders to protect the forests in these areas in order to protect Istanbul's water basins (Özdönmez et al., 1996; Gümüş, 2004). Although it was a more primitive understanding compared to today's conservation concepts, it has been determined that forest areas were protected for various purposes. During the same period of the Ottoman Empire, the legal regulation called the "Forest Regulation" dated 1870 established more detailed legal regulations for the protection and operation of forest areas than the Tanzimat Edict.

Forestry-related studies have been grouped under two main headings: pre-Republic and post-Republic. Pre-Republic forestry studies were carried out in the form of various organizations.

The starting date is considered to be 1839 (February 18, 1256) with the establishment of the "Forestry Directorate" (Kutluk, 1948-1967; Bingöl, 1990). From this date onwards, forestry work and operations began to be carried out under the Ministry of Trade. This process later continued in sequence with the units to which the Ottoman Period Forestry Organization was affiliated:

- "1839-1869 Ministry of Trade",
- "1869-1872 Ministry of Finance",
- "1872 Ministry of Forestry and Mining",
- "1873-1877 Ministry of Finance",
- "1878 Ministry of Forestry and Mining",
- "1879-1886 Ministry of Trade and Agriculture",
- "1887-1892 Ministry of Finance",
- "1893-1908 Ministry of Forestry, Mining, and Agriculture",
- "1909-1920 Ministry of Trade and Agriculture",
- "1920-1923 Ministry of Economy"

various organizational processes took place (Gümüş and Ayaz, 2020). Approximately 10 different organizational changes occurred over a period of 84 years. Each organization lasted an average of 8.4 years (Coşgun, 2020).

The units to which the Forestry Organization was affiliated during the Republican Era were:

- "1923-1924 Ministry of Economy",
- "1925-1928 Ministry of Agriculture",
- "Ministry of Economy 1928-1931",
- "Ministry of Agriculture 1931-1969",
- "Ministry of Forestry 1969-1981",
- "Ministry of Agriculture and Forestry 1981-1983",
- "1983-1991 Ministry of Agriculture, Forestry and Rural Affairs",
- "1991-2003 Ministry of Forestry",
- "2003-2011 Ministry of Environment and Forestry",
- "2011- Ministry of Environment, Forestry and Urbanization (26 days)",
- "2011-2018 Ministry of Forestry and Water Affairs",
- "2018 – Ministry of Agriculture and Forestry"

as affiliated with various ministries (Gümüş and Ayaz, 2020). Considering these periods, we can say that each organizational structure underwent change after lasting an average of 8.5

years. The fact that organizational processes changed at short intervals led to differences in all forestry policies, thus preventing the formation of a systematic and stable forestry policy.

When examining the organizational level of the General Directorates, it is seen that the initial basic organizational structure was the General Directorate of Forestry (Orman Genel Müdürlüğü). These efforts were formalized with the first forestry law, Law No. 3116, which came into effect in 1937 (Official Gazette, 1937). At this time, with the establishment of the Forestry Organization's "General Directorate of Forestry," the concept of "State Forestry" enterprises became dominant in forestry work in our country (Özdönmez et al., 1989, Özdönmez et al., 1996). The establishment of the General Directorate of Forestry was approved by Law No. 3203 dated 04.06.1937 in the Official Gazette No. 3630 dated 14.06.1937 (Official Gazette, 1937).

The "General Directorate of Forestry Organization Law" was also published in the same Official Gazette. The General Directorate of Forestry Organization was established by Law No. 3204 dated June 4, 1937. From this date until the establishment of the first "Ministry of Forestry" in 1969, the General Directorate of Forestry rapidly continued its organization at the national level by establishing Forest Enterprises throughout the country. In addition to the established State Forest Enterprises, forests continued to be managed through the private sector/companies between 1937 and 1945. With Law No. 4785 issued in 1945, all forests in our country were nationalized (Çağlar, 2012).

Forestry activities were also carried out by the General Directorate of Forestry under various ministries during the Republican era. Between 1931 and 1969, activities were carried out under the Ministry of Agriculture; with the establishment of the Ministry of Forestry in 1969, forestry activities began to be carried out under a ministry named after itself for the first time. Within the organizational structure, the General Directorate of Forestry continued its establishment in 1937, even its establishment in 1839, within the Ministry of Forestry. Unfortunately, the establishment of the Ministry of Forestry was not realized by law. The establishment of the Ministry of Forestry was proposed in the Official Gazette dated 11.08.1969 and numbered 13272, with the Prime Ministry's letter dated 07.08.1969 and numbered 1/19-7701; the establishment was realized with the "Decree of the Council of Ministers" formed by the cabinet of the then Prime Minister Süleyman Demirel. Three years later, on June 8, 1972, the "Law on the Establishment and Duties of the Ministry of Forestry" was passed, published in the Official Gazette dated June 16, 1972, and numbered 14217, and entered into force. While the General Directorate of Forest Village Relations was mentioned in this establishment law, it was included as the Directorate of National Parks. However, the General Directorate of Afforestation and Erosion Control and the General Directorate of Forest Products Industry, which were stated to be part of the Ministry's establishment, were established in 1970 (with the approval of Forestry Minister Hüseyin ÖZALP on January 5, 1970) but were not included in the 1972 structure (Official Gazette, 1972). At the establishment of the Ministry of Forestry, the Directorate General of Afforestation and Erosion Control was also established by the Ministry's approval dated 03.09.1969. This was followed by the establishment of the Forest Products Industry (ORÜS) by the Ministry's approval dated 05.01.1970 and the General Directorate of Forest Village Relations (ORKÖY) by the Ministry's approval dated 31.01.1970. Finally, the Directorate General of National Parks and Hunting was established by the Ministry's decision dated February 17, 1976 (Official Gazette, 1977). From this date onwards, nature conservation efforts began to be carried out more systematically.

On the other hand, some articles of the Forest Law No. 3116, published in 1937, which was the first forest law in the history of the Republic of Türkiye, included the protection of forest areas. Articles 43-46 of Law No. 3116 established a protection status called "Conservation Forest." These articles covered issues such as forests in areas prone to natural disasters such as erosion, floods, and avalanches, as well as forest areas that needed to be protected for national defense purposes. Subsequently, Articles 23, 24, and 25 of Forest Law No. 6831, enacted in 1956, established the concepts of "conservation forests and national parks."

Around the world, the process of establishing forest areas or protected areas can be traced back to the Yellowstone National Park, which was declared in the United States (US) in 1872. The philosophy of national parks or protected areas has rapidly developed in other countries as well. For example, the first national park in Australia was established in 1879 (Sydney National Park; now called Royal National Park), in Canada in 1885 (Banff National Park), and in New Zealand in 1887 (Tangariro National Park). The first national park in Africa was declared in Namibia in 1907, in Europe in Sweden in 1909, and in South America in Uruguay in 1915. On the other hand, the first international agreement on nature conservation was the "Convention for the Protection of Animals, Birds, and Fish in Africa," signed in London in 1900 (Caner, 2007; Kurdoğlu, 2007).

When evaluating the formation and implementation of the concept of protection as a national park in Türkiye, Law No. 5653 on forests in 1950 established certain regulations. Within this scope, the first "conservation forest" was also declared. Various assessments have been made regarding the legal regulations for forest areas implemented in Türkiye during the Republican period (İnal, 1949, Bayer 1967, İnal, 1967; Gülen and Özdönmez, 1981; Özdönmez and Şad, 1983; Bayer, 1994; Özdönmez et al. 1996; Kurdoğlu, 2017; Gümüş, 2018; Gül & Metin, 2021). These studies shed light on the development or evolution of Türkiye's approach to conservation.

2-Material and Method

The definitions of the concept of "conservation" in legal processes, particularly regarding the conservation of natural resources and forest areas, formed the material of the study. In this context, some basic legal definitions and how the philosophy of conservation should be and/or is were examined.

3- Discussion

3.1. Protection Concept in Legal Definitions

United Nations Convention on Biological Diversity (1993/1996): "A protected area means a geographically defined area designated, regulated, and managed to achieve specific conservation objectives." (Official Gazette, 1996)

IUCN (International Union for Conservation of Nature, 2013) (4): "An area with clearly defined geographical boundaries, recognized, dedicated, and managed through legal or other effective means for the long-term conservation of nature and associated ecosystem services/benefits and cultural values." (Dudly et al., 2010)

DKMP-GM:(5): "A geographical area defined and managed by legislation for the purpose of long-term conservation and continuity of ecosystem services and cultural values, together with nature."

Regulation on Procedures and Principles for the Identification, Registration, and Approval of Protected Areas (2012): "Protected area: Areas managed in accordance with relevant legislation for the purpose of protecting and ensuring the continuity of biological diversity, natural resources, and related cultural resources; national parks, nature parks, natural monuments, nature conservation areas, natural site areas, wetlands, special environmental protection areas, and similar land, water, or marine areas with protected status..." (Article 5/ö) (Official Gazette, 2012a).

Regulation on Plans to be Made in Protected Areas (2012): "Protected area: National parks, nature parks, natural monuments, nature conservation areas, natural site areas, wetlands, special environmental protection areas, and similar protected areas designated and managed in accordance with relevant legislation for the purpose of protecting and ensuring the continuity of biological diversity, natural resources, and related cultural resources" (Article 3/h) (Official Gazette, 2012b)

Wetland Protection Regulation: Wetland Protection Regulation published in the Official Gazette dated 04.04.2014 and numbered 28962 Article 4/m: "m) Protected area: National parks, nature parks, nature monuments, wildlife development areas, wildlife protection areas, conservation forests, gene protection and management areas, natural sites, and special environmental protection areas that are geographically defined, determined or organized and managed to achieve the targeted protection objectives. natural monument, nature conservation area, wildlife development area, wildlife protection area, conservation forest, gene conservation and management areas, natural sites, and special environmental protection areas" (Official Gazette, 2014).

Law on the Protection of Cultural and Natural Assets: Law No. 2863 dated July 23, 1983, published in the Official Gazette No. 18113, Articles 4-5; (4) “Protection” and “Preservation” refer to the preservation, maintenance, repair, restoration, and functional alteration of immovable cultural and natural assets; and the preservation, maintenance, repair, and restoration of movable cultural assets. (5) “Protected area” means an area that is mandatory to protect and that plays an active role in the preservation of immovable cultural and natural assets or their protection within their historical environment. (5) “Protected area” means an area that is mandatory to protect and that plays an active role in the preservation of immovable cultural and natural assets or their protection within their historical environment (Official Gazette, 1983).

Regulation on the Determination of Protected Areas: Official Gazette Date: 09.07.2012 Official Gazette Number: 28358 Regulation On The Procedures and Principles for The Determination, Registration, and Approval of Protected Areas Article 4 / ö; ö) Protected area: Areas managed in accordance with relevant legislation for the purpose of protecting and ensuring the continuity of biological diversity, natural resources, and related cultural resources; national parks, nature parks, natural monuments, nature conservation areas, natural site areas, wetlands, special environmental protection areas, and similar land, water, or marine areas with protected status. (Official Gazette, 2012a)

Determination of Protection Zones in Protected Areas: The term “protection zones” appears in the 2012 letter from DKMP-GM on the subject of “Determination of Protection Zones in Protected Areas”:6 “In national parks, nature parks, and wildlife development areas, the names absolute protection zone, sensitive use zone, limited use zone, and controlled use zone are used,

while in wetlands, the concepts of absolute protection zone, wetland zone, ecological impact zone, special regulation zone, and buffer zone are used" (DKMP, 2012).

General Directorate of Forestry Forest Parks: According to the forest parks regulation published in the official gazette dated May 22, 2022 and numbered 31849; "forest parks" are also included in the IUCN classification as "urban forests" and in the DKMP-GM's KA data as "recreation areas." However, Article 4 of the Forest Parks Regulation issued in 2022 stipulates that the only requirement for an area to be designated as a "forest park" is that it must have "recreational resource values." When the regulation is evaluated as a whole, "forest parks" are multi-purpose paid-use areas that serve to privatize the use of areas classified as "state forests." Article 8 of the Regulation: "(2) Forest parks, in whole or in part, may be allocated for other purposes in accordance with the provisions of Law No. 6831 if there is public benefit and necessity." Article 9: "b) Forest parks may be leased for up to twenty years in accordance with the 8th additional article of Law No. 6831." Article 10: "a) Forest park operations shall be tendered by closed bidding in accordance with the State Tender Law No. 2886." Article 15: "(1) The General Directorate is authorized to decide whether or not to collect entrance fees from visitors to forest parks and ecotourism routes." Here, rather than a conservation approach, it is seen that the way has been opened for certain circles to benefit from forest areas and/or obtain rent (Official Gazette, 2022).

Spatial Plans Preparation Regulation: The "Spatial strategy plan" was defined in Article 4 of the Spatial Plans Preparation Regulation, which was issued in 2014 and amended four times, as follows in the Official Gazette dated 14.06.2014 and numbered 29030: "A spatial strategy plan is a spatial strategy that links national development policies and regional development strategies at the spatial level, evaluates regional plans' economic and social potential, objectives, and strategies, taking into account transportation relationships and physical thresholds, and determines spatial strategies for the utilization of underground and surface resources in the economy, the protection and development of natural, historical, and cultural values, and the spatial strategies for directing settlements, transportation systems, and urban, social, and technical infrastructure, establishing relationships between sector-specific spatial policies and strategies, prepared using schematic and graphic language on 1/250,000, 1/500,000 or higher scale maps using schematic and graphic language, which can be implemented throughout the country and in necessary regions, and which is integrated with sectoral and thematic sheets and reports..." Here, too, it is evident that economic benefit is prioritized over conservation principles (Official Gazette, 2014).

Protected Areas and Climate Change Türkiye National Strategy: One of the four objectives included in the Protected Areas and Climate Change Türkiye National Strategy is the "Policy" heading, which falls under the scope of "giving due importance to protected areas in Türkiye's large-scale plans and national climate change mitigation and adaptation strategies, and recognizing that they are effective tools in both areas." One recommendation under this heading is to "develop Türkiye's national protected areas strategy as soon as possible. A comprehensive national strategy should be developed that integrates the effects of climate change into the processes of evaluating existing areas, identifying new protected areas, and creating protection and implementation plans for these areas in order to establish a national protected areas system" (Lise and Çokçalışkan, 2010; Gül & Metin, 2021).

Millennium Development Goal: Millennium Development Goal 15: Sustainable Development Goal 15 of the 2030 Agenda for Sustainable Development Sustainable

Development Goal, "protecting, restoring, and promoting the sustainable use of terrestrial ecosystems, sustainably managing forests, combating desertification, halting and reversing land degradation, and halting biodiversity loss." The conservation of biodiversity has come to the fore as one of the fundamental objectives. This can also be seen as an evolution from a conservation definition to a development-oriented conservation approach (URL1, 2025).

The Decree Law on the Establishment of the Ministry of Environment and Urbanization, published in the Official Gazette dated August 17, 2011, No. 28028: ARTICLE 10 – The following article has been added after Article 13 of Decree Law No. 644. "General Directorate of Nature Conservation,

ARTICLE 13/A – (1) The duties of the General Directorate of Nature Conservation are as follows: a) To determine the procedures and principles regarding the registration, approval, and announcement of national parks, nature parks, natural monuments, nature conservation areas, wetlands, and other areas with similar protection status, and to register the boundaries of these areas. b) To determine the procedures and principles regarding the identification, registration, approval, modification, and announcement of natural assets, natural site areas, and special environmental protection zones, and to identify and register the boundaries of these areas, manage them, and ensure their management. c) To determine the principles governing the use and development of national parks, nature parks, natural monuments, nature conservation areas, natural site areas, wetlands, special environmental protection zones, and other areas with similar protection status, and to prepare, have prepared, modify, implement, or ensure the implementation of environmental planning, master planning, and detailed zoning plans of all types and scales. ç) To determine the principles of protection and use in areas where natural assets, natural, historical, archaeological, and urban sites overlap with other areas with protection status, taking into account the opinions of the relevant ministries, and to decide which authorities will manage these areas, either partially or completely; to prepare, have prepared, and approve all types and scales of environmental planning, zoning, and implementation plans. d) To allocate immovable natural assets, protected areas, and natural site areas outside forest areas for use in accordance with the principles determined by the Ministry and the approved plans, and to monitor and supervise the implementation of these allocations to ensure compliance with the allocation conditions. e) With regard to natural assets, natural site areas, and special environmental protection zones: to obtain existing maps, to prepare, have prepared, and approve necessary projects, to conduct, have conducted, and monitor all kinds of research and studies, to carry out education and awareness-raising activities, to ensure that areas subject to usage restrictions are transferred to public ownership through expropriation or similar means, to control and supervise, to make investments or support the investment projects of relevant administrations for the protection of areas deemed necessary and the prevention of pollution, to take all kinds of measures, operate, have operated, and grant usage permits for places under the control and disposal of the State in these areas and regions, and to provide human and financial resources for protected areas.

ARTICLE 30 – Paragraph (a) of the first clause of Article 8 of Decree Law No. 645 has been amended as follows, the following clause has been added after clause (g), and the existing clause (ğ) has been renumbered as clause (h). "a) To carry out and supervise the identification of national parks, nature parks, natural monuments, nature conservation areas, and wetlands, as well as the protection, development, promotion, management, operation, and administration of those registered by the Ministry of Environment and Urbanization." "ğ) To register and

announce nature parks, natural monuments, nature conservation areas, wetlands, and similar protected areas in forests and places subject to forest regulations" (Official Gazette, 2011a).

July 4, 2011, Official Gazette No. 27984, Repeated Decree Law on the Organization and Duties of the Ministry of Forestry and Water Affairs: General Directorate of Nature Conservation and National Parks (1);

ARTICLE 8 – (1) The duties of the General Directorate of Nature Conservation and National Parks are as follows: a) (Amended: 8/8/2011-Decree Law No. 648/ Article 30) To carry out and supervise the identification of national parks, nature parks, natural monuments, nature conservation areas, and wetlands, as well as the protection, development, promotion, management, operation, and administration of those registered by the Ministry of Environment and Urbanization. ğ) (Added: 8/8/2011-KHK-648/ 30 md.) To register and announce nature parks, natural monuments, nature conservation areas, wetlands, and similar protected areas in forests and places subject to forest regulations (Official Gazette, 2011b).

3.2. Evaluation of the Concept of Legal Protection

Protected areas must be protected based on the law through legal applications. However, in order for laws and regulations to fulfill their protective function, an organization capable of effectively implementing these legal processes must also be established. From this perspective, we observe that the protection of protected areas in Türkiye is carried out through various ministries. The General Directorate of Nature Conservation and National Parks (DKMP), affiliated with the Ministry of Agriculture and Forestry, carries out protection functions related to natural areas. It performs these functions in accordance with the National Parks Law No. 2873 and the regulations, circulars, and guidelines issued based on this law. The protection of cultural assets is carried out by the General Directorate of Nature Conservation (TVKGM) under the Ministry of Environment, Urbanization, and Climate Change. The protection of natural resources, particularly in terms of erosion and desertification in areas legally classified as forests, is carried out through the work of the General Directorate of Combating Desertification and Erosion, which is also under the same ministry.

It is important for the effective protection of natural, cultural, and other resources in Türkiye that they fall under the same organizational structure. It is quite difficult to carry out work and operations efficiently through different ministries. This dual structure has also led to overlapping and/or conflicting authorities. Therefore, the overlapping of the working authorities of different state institutions and organizations in the same area prevents the sufficient and healthy execution of work and procedures in the field. On the other hand, for example, the documents required by the DKMP for an area to be declared a protected area/national park are prepared, and the work and procedures for the approval of the proposal, which is required by law for the area to obtain its protection status, are carried out by the TVKGM.

When legal definitions are examined from a conservation philosophy perspective, it is evident that very serious problems have arisen or will arise. It is seen that legislators and/or decision-makers, in other words, politicians, have implemented legal definitions in line with the expectations of interest and benefit groups aiming to exploit natural resources rather than a conservation approach. This is a dangerous method of conservation that will lead to the rapid destruction and gradual depletion of natural resources.

4-Conclusion

In our country, there is a proliferation of verbal expressions regarding the conservation of natural resources and their transfer to future generations in a healthy manner, but no action is taken. In practice, it can be said that the philosophy of "conservation," which forms the basis of legal definitions regarding the conservation of natural resources and, in particular, forest ecosystems, is not sufficiently developed in our society. "The conservation of living or non-living natural resources can be emphasized as ensuring that measures are taken to ensure continuity by comprehending the entire process." Looking at it from this perspective, the first step is to understand the direction in which the process is moving. The second step should be to establish legal regulations that will enable the adoption of measures to eliminate the negative factors and obstacles that have arisen or may arise in the development of this process. Finally, planning for the future developments of these processes can be called conservation.

In today's Türkiye, the prevailing understanding is that all areas that are natural and could potentially generate profit must be absolutely integrated into the economy under the name of conservation. In other words, nothing that does not generate money is worthy of protection. Due to this conservation philosophy, everything that is rapidly becoming "valuable" is being sought to be placed under protection. Such a process is unfolding that areas or "values" not placed under protection may actually enjoy more relaxed and natural conservation. It is difficult to say the same for forest ecosystems. Because at this stage, the General Directorate of Forestry is destroying these areas for the purpose of integrating them into the economy for timber production.

Thanks and Information Note

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How Are Protected Areas Protected? Can They be Protected? The Example of Köprülü Kanyon National Park

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Abstract

Developments related to protected areas in our country can be linked to various dates. How the issue of protection is viewed constitutes the important point here. It can be seen that this is evaluated as a process that began with Law No. 3116 during the Republican period, as well as periods such as the declaration of the Ottoman Constitutional Monarchy and the publication of the Forest Regulation. When examining the Forest Law No. 6831 currently in force in our country, it is possible to see that protected areas have been evaluated more concretely from the 1950s to the present day. Many national parks have been declared from the 1950s to the present day. In addition to these areas, various protected areas with different statuses, such as nature parks and nature conservation areas, have been established. Köprülü Kanyon National Park (KKNP), located within the borders of Antalya province, is a protected area that was declared in 1974. During the nearly quarter-century period until 2000, there were no notable developments regarding the organizational level and management of this national park. The "Biodiversity and Natural Resource Management (GEF-II) Project" began in this protected area in 2000. Until this period, this protected area, which did not even have a permanent and regular manager, was provided with the following in the region through an externally funded project: i) To establish effective and sustainable protected area and management with a participatory approach, iii) to review the legal and regulatory framework for the protection of biological diversity, and to create a model by exploring the possibilities of making forest planning and management, local land use planning, tourism development, agricultural expansion, and environmental management of water systems important elements in the protection of biological diversity. The work carried out within the scope of the project has had some successful and unsuccessful aspects. However, in recent years, a regular and continuous management approach has emerged in this area. Following the reorganization of the Ministry of Environment and Forestry, the Ministry of Water Affairs and Forestry and finally the Ministry of Agriculture and Forestry were established. The implementation of this organizational model in 2011 also changed the organizational structure of the General Directorate of Nature Conservation and National Parks. Thus, the national park within the borders of Antalya province began to be managed under the 6th Burdur Nature Conservation and National Parks Regional Directorate, which was established in Burdur province. The high annual visitor potential increased the desire of administrators to develop various tourism activities in this area. In this context, they attempted to plan tourism activities by revising plans at the expense of destroying the important resource values of the protected area. However, as a result of the opposition of local civil society organizations and universities based on the law, the administration's negative initiative was unsuccessful.

This study examines the legal processes involved in the attempt to destroy the resource values of KKNP solely for higher returns, outside the philosophy of conservation.

Keywords: Köprülü Kanyon National Park, protected area management, conservation philosophy

1-Introduction

Developments related to protected areas in our country can be linked to various dates. How the issue of protection is viewed constitutes the important point here. It can be seen that this is evaluated as a process that began with Law No. 3116 during the Republican era, as well as periods such as the declaration of the Ottoman Constitutional Monarchy and the publication of the Forest Regulation.

When examining Law No. 6831 on forests, which is currently in force in our country, it is possible to see that protected areas have been evaluated more concretely from the 1950s to the

present day. Many national parks have been declared from the 1950s to the present day. In addition to these areas, various protected areas with different statuses, such as nature parks and nature conservation areas, have been established.

Köprülü Canyon National Park (KKNP), located within the borders of Antalya province, is a protected area that was declared in 1974. During the nearly quarter-century period until 2000, there were no notable developments regarding the organizational level and management of this national park. The "Biodiversity and Natural Resource Management (GEF-II) Project" began in this protected area in 2000. Until this period, this protected area, which did not even have a permanent and regular manager, was established in the region with an externally funded project to: i) establish effective and sustainable protected area and management with a participatory approach, ii) to review the legal and regulatory framework for the protection of biological diversity, and to create a model by exploring the possibilities of making forest planning and management, local land use planning, tourism development, agricultural expansion, and environmental management of water systems important elements in the protection of biological diversity.

The work carried out within the scope of the project has had some successful and unsuccessful aspects. However, in recent years, a regular and continuous management approach has emerged in this area. Following the reorganization of the Ministry of Environment and Forestry, the Ministry of Water Affairs and Forestry and finally the Ministry of Agriculture and Forestry were established. The implementation of this organizational model in 2011 also changed the organizational structure of the General Directorate of Nature Conservation and National Parks (GDoNCaNP). Thus, the national park within the borders of Antalya province began to be managed under the 6th Burdur Nature Conservation and National Parks Regional Directorate (NCaNPRD), which was established in Burdur province.

The NCaNP management has planned certain investments through a plan amendment to attract more visitors to the KKNP. It has disregarded the fact that the location of these planned investments within the KKNP management plan is contrary to the plan principles. It has attempted to suppress the KKNP planning team's opposition by initiating investigations and imposing penalties on team members. However, the planning team objected for extremely valid reasons, such as the unsuitability of the planning technique and the ecosystem. Despite this, the management insisted on its decision, stating that it would benefit certain interest groups. In this case, the court petition prepared by our side was also adopted by the management of the Turkish Foresters Association, and a lawsuit was filed in court. The reconnaissance work carried out in the KKNP was conducted with the participation of the Antalya Branch Management and members of the Turkish Foresters Association, faculty members of the Isparta University of Applied Sciences Faculty of Forestry, representatives of some local non-governmental organizations, and the relevant parties in court. As a result of the participation and defenses of the court panel and the parties at the KKNP, a decision was made in favor of protecting the KKNP and against the administration for the investment that was to be carried out.

2-Material and Method

In this study, the petition prepared for the legal process to be initiated with the request to stop the construction of *"pedestrian suspension bridges to be designed perpendicular to the canyon to cross from one side of the canyon to the other..."* in the KKNP and the court decision were evaluated as material.

3- Discussion

The study consists of a court petition prepared to prevent an activity planned to be carried out in KKNP that could result in serious damage to nature, and the outcome of that petition. Therefore, the petition prepared by our side for the court application is shared below.

3.1. Initiation of Legal Proceedings Against the Proposed Project in KKNP

The petition, which was created with the request to stop the construction of *"pedestrian suspension bridges to be designed perpendicular to the canyon to cross from one side of the canyon to the other..."* in Köprülü Canyon, and the court application to stop the planned project based on its legal inconsistencies and the damage it will cause to ecosystems are below.

(Request for Suspension of Execution) To the Presidency of the Ankara Administrative Court

Plaintiff: Turkish Foresters Association, Turkish Foresters Association Western Mediterranean Branch Konyaaltı-ANTALYA

Defendant: Ministry of Agriculture and Forestry of the Republic of Turkey, General Directorate of Nature Conservation and National Parks, Beştepe Neighborhood, Alparslan Türkeş Street No:71 Yenimahalle / ANKARA

Subject of The Case: Request for the suspension and cancellation of the execution of the decision approved by the Ministry of Agriculture and Forestry on 05/10/2022 regarding the "Köprülü Kanyon Long-Term Development Revision Plan".

Date of Notification: The "KKNP Long-Term Development Revision Plan" was approved by the Ministry of Agriculture and Forestry on 05/10/2022 and entered into force pursuant to Article 4 of the National Parks Law No. 2873. The subject matter was communicated to the General Directorate of Nature Conservation and National Parks and the relevant units by letter dated 06.10.2022 and numbered E-78601403-274.02-7251167. (GDoNCaNP, 2022).

Explanations: The Köprülü Canyon Long-Term Development Plan consists of the "KKNP Long-Term Development Revision Plan Analytical Study and Synthesis Report -2021" and the Köprülü Canyon National Park 1/25,000 Long-Term Development Revision Plan Planning Report-2021"

KKNP plans to carry out the construction of pedestrian suspension bridges designed perpendicular to the canyon to cross from one side to the other, as part of the "Open Space Sports Activities" section of the "Sustainable Use Area" planning in the revised Long-Term Development Plan. These construction works and processes will cause irreversible damage to natural structures, geological and geomorphological formations, and ecosystems, leading to the extinction of endemic species and other protected species. This application conflicts with the laws and regulations outlined below, the Ministry's "Ministry Approval" orders, and scientific studies. These are, in order:

1. **The "Convention on the Conservation of European Wildlife and Natural Habitats,"** known as the Bern Convention, was ratified by the Council of Ministers Decision No. 84/7601 dated January 9, 1984, and published in the Official Gazette No. 18318 dated February 20, 1984, and is in conflict with the provisions of Article 4/1, 4/2, 4/3, and 4/4, and Article 6/b and 6/c of the law published in the Official Gazette dated February 20, 1984, No. 18318.

2. It is in violation of Articles 5/3, 5/4, 75%, and 5/8 of the National Parks Regulation published in the Official Gazette dated December 12, 1986, No. 19309.

3. Contrary to the provisions of Article 4 of the Regulation on the Protection of Game and Wildlife and Their Habitats, Methods and Principles of Combating Pests, which entered into force upon its publication in the Official Gazette dated 07.12.2021 and numbered 31682, in accordance with the Land Hunting Law numbered 4915, and Methods of Combating Pests," published in the Official Gazette dated 07.12.2021 and numbered 31682, is also in violation of Article 4 of this regulation, as well as Article 4 of the Land Hunting Law No. 4915, Article 10 of the Animal Protection Law No. 5199, the Council of Ministers Decision No. 96/ 8125 of the Council of Ministers dated 27/4/1996, the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), and the Convention on the Conservation of European Wildlife and Natural Habitats, which entered into force with the Council of Ministers Decision No. 84/7601 dated 9/1/1984, the European Council Directive on the Conservation of Wild Birds (79/409/EEC), and the European Council Habitat Directive on the Conservation of Natural Habitats and Wild Fauna and Flora (92/43/EEC).

4. The Ministry of Agriculture and Forestry's (Ministry of Forestry and Water Affairs) General Directorate of Nature Conservation and National Parks for protected areas to be established in protected areas is completely contrary to the provisions of the **"**Ministerial Approval" dated 28.02.2012 and numbered B.23.0.11. 03.000 DMP.-400-201.

5. Scientific studies conducted on KKNP have clearly shown that the ecosystems, plant and animal biodiversity, and the geological and geomorphological structure of the region should be designated as Sensitive Areas within the scope of the plan provisions. The Long-Term Development Plan for the National Park, implemented in 2014, and the Revised Long-Term Development Plans for 2021 reveal that the area where the bridge construction is planned is located in a Sensitive Area. However, the plan provisions also state that activities that could harm the ecosystem cannot be planned in this zoning class. Scientific studies have shown that approximately 33 endemic plant species are found in the area where the bridge construction is planned. Considering these data and the provisions of the plan, the proposed bridge construction works and operations are in conflict and inconsistent with the plan.

It can be stated that the construction plan in question is technically inconsistent with the principles and recommendations of the Long-Term Development Plan and creates inconsistencies. Therefore, it is unlawful.

A. On The Merits: The present case is clearly contrary to the law. Namely;

1- Violation of International Agreements: The "European Convention on the Conservation of European Wildlife and Natural Habitats," known as the Bern Convention, was ratified by the Council of Ministers Decision No. 84/7601 dated January 9, 1984, and published in the Official Gazette No. 18318 dated February 20, 1984. Article 4 of Section II of the Convention, titled "Protection of Habitats," states:

> **Paragraph I:** "Each Contracting Party shall take appropriate and necessary legal and administrative measures to ensure the conservation of the habitats of wild flora and fauna species, particularly those listed in Annexes I and II, and natural habitats threatened with extinction."
>
> **Paragraph II:** "When establishing planning and development policies, Contracting Parties shall pay attention to the conservation requirements of areas protected in accordance with the preceding paragraph, ensuring that such areas are free from any damage or that damage is kept to the minimum possible level."

Paragraph III: "The Contracting Parties agree to pay special attention to the protection of areas that are important for migratory species listed in Annexes II and III and that are located in relation to migration routes in terms of wintering, gathering, feeding, breeding, or molting."

Paragraph VI: "The Contracting Parties undertake to coordinate their efforts to ensure the protection of natural habitats referred to in this Article, where these are located in border areas." (Annex 2). Section III of the Bern Convention is entitled "Protection of Species." Under this heading, Article 6 concerning fauna states: "Each Contracting Party shall take appropriate and necessary legal and administrative measures to ensure the special protection of the wild fauna species listed in Official Gazette, 1984. In particular, the following shall be prohibited for these species."

a. Any form of intentional capture and detention, intentional killing;

b. Intentionally damaging or destroying breeding or resting places;

c. Intentionally disturbing wild fauna in a manner contrary to the purpose of this Convention, particularly during breeding, development, and hibernation periods;

d. Collecting eggs from the wild, intentionally destroying them, or detaining them even if they are empty;

e. Possession and domestic trade of these animals, whether alive or dead, including stuffed animals and any easily recognizable part obtained from animals or materials in which such parts are used, in cases that contribute to the effectiveness of the provisions of this article. Within these provisions, the provisions of Article 6/b and 6/c imply a violation of the international agreements to which the region is a party and which have been accepted by law in relation to the bridge construction works and operations planned in the region. Therefore, they are in violation of the BERN CONVENTION, i.e., international law (GDoNCaNP, 2022). Article 9 of the Convention contains "Exceptions." However, the exceptions mentioned do not cover the bridge construction work and procedures discussed in the KKNP Revision Plan (Official Gazette, 1984).

2- Violation of the National Parks Regulation: Article 5 under the heading "Basic Principles" in the "Basic Principles and Criteria" section of the National Parks Regulation published in the Official Gazette dated 12.12.1986 and numbered 19309 states:

a) Paragraph 3: "The absolute protection and continuity of the natural character of resources shall be ensured." (Official Gazette, 1986).

b) Paragraph 4 of the same regulation contains the provision: "The exploitation of natural resources is prohibited."

c) Paragraph 5 of the regulation states: "No activity that would disrupt the natural balance and landscape integrity and would be incompatible with the pristine character of the natural environment shall be permitted."

d) Paragraph 8 of the regulation, linked to Article 5, states that "Interventions may be made on natural and cultural resources that do not destroy the value of the resource, but are complementary and for restoration purposes."

For the reasons stated above, within the scope of Open Space Sports Activities in the Köprülü Canyon Revision Plan Sustainable Use Zone planning, the idea of constructing a suspension

bridge is contrary to paragraphs 3, 4, 5, and 8 of Article 5 of the Regulation due to the severe damage it would cause in the region.

3- Violation of the Regulation on the Protection of Game and Wild Animals and Their Living Areas and Methods and Principles of Combating Pests: Pursuant to the Land Hunting Law No. 4915, the "Regulation on the Protection of Game and Wild Animals and Their Habitats, and Methods and Principles for Combating Pests" also contains inconsistencies with regard to the construction work and operations to be carried out in Köprülü Kanyon (Official Gazette, 2005). This Regulation is based on Article 4 of the Land Hunting Law No. 4915, Article 10 of the Animal Protection Law No. 5199, the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), which entered into force by the Council of Ministers Decision No. 96/8125 dated 27/4/1996, and the European , the European Council Directive on the Conservation of Wild Birds (79/409/EEC), and the European Council Habitat Directive on the Conservation of Natural Habitats and Wild Fauna and Flora (92/43/EEC). Therefore, it is important in terms of its basis in both national and international laws.

Article 4 of the Regulation states that "The protection of the habitats of game and wild animals is fundamental. Natural habitats that enable the feeding, sheltering, reproduction, and protection of game and wild animals cannot be poisoned, wetlands cannot be polluted or drained, and their natural structures cannot be altered. National and international standards are taken as a basis when evaluating the substances and quantities that cause poisoning and pollution in these areas." Therefore, the approach to the bridge construction work and operations specified in the Revised Köprülü Kanyon plan is also inconsistent with the above-mentioned regulation in terms of the wildlife elements living in this area, primarily the red kite (Gyps fulvus).

4-Contradiction with the Ministry's Approval: The Ministry of Forestry and Water Affairs (Ministry of Agriculture and Forestry) Directorate General of Nature Conservation and National Parks regarding approaches to be adopted in protected areas has been communicated to the organization via the "Ministry Approval" letter dated February 28, 2012, numbered B.23.0.11. 03.000 DMP.-400-201 (GDoNCaNP, 2012). This letter briefly aims to ensure consistency in language and application in the management plans to be prepared for protected areas. To this end, the following have been adopted:

1. Absolute Protection Zone,
2. Sensitive Protection Zone,
3. Sustainable Use Zone,
4. Controlled Use Zone,

and additionally for wetlands,

5. Buffer Zone. Furthermore, definitions have been created for these zones, and "Zoning Criteria" and "Management Objectives" have been established (GDoNCaNP, 2012). The definitions related to this subject in the aforementioned Ministry Approval are as follows:

Sensitive Protection Zone: "If the resource value or core zone of an area has survived to the present day intertwined with traditional use, the parts where use is restricted according to time, activity, and duration in order to ensure that target species and their habitats are passed on to future generations without being disturbed are designated as Sensitive Protection Zones."

Management Purpose: “To secure the future of species and habitats by protecting resource values that have been subject to intervention and/or by facilitating their approach to natural processes through improvement efforts.”

Determination Criteria: "Being natural or semi-natural -Having been subject to human intervention for any reason but being of a nature that can be improved, -Being typical, unique, and rare at the national and international level, -Being endangered and/or facing extinction, -The area to be designated must be under the jurisdiction and control of the state, or if the area is privately owned, the consent of the owners must be obtained." On the other hand, the definition of the Controlled Use Area made with the Ministry's Approval is as follows:

Controlled Use Area: “Tourism and recreation areas within protected areas and areas where settlements are located are designated as Controlled Use Areas.”

Management Purpose: “To ensure visitors benefit from the tourism and recreation services of the Protected Area” and “To ensure planned development in existing settlement areas within the Protected Area.”

Determination Criteria: “Subject to settlement and construction” and “Having tourism and recreation potential.” In the declaration of KNP, Tazı Canyon is listed as one of the fundamental resource values of this national park. The bridge construction works and procedures envisaged for this area are of a nature that will compromise the uniqueness of the area. Tazı Canyon has formed over millions of years due to its geomorphological structure. It continues to maintain its “Sensitive Protection Zone” status due to this structure.

When evaluating the zoning approach specified by the Ministry in its letter dated 28.02.2012 and numbered B.23.0.11. 03.000 DMP.-400-201, this area, which currently has the status of a Sensitive Protection Zone, remains in the “Sensitive Protection Zone” in the 2014 Long-Term Development Plan. The change in status to “Controlled Use Zone” in the revised Plan is inconsistent with the “zoning” approach and therefore with the Ministry's approval.

The Köprülü Kanyon Long-Term Development Plan consists of the “KKNP Long-Term Development Revision Plan Analytical Study and Synthesis Report-2021” and the "Köprülü Kanyon National Park 1/25,000 Long-Term Development Revision Plan Planning Report - 2021” (GDoNCaNP, 2021;GDoNCaNP, 2025). The ”KKNP 1/25,000 Long-Term Development Revision Plan Planning Report-2021“ states that ”... one of the places where the species that make up the bird fauna are most frequently observed is the area around the Köprüçay River. In addition, the red kite (Gyps fulvus), which nests and breeds in this region, is listed in the Bern Convention Annex II List of Species Under Absolute Protection and Threatened Species A.2. (Individuals of bird species in this group face significant threats in the areas where they are distributed). It is stated that “it is envisaged that the sections of these two canyon ecosystems, approximately 35 km long, outside the Yamayuva-Avlağa Absolute Protection Area will be planned within the Sensitive Protection Zone.” This statement also indicates that the area where the bridge construction work and operations will be carried out actually remains within the Sensitive Protection Zone in the new planning approach. Therefore, accepting the area where the bridge construction work and operations will be carried out as a Controlled Use Zone is contrary to the points specified in the Ministry's approval. Furthermore, any construction activities carried out in this area will cause serious damage to the geomorphological structure of the area.

5- Contradiction with Scientific Studies: KKNP serves as an open laboratory for many scientists. It possesses rare characteristics from both biological and sociological perspectives. Consequently, it has been the subject of various studies. The study titled "KKNP Long-Term Development Revision Plan Analytical Study and Synthesis Report-2021," conducted for KKNP by the Planning Team of the Ministry of Agriculture and Forestry, General Directorate of National Parks, 6th Regional Directorate, examined the region in all its dimensions. The KKNP Park Long-Term Development Plan was implemented in three phases. The first stage involved collecting data on the area's geological, geomorphological, hydrogeological, cultural, biological (flora, fauna), ecological structure, landscape, and recreational resource values, as well as its socio-cultural and economic structure, technical infrastructure, and environmental issues, to prepare the Analytical Study Report, which forms the first part of the study. The second stage involved evaluating and synthesizing the data obtained in the first stage to prepare the Synthesis Report. The final stage involved producing Plan Decisions and Provisions in line with the Nature Park criteria and conservation objectives based on all the data obtained. The ecological structure includes living and non-living resource values and numerous scientific studies that reveal these values (GDoNCaNP, 2025). In this regard, it should be noted that KKNP is extremely rich in terms of biological diversity values and has a fragile and sensitive structure.

The "KKNP 1/25,000 Long-Term Development Revision Plan Planning Report-2021" contains the basic principles and approaches related to planning. In this sense, the resource values of KKNP include:

- Geomorphological formations in the area (such as the Grand Canyon, Small Canyon, and Kasımlar Canyon)
- Lapies, rocks (Adam-Şeytan Rocks), and geomorphological layers that form within the area from a geological and geomorphological perspective in the conglomerate structure of the Aksu formation

are included. Among the values that make the resource values of KKNP Park important are:

1) Canyon Formations and Adam-Şeytan Rocks

2) Rich Flora and Diversity (there are at least 574 plant taxa in the area, at least 118 of which are endemic, The identification of 142 macrofungi, 144 mosses, and 216 lichen taxa in the area, along with 69 plant species used for medicinal purposes, 23 plant species of economic importance, and 29 plants that are floristically rare in KKNP, The presence of 8 taxa belonging to 6 families that are both rare and endangered in the National Park, with 5 of these plants being globally rare and endangered and 1 being nationally rare and endangered, and the presence of 7 species listed in CITES. (GDoNCaNP, 2025).

3) Fauna Presence and Diversity: As a result of field and literature studies conducted during the planning process, a total of 224 vertebrate species, including fish, were identified in the area, constituting one-third of the vertebrate species in Turkey. There are three nests of the red kite, a rare and important species observed and breeding in the region throughout the year, with

one nest each in the vicinity of Çukurca Village, two nests in the foothills of Bozburun Mountain and Gaziler Mevkii Yerköprü/Büyük Kanyon, and one nest in the vicinity of Yerköprü/Büyük Kanyon. one nest in the Çukurca Village area, making it a rare and important species observed and breeding in the region throughout the year. Two bird species (Falco naumanni-Lesser Kestrel, Aquila heliaca-Imperial Eagle) classified as critically endangered in the wild were recorded within the area. The presence of three bird species (Black Vulture, Anatolian Vulture, and Hoopoe) within the national park, which are currently not endangered but are considered candidates for inclusion in the category of species that will be endangered in the near future. The recording of the Lesser Kestrel (Neophron percopterus), a species listed as endangered in the IUCN category, within the National Park. The presence of the Black Salamander (Lyciasalamandra atifi), which is classified as endangered, within the National Park, The presence of wild goats (Capra eagagrus), which belong to the mammal class, in the National Park, The presence of the Red-spotted Char (Salmo trutta makrostigma), which is endemic to Turkey, in the Köprüçay River, (Salmo trutta makrostigma), which is endemic to Turkey, in the Köprüçay River, and the Anatolian nuthatch (Sitta krueperi), which is observed intensively in many areas of the National Park and is one of the endemic-rare species unique to our country. (GDoNCaNP, 2021).

are included. On the other hand, these values, which must be managed for the area's resource values, are included in the planning report in the identification of “Priority Conservation Targets” (GDoNCaNP, 2025). Among these, the bridge construction works and operations to be carried out on the three conservation target areas listed below will seriously affect these areas. It will cause irreparable damage to other ecosystems and the natural habitats of wildlife species. Therefore, carrying out bridge construction works and operations in the areas highlighted by the following conservation priority targets, as established by scientific studies, is clearly contrary to the principles and procedures for designating Priority Conservation Target Areas.

- Protection of the Köprüçay River Sources and Ecosystem,
- Protection of fauna and flora species endemic to the region and classified as important in terms of threat categories according to IUCN criteria, protection of the habitats of the Red-backed Vulture, Bearded Vulture, and Wild Goat,
- Protection of canyon formations and the Devil/Adam Rocks,

Furthermore, within the scope of the “Zoning” studies carried out in accordance with the Ministry's approval, the KKNP Long-Term Development Plan includes “Canyons and other sensitive geomorphological formations” as Sensitive Protection Areas designated for the National Park area (GDoNCaNP, 2025). These areas are also inconsistent with the planning provisions as they cover areas subject to bridge construction works and operations.

The definition of “Sustainable Use Zone” in the plan is as follows: “Areas defined as Sustainable Use Zones within the National Park cover parts that have undergone significant change as a result of human activities and are partially damaged or currently being damaged.” The Sustainable Use Zone includes:

- Agricultural areas surrounding settlement areas,
- Areas where forest by-products are obtained (thyme, chestnut, carob, etc.),
- Highlands,

• Grazing areas,

• Low-altitude red pine ecosystems located around settlement areas with intense human intervention,

as specified (GDoNCaNP, 2025). The Area Planned for Bridge Construction Works and Operations is not included in the Sustainable Use Zone described above.

The definition of Open Space Sports Activities included in the Sustainable Use Zone planning content consists of a total of 4 paragraphs (GDoNCaNP, 2025). In this context, the 3rd Paragraph states: “The number of pedestrian suspension bridges designed perpendicular to the canyon to cross from one side to the other cannot exceed 2, and the routes these bridges pass through in sensitive protected areas are considered sustainable use zones.” This approach contradicts the priority protection objectives within the Plan itself. Therefore, it constitutes a violation of the Plan Provisions.

On the other hand, the statement in the same paragraph, “The number of pedestrian suspension bridges designed perpendicular to the canyon to cross from one side of the canyon to the other cannot exceed two, and the routes that these bridges pass through in sensitive protection areas are considered sustainable use areas,” This statement covertly alters the zoning approach implemented within the Plan. It also contains errors from a planning technique perspective. The Plan is inconsistent with the zoning approach it sets forth within itself.

The second section of the third paragraph within the Sustainable Use Zone planning for Open Space Sports Activities states: “Suspension bridges as described in this article cannot be built south of the Gaziler Neighborhood Day Use Area. These areas must be selected from locations distant from vulture nesting areas.” This statement makes it clear that the bridge construction work to be carried out in the region will affect the red vulture ecosystems in terms of wildlife. HOWEVER, the phrase “... must be selected from locations distant from vulture nesting areas” is a clear admission of the fact that ecosystems will be harmed.

Paragraph 4 of Open Space Sports Activities within the Sustainable Use Area plan states: “Activities to be carried out in the Adventure Park shall not cause any damage to the ecological, geological, and geomorphological structure.” This makes the bridge construction work and operations impossible. The Plan is Contradictory and Inconsistent Due to Two Provisions It Contains.

The richness of KKNP in terms of endemic plant species has been mentioned above (GDoNCaNP, 2025). As a result of applying the coordinates of the endemic plant species mentioned in the scientific studies conducted in the area to the digital maps of the national park, it has been determined that there are approximately 33 endemic plant species in the area where the bridge construction work and operations will be carried out within the national park (Ayaşlıgil, 1987; Ayaşlıgil, 1990; Güngöroğlu et al., 2008; Fakir, 2006a; Fakir, 2006b; Özçelik, 2012; Özçelik, 2018). Therefore, the area where the bridge construction work and operations will be carried out is a Sensitive Protection Zone. The bridge construction to be carried out will clearly harm the ecosystem. For this reason, the scientific studies are directly contradictory.

According to the revised "KKNP 1/25,000 Long-Term Development Revision Plan Planning Report -2021" states that the red kite species, which is important for wildlife in the region, is listed in Annex II of the Bern Convention as a Species Under Absolute Protection and in the

List of Threatened Species under category A.2. (Individuals of bird species in this group face significant threats in the areas where they are distributed) (GDoNCaNP, 2025).

The habitats of this species are as follows: "Two active nests were identified at the northern entrance of the Grand Canyon in the area. Fifteen individuals were identified in this area and around Bozburun Mountain during the research." It is clear that the areas where the planned bridge construction works and operations will be carried out within the national park overlap with these areas (GDoNCaNP, 2025; GDoNCaNP, 2021). On the one hand, the plan provisions aim to protect the resource values and ecosystems of the national park. On the other hand, the negative impacts on natural life that will arise from the planned bridge construction and the visitor potential it will create have been overlooked. Therefore, the Plan is Inconsistent in this Respect. From a Planning Technique Perspective, it Contains Approaches that are Contrary to its Own Provisions.

B. Request for Suspension of Implementation:

The planning of the “Sustainable Use Zone” within the subject matter of the case, the KKNP Reserve Long-Term Development Plan “Open Space Sports Activities” section of the KKNP Reserve Long-Term Development Plan, which involves the construction of “pedestrian suspension bridges designed perpendicular to the canyon to cross from one side to the other,” is clearly contrary to international agreements and therefore the law, the regulations mentioned above, the Ministry of Agriculture and Forestry (Ministry of Forestry and Water Affairs) Ministry Approval, and the results of scientific studies conducted in KKNP; it is unlawful and, if implemented, will cause damage that is difficult or impossible to remedy. For the reasons clearly emphasized above, we request that a decision be made to suspend the execution of the proceedings in question.

Evidence: Attached documents, scientific and judicial precedents, expert examination, all types of legal evidence.

Conclusion and Request: For the reasons stated above and those to be found ex officio, in light of the laws, regulations, the Ministry's approval, and the facts presented in impartial scientific publications; the “KKNP Long-Term Development Revision Plan Analytical Study and Synthesis Report-2021” and the “KKNP 1/25,000 Long-Term Development Revision Plan Planning Report-2021” approval process, which will clearly lead to the rapid destruction of endemic flora and fauna, wildlife, and unique ecosystems, thereby undermining the sustainable use of natural resources, -2021“ and the ”KKNP 1/25,000 Long-Term Development Revision Plan Planning Report-2021" should be suspended and subsequently CANCELLED as a result of the trial, and that the defendant administration should cover the trial costs and attorney's fees...

3.2-Legal Proceedings Against the Implementation in KKNP

The proceedings initiated against the implementation in KKNP, which was contrary to nature and legal sanctions, were carried out by the court with experts and participants conducting an on-site inspection in KKNP with the participation of the Faculty of Forestry of Isparta Applied University, the Antalya Branch Management and members of the Turkish Foresters Association, representatives of other civil society organizations, local residents, and representatives of the KKNP administration. The oral defenses of the parties against the proposed project were particularly significant in this application. The court's decision can be summarized as follows. The approaches on which the court's decision is based are reflected in

detail in the decision of the Administrative Cases Board of the Council of State of the Republic of Turkey, No. 2025/152. Ultimately, the court reached the following decision.

1. Acceptance of The Plaintiff's Objectıon,

2. Regarding the decision dated 30/09/2024 and numbered E:2023/540, issued by the Sixth Chamber of the Council of State, partially accepting and partially rejecting the request to suspend the execution, The part of the decision rejecting the request to suspend the execution of the KKNP Long-Term Development Revision Plan amendment regarding the conversion of the Sensitive Protection Area designated in Tazı Canyon into a Controlled Use Area is REVOKED, and the execution of the aforementioned part is SUSPENDED.

3. The defendant administration's OBJECTION, the Chamber's decision, the part of the KKNP Long-Term Development Revision Plan amendment regarding the regulations on the construction of pedestrian suspension bridges in Tazı Canyon and the east of the aforementioned Canyon, is REJECTED for the reasons stated above.

4. The decision was made by majority vote on 05/28/2025.

4-Conclusion

KKNP was declared a national park in 1974. After a long period of time, it acquired a regular and systematic management structure starting in 2000. Until this time, it did not have a permanent manager for more than 2-3 years. The "Biodiversity and Natural Resource Management (GEF-II) Project" began in this protected area in 2000. Until this period, this protected area, which did not even have a permanent and regular manager, was subject to an externally funded project in the region to:

i) Establish effective and sustainable protection areas and management through a participatory approach,

ii) ii) to review the legal and regulatory framework for the protection of biological diversity, and to create a model by exploring the possibilities of making forest planning and management, local land use planning, tourism development, agricultural expansion, and environmental management of water systems important elements in the protection of biological diversity.

The KKNP Management Plan, which was to be implemented within the framework of the project, was not fully adopted by the DKMP senior management due to certain political differences in understanding and therefore could not be implemented. However, a classic management plan was later created under the name of the Long-Term Development Plan.

KKNP is an area with a very high annual visitor capacity. Approximately 1-1.5 million people visit the park annually, mainly for rafting. The price for rafting in this area ranges from 5 to 50 euros per person. With this dimension, it is an area with extremely high profitability. The plan change initiative, which was forced upon the DKMP management with the aim of increasing visitor capacity by creating "pedestrian suspension bridges designed perpendicular to the canyon to cross from one side of the canyon to the other," was opposed by the employees who were part of the planning team at the time. As a result of the administration's demands not being met, the planning team was investigated and faced penalties. During this process, a lawsuit was filed to reject the administration's request, citing reasons such as the damage the proposed

suspension bridges would cause to nature and their violation of certain legal requirements. After conducting the necessary investigations, the court ruled that the planned initiatives were inappropriate.

This example is very meaningful in that it shows that initiatives such as the KKNP, which are intended to be carried out against nature and will harm nature, cannot be offered solely for the benefit of certain interest and benefit groups. However, in our country, many administrators and sometimes scientists allow practices that benefit certain interest groups. These practices sometimes involve environmental impact assessment reports being concluded positively, sometimes decisions that environmental impact assessments are unnecessary, and sometimes management plans being altered to serve the interests of certain groups. Turkey's nature should not be destroyed for short-term gains.

Thanks and Information Note

The article complies with national and international research and publication ethics. Ethics Committee approval was not required for the study. All authors contributed equally to the article.

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In the Process of Mitigating Climate Change Impacts Importance and Relationship of Land Uses

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Abstract

Climate change is one of the most critical problems affecting environmental, social and economic systems on a global scale. This process, triggered by the increase in greenhouse gas emissions, not only increases atmospheric temperatures, but also leads to changes in precipitation regimes, loss of biodiversity and soil degradation. Therefore, combating climate change requires strategic approaches in critical areas such as land management and land use, going beyond the reduction of emissions from energy production and industry. Land use covers a wide range of activities such as natural resource management, urbanisation, agriculture, forestry and pasture management, and plays a decisive role both in the processes that cause climate change and in mitigating the impacts of this process. Sustainable land use practices (conservation of forests with high carbon sequestration capacity, regenerative agricultural techniques, green infrastructure and soil improvement methods) offer effective and concrete solutions to combat climate change. In this context, the interaction between land use and climate change is fundamental to understanding land-based climate mitigation options and improving the adaptive capacity of societies to climate change in the future. Restructuring land use policies, adopting a climate change-sensitive planning approach and developing multi-scale governance mechanisms are critical for both the protection of ecological integrity and the sustainability of social welfare. The study aims to reveal how land changes affect climate change with concrete examples and to emphasise the strategic role of land use in global and regional climate mitigation process.

Keywords: Adaptation, climate change, land use, mitigation, policy integration, sustainable land management.

1. Introduction

Climate change is recognized as one of the most significant global challenges humanity faces today, with its environmental, social, cultural, and economic dimensions (Intergovernmental Panel on Climate Change (IPCC, 2021). Human activities such as increasing unconscious consumption habits, rapidly developing industrialization, urbanization processes, and deforestation cause the destruction of natural areas, increased greenhouse gas emissions, ecosystem degradation, and a decline in biological diversity. This process deeply affects not only environmental balances but also social welfare, cultural values, and economic sustainability. The concentration of greenhouse gases accumulating in the atmosphere leads to an increase in global average temperatures and an increase in the frequency and intensity of extreme weather events (drought, floods, storms). Furthermore, water and air pollution, the

drying up of wetlands, declining agricultural productivity, and threats to the sustainability of natural resources pose serious challenges (UNEP, 2022).

In this context, when both the causes and consequences of climate change are evaluated, it is evident that land use and land cover changes are central to the process. Land use is a factor that directly affects the structure of natural ecosystems and the carbon cycle. Changes in land use, particularly in agriculture, forestry, settlements, and industrial areas, are one of the most important processes determining atmospheric carbon concentration (FAO, 2020). Land use practices such as unplanned urbanization, intensive agricultural activities, mining, and infrastructure investments have a direct impact on the carbon cycle and ecosystem services. Improperly planned land use leads to a reduction in forest areas, soil erosion, a decrease in carbon sequestration capacity, and an increase in greenhouse gas emissions (Lal, 2019). In contrast, sustainable land management, green infrastructure practices, and the protection of natural sinks are among the key components of climate change mitigation and adaptation strategies (IPBES, 2021).

The relationship between climate change and land use has a two-way dynamic. On the one hand, land use changes resulting from human activities affect the climate system by altering the balance of greenhouse gases in the atmosphere (Turner et al., 2020). On the other hand, climate change has decisive effects on agricultural productivity, water resource management, biodiversity, and the sustainability of settlement areas (IPCC, 2022).

This situation highlights the need for land use planning and climate policies to be evaluated holistically rather than independently (UN-Habitat, 2020). In this context, it is crucial to consider land use planning as a strategic tool in combating climate change. The integration of adaptation and mitigation strategies with land use contributes significantly to sustainable development goals in terms of protecting carbon sinks, promoting energy-efficient settlement patterns, and strengthening ecosystem services (OECD, 2023).

This study aims to examine the role of land use in mitigating the effects of climate change, the mechanisms of mutual interaction, and sustainable land management approaches. Thus, a scientific framework for the development of climate-friendly land policies has been presented.

2. Interaction Mechanisms between Land Use and Climate Change

The relationship between climate change and land use is a complex process that operates through reciprocal feedback mechanisms. Land use patterns play a decisive role in the global climate system by directly affecting atmospheric greenhouse gas concentrations, surface energy balance, albedo (reflectivity) values, and the carbon cycle (IPCC, 2021). Conversely, climate change also reshapes land use potential through changes in temperature, precipitation patterns, soil moisture, and vegetation cover (FAO, 2020).

Factors determining land use;

Factors determining land use are multidimensional and linked to both natural and socio-economic processes.

a. **Natural Factors:** Topography, climate characteristics, soil structure, water resources, flora, fauna, and biological diversity are fundamental elements that determine a region's ecological carrying capacity and, consequently, its form of use. These natural conditions form the ecological basis for land use decisions and increase the risk of land

degradation and multifaceted problems if environmental constraints are not taken into account (FAO, 2020).

b. Socio-economic Factors: Population growth, urbanization, economic development level, technological advancement, and agricultural production systems are the main factors affecting land use and conversion dynamics (UNEP, 2022). In addition, national and international economic trends and investment priorities that do not take ecosystem values into account lead to a weakening of sustainable land management principles. The economic pressures brought about by the globalization process encourage the overuse of natural resources, increasing the risk of ecosystem degradation and loss of biological diversity. Furthermore, rising income levels and the associated changes in consumption habits are expanding production processes by increasing demand for energy, water, and food; this results in increased greenhouse gas emissions, shrinking forest areas, and accelerated land cover change (IPCC, 2021). Therefore, reassessing economic growth and changing consumption patterns within ecological limits is emerging as a fundamental requirement in the fight against climate change.

c. Political and Institutional Factors: Planning policies, land tenure regimes, environmental legislation, and sustainable development strategies play a direct and decisive role in the conservation or degradation of land (OECD, 2021). The failure to establish an effective institutional framework leads to fragmented approaches to land management and limits the applicability of ecosystem-based planning processes (OECD, 2021). Furthermore,

- Central-local interaction and inter-agency coordination
- Conflicts of authority in planning and implementation
- Amnesties for illegal land use (urbanization amnesties)
- Agricultural production support policies
- Constantly changing legal regulations (laws on non-agricultural land use)
- It can be said that the content of the laws conflicts with the sustainability of the ecosystem (opening up agricultural and forest areas to economic investment through laws).

d. Infrastructure Investments: Investments in irrigation, urban settlement, transportation, and energy infrastructure bring about the physical transformation of large areas. Large-scale investments, particularly in highways, energy transmission lines, and dam projects, disrupt ecosystem integrity, leading to habitat fragmentation, reduced agricultural land, and changes in land cover (OECD, 2021). This directly affects the feasibility of natural resource management and climate adaptation policies.

e. Traditional and Cultural Structure: The inability to develop sustainable land use models that serve as alternatives to local communities' traditional production practices makes it difficult to transform existing usage patterns in terms of environmental sustainability. Although traditional production systems may have qualities that preserve environmental balance in some cases, the exclusion of these systems during the modernization process leads to the loss of local ecological knowledge (FAO, 2020).

f. **Unplanned Development:** Unplanned and unorganized land use is one of the fundamental problems arising from the uncontrolled spread of urbanization and agricultural activities. Such disorderly developments lead to the unplanned expansion of settlement areas, the reduction of agricultural and forest areas, and the unsustainability of infrastructure services (UNEP, 2022). In the long term, this situation leads to negative consequences such as land degradation, a decrease in ecosystem services, and an increase in climate vulnerability.

g. **Incorrect and Misguided Planning Decisions and Implementation Process:** Problems and shortcomings in spatial planning hierarchy and scale detail, in the provision and correlation of up-to-date, reliable, and complete natural and cultural data, in incomplete and incorrect analyses and interpretations, in limited and insufficient participation, in incorrect and biased planning decisions and their implementation, etc., constitute the most important fundamental problem in land use. However, even when scientifically and technically sound decisions are made, the modification of planning decisions by administrators and decision-makers and the implementation of arbitrary practices are among the most critical issues in land use.

The relationship and interaction between these factors, particularly the prioritization of economic growth targets, increases land degradation and the loss and destruction of ecosystem services in less developed and developing countries. Therefore, for climate change mitigation policies to be effective, land use planning and management must be integrated with an ecosystem-based approach. For this reason, the interaction between the two systems is evaluated in terms of both cause-and-effect relationships and feedback loops.

2.1. Effects of Land Use on the Climate System

Changes in land use have powerful effects, particularly on the carbon cycle and surface energy balance. Processes such as deforestation, expansion of agricultural areas, and destruction of pastures and wetlands accelerate global warming by releasing carbon stored in soil and plants into the atmosphere (Lal, 2019). According to IPCC (2022) data, greenhouse gas emissions from land use changes account for approximately 23% of total anthropogenic emissions. However, reforestation, restoration of natural ecosystems, and sustainable agricultural practices contribute to mitigating climate change by increasing carbon sequestration capacity (IPBES, 2021). Preserving soil organic carbon, supporting agroecological production systems, and expanding carbon sink areas are important strategies for achieving carbon neutrality and increasing ecosystem resilience (OECD, 2023).

2.2. Effects of Climate Change on Land Use

The effects of climate change on land use manifest themselves in different ways at the regional level. Rising temperatures, changing rainfall patterns, and more frequent droughts directly affect agricultural production patterns, the availability of water resources, and the sustainability of settlement areas (Turner et al., 2020). Particularly in semi-arid regions, decreasing soil moisture and increasing salinity reduce agricultural productivity, thereby increasing pressures on land use (FAO, 2020). Furthermore, rising sea levels and the increased frequency of extreme weather events are redefining the use of coastal areas, deltas, and wetlands, leading to socio-economic consequences such as land loss, settlement changes, and migration movements in these areas (UNEP, 2022). This situation highlights the need to

integrate climate change adaptation policies into spatial planning processes (UN-Habitat, 2020).

2.3. Feedback Loops and Spatial Interactions

The relationship between land use and climate change is not merely a one-way chain of cause and effect; it is also a dynamic system that influences each other through feedback loops. For example, deforestation increases atmospheric CO_2 concentrations, raising temperatures, while rising temperatures also increase the risk of drought and forest fires, leading to further carbon emissions (IPCC, 2022). Similarly, increased artificial surface areas in urbanization processes alter local climate conditions by strengthening the albedo effect and heat island formation, which indirectly increases energy consumption and emissions (Seto et al., 2018). Such feedback relationships demonstrate that land use decisions must be addressed in alignment with global, regional, and local climate policies. Climate-friendly spatial planning, land management, forestry, agriculture, industry, tourism, mining, and other sectors and subsectors play a key role in achieving both mitigation and adaptation goals through the comprehensive implementation of policies (OECD, 2023).

3. Sustainable Land Use and Policy Approaches to Combating Climate Change

Land use policies have become a fundamental component of environmental management systems in the processes of mitigating the effects of climate change and adapting to it. Sustainable land use is a holistic approach that aims to protect natural resources, ensure the continuity of ecosystem services, strengthen carbon sinks, and achieve socio-economic development within environmental limits (FAO, 2020). This approach is directly related to climate policies developed at both the global and national levels.

3.1. Global Policy Frameworks

In today's world, where international relations are increasing and becoming more complex every day, it is necessary for countries around the world to follow a common path, especially on issues related to environmental problems. It has become imperative for countries to set standards and regulate and monitor areas such as climate change and global warming, which have a global impact. At the international level, the United Nations Framework Convention on Climate Change [UNFCCC] (1992) and the Paris Agreement (2015) define land use, land-use change, and forestry (LULUCF) processes as key policy areas for monitoring and reducing greenhouse gas emissions (IPCC, 2022). Article 4 of the Paris Agreement emphasizes that the conservation and enhancement of carbon sinks are a priority objective within the scope of nationally determined contributions (NDCs) (UNFCCC, 2015).

Under the Paris Agreement, it is expected that approximately one-quarter of the global greenhouse gas reduction targeted by 2030 will be achieved through land-based mitigation options, as outlined in the nationally determined contributions (NDCs) submitted by countries (Griscom et al., 2017; IPCC, 2022). These options include nature-based solutions such as preventing deforestation, reforestation, sustainable agricultural practices, increasing soil carbon, and ecosystem restoration. This clearly highlights the importance of integrating land use policies with climate goals.

Additionally, Goal 13 (Climate Action) and Goal 15 (Life on Land) among the United Nations Sustainable Development Goals (SDGs) directly support sustainable land management, forest conservation, and ecosystem restoration policies (UN, 2020). These goals

envisage that land use decisions should be developed in a manner consistent not only with economic efficiency but also with environmental resilience and social welfare criteria.

3.2. Regional and National Policy Approaches

The first direct law addressing climate change in our country is the Environmental Law No. 2872, published in the Official Gazette No. 18132 on August 11, 1983. In addition, the Energy Efficiency Law (2007) and the Law on the Use of Renewable Energy Sources for Electricity Production (2005) are laws that directly affect climate change.

Within the framework of the European Green Deal, the land use sector has been identified as one of the key areas for achieving the goal of "climate neutrality by 2050" (European Commission, 2021). In this context, the Land Use, Land Use Change, and Forestry (LULUCF) Regulation has strengthened member states' obligations to protect and expand carbon sinks. Furthermore, the Zero Net Land Degradation (ZNLD) principle is an environmental management approach developed under the United Nations Convention to Combat Desertification (UNCCD). This principle supports policies for the rehabilitation of degraded land functions, ecosystem restoration, sustainable management of agricultural areas, and reduction of urbanization pressure (EEA, 2022). In this context, it is necessary to adopt planning principles appropriate to natural geographical conditions and to make land use decisions based on data on soil, climate, hydrology, and ecosystem services.

In Türkiye, the policy framework for combating climate change is shaped by the Climate Change Adaptation Strategy and Action Plan (2024-2030), the Energy Efficiency 2030 Strategy and the Second National Energy Efficiency Action Plan (2024-2030), the Green Deal Action Plan (2021), and the 7552 Climate Law (2025). These documents emphasize the integration of land use and ecosystem-based adaptation approaches with forest management, agricultural production planning, urban development, and water resources management policies (Ministry of Environment, Urbanization, and Climate Change, 2025). Additionally, the National Green Certification System (YeS-TR) and Integrated Urban Development Strategies contribute to low-carbon development goals through sustainable settlement patterns and green infrastructure applications.

3.3. Policy Integration and Implementation Challenges

There are various structural and managerial challenges in integrating land use policies with climate goals. These include institutional fragmentation, differing sectoral priorities, data gaps, and uncertainties regarding land ownership (Turner et al., 2020). Furthermore, short-term economic gains overshadowing long-term ecological costs limit the effectiveness of sustainable policy implementation (Lal, 2019).

When evaluated specifically in the context of Türkiye, it is frequently emphasized that land use planning decisions must be approached with an interdisciplinary approach. However, the absence of an institutional structure to coordinate this process in a comprehensive manner is a significant shortcoming. Furthermore, the lack of deep-rooted and rational practices, coupled with the dominance of political priorities over scientific approaches, hinders the achievement of sustainability in land management.

As a result of this situation, inefficient and misguided land use is becoming widespread, leading to an increase and diversification of environmental problems at both the national and local levels. Therefore, it is necessary to establish comprehensive land use policies at the

national level and to establish a coordinating body within this framework. Furthermore, land use decisions made at the local level should be guided in a manner consistent with national policies and considered an effective tool in combating climate change.

3.3.1. Inadequacy of Accurate and Up-to-Date Data and Soil Maps to Form the Basis for Land Use Decisions

Land use planning is of critical importance for the sustainable management of natural resources and the achievement of environmental goals. The soundness and feasibility of these plans depend on the availability of bases based on accurate and up-to-date soil data. An examination of the current situation in Türkiye reveals that these bases are significantly lacking or inadequate. The maps showing major soil groups, land capability classes, and land use, prepared by the General Directorate of TOPRAKSU between 1966 and 1971, were created using the survey method. This method causes the maps to fall short of meeting today's requirements in terms of both quality and accuracy. Between 1982 and 1984, these studies were reviewed under the name of Türkiye Soil Potential Studies and Non-Agricultural Land Use Planning Project. In 1984, this work was transferred to the abolished General Directorate of Village Services (KHGM). However, despite various studies being conducted in our country for various purposes since the closure of the General Directorate of Land Registry and Cadastre (KHGM) in 2005, no detailed study has been carried out on agricultural lands. Furthermore, although Law No. 5403 on Soil Protection and Land Use provides for the preparation of maps, it does not clearly regulate how this process should be carried out and by which institution. This situation limits the availability of up-to-date and reliable data and creates significant gaps in land use planning (Topçu, 2012).

In Türkiye, various institutions and organizations such as the General Directorate of Agricultural Reform (TRGM) and the General Directorate of State Hydraulic Works (DSİ) produce land maps of different scales and characteristics to serve their purposes, either using their own resources or by procuring services. Due to a lack of inter-agency coordination, common standards and methods are not used, meaning that a map produced by one agency may not meet the needs of another agency or be usable by it. As a result, multiple soil mapping studies are conducted on the same land for different purposes.

Current shortcomings directly affect the development and implementation of land use plans. The lack of a sound data infrastructure leads to errors in plans and causes the planning process to deviate from its scientific basis. The lack of basic soil maps not only reduces the quality of planning but also hinders the achievement of sustainable land management goals. Therefore, the creation of accurate and up-to-date data and detailed soil maps is a priority requirement for the effectiveness and feasibility of land use decisions.

3.3.2. Inadequacy of Land Use Policy at the National, Regional, and Local Levels

The main reasons for the ineffective implementation of land use policies at the national, regional, and local levels include the lack of an interdisciplinary approach, institutional inadequacies, and weak science-based planning. Although land use decisions should be addressed from a perspective that brings together different disciplines such as the environment, economics, sociology, and law, the lack of institutional structures that adopt such a holistic approach reduces the effectiveness of planning processes. Furthermore, most current planning practices are not based on a solid and rational foundation; political and short-term interests take precedence over scientific data and analysis. These shortcomings lead to

wrong and inefficient decisions in land use, increasing and diversifying environmental problems. In particular, unplanned and uncontrolled construction causes the depletion of natural resources, a decline in biodiversity, and the deterioration of ecosystem services. For example, a study conducted in the province of Izmir indicated that environmental regulation plans did not sufficiently consider ecosystem sensitivity, leading to environmental incompatibilities (Salata et al., 2022).

To overcome these challenges, comprehensive land use policies must be developed at the national level, and institutional mechanisms must be established to implement these policies. In this context, the establishment of an institution under the leadership of the Ministry of Agriculture and Forestry that will address land use with an interdisciplinary approach will enhance the effectiveness of policy development and implementation processes. Furthermore, shaping land use decisions taken at the local level in line with national policies and scientific principles is critical for ensuring sustainable land management. In this process, increasing stakeholder participation and strengthening local knowledge systems will enhance the transparency and accountability of decision-making processes.

3.3.3. Lack of Coordination Among Land Use Institutions and Ineffective Implementation of Legislation

One of the main reasons for the lack of institutional coordination regarding land use in Türkiye is the lack of holistic determination of sectoral policies at the national level. This leads to unclear distribution of duties and authorities among institutions and the failure to implement practices as stipulated by legislation. Land use regulations in Türkiye consist of various hierarchical plans, and the coordination, implementation, and amendment of these plans are subject to significant inefficiencies.

Lack of institutional coordination leads to multiple institutions being authorized to carry out work in a given area, resulting in a chaotic environment based on conflicting authority. This leads to delays in land use decisions, inefficiency, and disruptions to environmental or social goals. Furthermore, prioritizing sectoral needs leads to land use incompatible with the natural landscape and an increase in environmental problems (Yüceer, 2020). Ensuring participation in the land use decision-making process is critical. In this context, the active participation of decision-making institutions and organizations, as well as local communities, civil society organizations, and other stakeholders, should be encouraged. A participatory approach will strengthen institutional coordination, reduce overlapping authority, and ensure effective implementation of legislation. Furthermore, holistic and scientifically based planning should be implemented to harmonize sectoral needs with the natural landscape.

3.3.4. Existing Land Uses Incompatible with Natural Geographical Conditions

In Türkiye, existing land use practices incompatible with natural geographic conditions are widespread. The main reasons for this include land users' lack of knowledge about soil, geomorphology, and climate characteristics, the prioritization of short-term economic gains over long-term ecological balances, and the low education and income levels of entrepreneurs, particularly those operating in the agricultural sector. Unconscious or unplanned land use disrupts natural processes, increasing the frequency of disasters such as floods, inundations, and landslides, and the loss of fertile soil through accelerated erosion. Furthermore, activities such as improper agricultural practices and overgrazing accelerate

desertification processes, particularly in semi-arid regions; a typical example of this is observed in the Karapınar region of Konya.

To prevent these negative impacts, it is crucial to disseminate soil and geographic information and ensure its effective use in decision-making processes. Furthermore, both the public and public personnel need to be educated and raised in their awareness of sustainable land management and natural resource conservation. Establishing and implementing incentive mechanisms that encourage land use patterns compatible with natural geographic conditions and support environmentally sensitive production models will contribute to preserving ecosystem integrity and reducing land degradation in the long term. Therefore, policymakers need to integrate nature-compatible development models, green finance instruments, and carbon market mechanisms into land-use planning to achieve both climate neutrality goals and implement ecosystem-based development principles (IPCC, 2022; OECD, 2023).

3.3.5. Land Use Classification and Awareness-Raising and Participation in Policy-Making

Classifying land use patterns and developing land use policies based on this classification is not only a technical planning process but also a governance and democratic one. In this context, the participation of a broad range of stakeholders, particularly civil society organizations, professional chambers, and local communities, is crucial in the development of land use policies. In the process of allocating a country's natural resources to different land use types (forest, agriculture, pasture, wetland, settlement, industry, mining, and other areas), it is essential to consider the natural formation processes of plant ecosystems and to demonstrate climate-ecosystem interactions with scientific data. The interplay between climate factors and ecosystem dynamics plays a decisive role in the ecological sustainability of land use decisions. Therefore, policymakers, public institutions, local governments, and civil society need to be informed and a common understanding developed on this issue. The awareness-raising process should not be limited to the transfer of information; it should be carried out within a participatory governance approach, with the active inclusion of all relevant groups in decision-making processes. This participatory process;

It should include the following steps:

1. Identifying relevant stakeholder groups,

2. Conducting information and awareness activities,

3. Creating discussion and negotiation environments,

4. Determining the decisions that will lead participants to broadly accepted action proposals,

5. Translating these consensuses into concrete policies and strategies.

Awareness-raising is the most fundamental stage in the development of diverse land use policies. Without effective awareness-raising, the link between scientific knowledge and decision-making mechanisms weakens, and the alignment of policies with sustainability principles is compromised. Therefore, all written, verbal, and visual communication tools—including public service announcements, media campaigns, educational programs, and digital platforms—must be actively utilized. This approach will contribute to the creation of a policy culture based not only on information sharing but also on social participation, transparency,

and the creation of shared wisdom. Thus, land use decisions will be both scientifically based and serve the goals of social sustainability.

3.3.6. Integrating long-term climate change ımpacts into the Environmental Impact Assessment (EIA) reporting procedure

Today, environmental impact assessment (EIA) processes serve as a fundamental tool for predicting and preventing the environmental consequences of projects. However, current EIA practices largely address short- and medium-term impacts, while the long-term impacts of global climate change are not systematically considered. This can undermine the climate resilience of land use decisions, natural resource management, and infrastructure investments.

Therefore, the content of EIA reports needs to be revised to consider the long-term impacts of climate change. This change should include both an assessment of greenhouse gas emissions at the project level and an analysis of the project's resilience under future climate conditions. The use of scenarios based on climate projections for 2050 and 2100 is particularly crucial in assessing the long-term environmental sustainability of projects.

In this context, it is recommended that the content of EIA reports include the following elements:

1. Climate scenario-based risk analysis: Assessing the impact of projections for temperature, precipitation patterns, sea level rise, and extreme weather events on the project using data from regional climate models.

2. Adaptation strategies: Identifying technical, structural, and managerial measures to increase the resilience of project activities to climate change.

3. Greenhouse gas emission inventory and mitigation plan: Calculating project-related emissions and analyzing mitigation options.

4. Long-term impacts on ecosystem services: Assessing the project's potential changes to land cover, biodiversity, and carbon sinks.

5. Cumulative impact analysis: Examining the cumulative impacts of other projects in the same region that increase or decrease climate change.

Such a content transformation will transform the EIA process from a technical report format that merely identifies environmental impacts into a strategic planning tool aligned with climate policies. It will also ensure consistency with the Paris Agreement, the EU Green Deal, and Türkiye's nationally recognized contribution declaration (NDC) objectives.

Consequently, integrating the long-term impacts of climate change into the content of EIA reports will both increase the climate resilience of projects and contribute to the achievement of national sustainable development goals. This approach will ensure a scientifically based, holistic, and forward-looking perspective is embedded in environmental decision-making processes.

3.3.7. Assessing land use patterns for greenhouse gas ınventories and promoting an ınterdisciplinary ıntegrated systems approach

Accurately identifying the sources and sinks of greenhouse gases, particularly carbon dioxide (CO_2), but also methane (CH_4) and nitrous oxide (N_2O), is crucial in combating climate

change. In this context, the contribution of land use patterns (agriculture, forests, pastures, settlements, wetlands, etc.) to greenhouse gas inventories must be systematically assessed.

Land use changes directly impact the carbon cycle and the carbon sequestration capacity of ecosystems. While forest destruction or agricultural expansion increases CO_2 emissions, sustainable land management practices—such as reforestation, pasture reclamation, agroforestry systems, or wetland restoration—can contribute to emissions reductions by strengthening carbon sinks. Therefore, land use decisions should be considered not only as spatial planning tools but also as an effective component of greenhouse gas mitigation strategies.

To achieve this goal, it is crucial to encourage interdisciplinary research and projects that address land use patterns with an integrated systems approach. These projects require collaborative efforts across diverse fields, including ecology, soil science, climatology, forestry, agriculture, geographic information systems (GIS), remote sensing, and socioeconomic analysis. Such a holistic approach allows for the assessment of not only the biophysical aspects of land use-greenhouse gas interactions but also their socioeconomic determinants.

Furthermore, the outcomes of such projects will increase the accuracy of national greenhouse gas inventories and strengthen the integration of the LULUCF (Land Use, Land-Use Change and Forestry) sector into climate policies. Such interdisciplinary studies will also enhance both data quality and policy effectiveness in terms of the traceability of Türkiye's nationally determined contribution declaration (NDC) targets under the Paris Agreement. In this regard, encouraging integrated system-based projects carried out at the national level by universities, public institutions, and civil society organizations will be key to effectively transforming policies for climate change mitigation.

4. Conclusion and Recommendations

The interaction between land use and climate change is a multidimensional issue at the intersection of environmental processes, economic development, and social welfare. As demonstrated in this study, land use patterns are both a cause of climate change and a key tool in mitigating its effects. Therefore, land use planning and management are not only a spatial planning tool but also a fundamental sustainability component that determines the success of climate policies (IPCC, 2022; OECD, 2023).

Taking into account socio-economic policies and national rural development strategies, large-scale environmental planning and land use planning should be addressed in an integrated, sustainable manner, in conjunction with a watershed management approach. This integration should provide a framework that strengthens the spatial planning hierarchy, taking into account the interaction between natural resource management, land use, agriculture, forestry, and water management.

In the preparation of lower-scale plans (master and implementation zoning plans), 1:25,000 scale environmental planning maps should be used as a basis, and compliance with this hierarchy should be ensured. The preparation of management plans for agricultural and forest areas at scales of 1:25,000 and larger is important for the accurate assessment of land potential. Furthermore, in natural resource management, it is necessary to identify plant species that are resistant to drought and local conditions and to link zoning plans with

production planning. This will enable the establishment of ecological and economic balance between planning decisions and production processes.

In order to strengthen the feasibility of plans, it is essential that preventive measures aimed at reducing social and economic pressures that could hinder the implementation process are taken into account in large-scale plans. In this context, coordinating local and rural development policies with environmental planning will increase social acceptance and support the effectiveness of plans.

Within the scope of the National Program for Combating Desertification in Türkiye, ensuring institutional coordination among relevant agencies, institutions, and civil society organizations is critical to the success of sustainable land management. This coordination should be strengthened through data sharing, monitoring and evaluation systems, and the definition of common objectives.

The requirements for implementation are as follows:

- Eliminating the fragmentation of authority caused by high-level planning authorities (Metropolitan Municipality Law, Municipality Law, Provincial Special Administration Law, Environment Law, Soil Protection and Land Use Law) and ensuring central coordination in the planning system,
- Sufficient financial resources and budget allocation for these efforts,
- Plans should be made publicly available, the public should be informed, and participation mechanisms should be strengthened.

When examining the effects of land use on the climate system, deforestation, mismanagement of agricultural areas, and increasing urbanization pressure stand out as the main factors accelerating global warming by disrupting the carbon cycle (FAO, 2020; Lal, 2019). In contrast, reforestation, restoration of natural ecosystems, sustainable agriculture, and green infrastructure practices both increase carbon sequestration and strengthen the capacity to adapt to climate change (IPBES, 2021; UNEP, 2022).

Globally developed policy frameworks (particularly the Paris Agreement and the United Nations Sustainable Development Goals) have made the integration of land use with climate goals mandatory. However, structural barriers at the implementation level—such as institutional fragmentation, data gaps, land tenure issues, and economic priorities taking precedence over environmental goals—limit the effectiveness of sustainable land management policies (Turner et al., 2020; EEA, 2022).

When evaluated in the context of Türkiye, national strategy documents and legislative initiatives have shown significant progress in recent years. In particular, the National Climate Change Action Plan, the Climate Law, and the YeS-TR Green Certificate System are positive steps towards institutionalizing low-carbon development and nature-compatible planning. However, the lack of capacity in local administrations, the inadequacy of data-based planning tools, and the limited interdisciplinary coordination make it difficult to achieve a comprehensive land-climate integration in practice (ÇŞİDB, 2022).

For land use policies to be effective in combating climate change, the following policy and management principles must be prioritized:

1. Ecosystem-based planning approach: Making land use decisions based on natural ecological boundaries and carrying capacity.

2. Multi-level governance: Strengthening inter-agency coordination at the national, regional, and local levels.

3. Data-driven decision mechanisms: Integrating technologies such as remote sensing, geographic information systems (GIS), and climate modeling into decision-making processes.

4. Green finance and carbon markets: Economically incentivizing projects that protect ecosystem services.

5. Participatory planning: Ensuring the active participation of local communities, academic institutions, and the private sector in decision-making processes.

These principles are critical not only for reducing greenhouse gas emissions but also for enhancing climate resilience, protecting biodiversity, and strengthening socioeconomic resilience.

Consequently, understanding the interrelationship between land use and climate change must be central to sustainable development policies. The fact that land use decisions are a process that both influences and is influenced by climate change necessitates the development of comprehensive environmental policies. The integrated implementation of sustainable land management approaches with national climate policies will enable the achievement of climate neutrality goals and the permanent provision of ecosystem-based well-being.

Thanks and Information Note

The article complies with national and international research and publication ethics. All authors contributed equally to the article.

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A Model Application at the Intersection of Cultural Heritage Preservation and Use: Isparta National Garden Gar1936

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Abstract

The preservation and repurposing of cultural heritage structures play an important role in the sustainable development of today's cities. Integrating historical structures that have lost their function into contemporary urban life contributes to both strengthening social memory and increasing economic and social dynamism. In this context, the restoration of the Gar1936 Repair Building in Isparta and its repurposing as the "Millet Bahçesi Gar1936 Cafe & Restaurant" provides a noteworthy example. Built in 1936 and contributing to railway services for many years, the structure lost its function over time and fell into disuse. During the restoration process, the original materials and construction techniques were preserved, and the missing parts were completed using the same methods. The wooden roof structure was reinforced, and interventions that could damage the load-bearing system were avoided. The technical equipment necessary for contemporary use was integrated without compromising the historical identity of the building. Thus, the building has been transformed into a functional space that meets today's needs without losing the traces of the past. With the implementation of the project, the building has not only been preserved but has also become an active part of social and cultural life. Gar1936, a new meeting point for the local community and a cultural attraction for visitors, is considered an example that strengthens the city's memory and supports its tourism potential. This application demonstrates that the preservation of cultural heritage is not only a necessity but also a process that translates into social benefit. In this study, the relationship between preservation and use was established within the scope of ecological sensitivity in the project design and implementation process of the "Millet Bahçesi Gar1936 Cafe & Restaurant," considering the relationship between the structure and its surroundings, the structure's load-bearing system, material selection and use, energy efficiency, integration of natural light into spaces, social and tourist contributions, semi-open plan design, fixtures and furniture used, and other general architectural features were examined and interpreted. In this context, general principles and recommendations were made regarding the preservation and use of cultural heritage architectural values.

Keywords: Millet Bahçesi Gar1936 Cafe & Restaurant, cultural heritage, conservation and use, ecological sensitivity, sustainability, cultural tourism.

1. Introduction

Cities are living structures that embody their history, culture, and natural features, encompassing social life practices and natural environmental dynamics, and are constantly changing and evolving as a result of the interaction between these two systems.

The rapidly increasing urbanization process today has transformed cities into narrow and congested living spaces dominated by dense construction. This situation has led to both a decrease in green spaces and an increase in the pace of daily life. This change limits urban dwellers' access to natural and cultural values, causing psychological pressure to increase. The stress brought about by urban life has made the need for society to turn to areas where they can connect with nature and cultural environments, calm down, and renew themselves more apparent (Akın & Gül, 2020).

In this context, open and green spaces serve as one of the fundamental building blocks of urban life, providing liveable environments that both enhance social interaction and enable individuals to physically and mentally recharge. In recent years, public gardens, which significantly fulfil these needs, have gained prominence in urban planning as multifunctional public spaces that contribute to the improvement of the urban ecosystem, offering opportunities for recreation and integration with nature, in addition to urban aesthetic and landscape design (Birol & Aydın, 2019).

Cultural heritage is one of the most fundamental components that nourish the historical continuity, social memory, and social identity processes of cities. Architectural structures, monumental elements, tangible and intangible cultural values that shape the urban experience not only represent the city's past but also shape the current city-human interaction and strengthen social belonging.

Due to the effects of intense urbanization and population growth, cultural heritage sites that carry the traces of the past into the present are mostly located along the city's main transportation and interaction axes. They are gaining even greater strategic and social importance due to rising land values and increasing demand for public spaces (Koçan, 2011). In this context, it is important to repurpose historical buildings and cultural heritage sites in a way that meets and adapts to current needs. In particular, the revitalization of industrial heritage sites for tourism purposes ensures the continuity of cultural identity while also emerging as a sustainable transformation model that contributes economically to the city (Tekin, 2025).

Since the second half of the 20th century, urbanization, technological transformation, and changes in transportation systems have caused many industrial and transportation structures to lose their function; this situation has led not only to physical decay but also to significant gaps in the urban memory. Filling these gaps is possible through the balance between conservation and use, which is at the heart of the modern conservation approach. International conservation documents (ICOMOS, 2013; UNESCO, 2011) emphasize that supporting cultural heritage with new functions and integrating it with social and economic sustainability is a fundamental requirement for its preservation. In this context, the relationship established between physical conservation and social benefit demonstrates that long-term sustainability can be achieved by opening heritage areas for active use.

This study also addresses the restoration and repurposing process of the Isparta Gar1936 Repair Building, which is considered industrial heritage, within the framework of this modern approach. The conversion of the building into the “Millet Bahçesi Gar1936 Cafe & Restaurant”

is an exemplary application that goes beyond a mere architectural intervention, harmoniously integrating the preservation of cultural heritage with contemporary use. Decisions such as integrating the building with its surroundings and the landscape design of Millet Bahçesi, reinforcing the load-bearing system, preserving original architectural elements, selecting energy-efficient materials, and integrating natural light demonstrate an approach that aims to ensure the sustainability of cultural heritage not only physically but also functionally and socially.

Additionally, the building's social and tourist contributions, its semi-open spatial organization, and the compatibility of its fixtures and furniture designs with current user needs support the multi-layered approach advocated by modern conservation principles. Thus, the Isparta Gar1936 example provides a powerful model demonstrating how the process of preserving and repurposing industrial heritage can contribute to the city's memory, social life, and cultural continuity.

In this context, the study aims to analyse the delicate balance established between the preservation and use of cultural heritage and to reveal how a holistic, harmonious, and sustainable conservation approach can be implemented through the example of Isparta Gar1936. It is clear that preserving heritage is only possible through such a holistic approach.

2. Materials and Methods

2.1. Work Area

Isparta is located in the Lakes Region in the west of Turkey's Mediterranean Region, forming a natural transition zone between the Mediterranean, Central Anatolia, and Aegean regions. The city, with an average elevation of 1,050 meters, is surrounded by the Taurus Mountains to the south and the Sultan and Söğüt Mountains to the north and is encircled by the Burdur and Eğirdir Lakes. Isparta, where continental and Mediterranean climatic influences are both seen, has hot, dry summers and cold, snowy winters. The province, which has been home to many civilizations throughout history, has significant tourism potential with its rich cultural heritage, natural beauty, rose cultivation, and carpet weaving. The Isparta train station, the site of the study, is located in the Karaağaç neighbourhood in the city centre. The historic building, spread over a total area of 86,000 m², has a long and flat form and is suitable for walking paths, recreational areas, and other historic buildings. The city centre and commercial areas are located to the north of the site, while green areas and settlements are located to the south. Its location at the end of the main transportation axis connecting to the Government House via Station Boulevard brings the train station close to the city's commercial centres and makes it easily accessible (Tekin, 2025).

Isparta Train Station is part of the Izmir-Aydın Railway Line, which was built by the British between 1861 and 1869. This line was extended along the Nazilli-Denizli-Dinar route and reached Eğirdir in 1912 (Nedim, 2002). Isparta Train Station is similar to Burdur Train Station as it is the only station in Turkey with a twin architectural project. Reflecting the architectural features applied during the Second National Architecture Period, this structure was designed as a long, horizontal, rectangular mass. Inside the building, there are hangar structures, technical service buildings, warehouses, toilets, cafeterias, and fountains (Çetin, 2010).

Geographically, Isparta is located at the centre of the Lakes Region and is surrounded by the eastern extensions of the Taurus Mountains, placing it at a crossroads of natural and cultural diversity. Historical structures such as Pisidia Antioch, Eğirdir Castle, Firdevs Bey Bazaar,

Kutlu Bey Mosque, Dündar Bey Madrasa, and Yılankıran Fountain reveal the city's multi-layered historical fabric (Kültür & Turizm Bakanlığı, 2013).

The Repair Building, the focus of this study, is an industrial structure located within the station complex where railway maintenance activities are carried out. The building, which has a single volume, stone masonry walls, and a wooden truss roof structure, lost its function when train services ceased in 2001 and remained unused for a long time (TCDD, 2014). Following the 2019 People's Garden Project, the building underwent restoration and was reintroduced to public life in 2023 with a gastronomic function (Çevre & Şehircilik Bakanlığı, 2021; TOKİ, 2023).

This study uses the Isparta Train Station Building and its surroundings as its material. The primary objective of the study is to examine in detail the restoration and repurposing process of the Isparta Station 1936 Renovation Building, which is considered industrial heritage, from the perspectives of architecture, interior architecture, and landscape architecture. The study discusses how conservation approaches and the relationship of reuse were established during the conversion of the building into the Millet Bahçesi Gar 1936 Café & Restaurant, and how this process contributed to the city's memory and social dynamism.

2.1.1. Development of the Isparta Historic Train Station and Conversion of the Repair Building

Isparta Station was completed in 1936 as part of the early Republican era's railway development strategy and became a critical hub for regional transportation (Anadolu Ajansı, 2023). During the Ottoman period, the railway only extended as far as Eğirdir, which prevented Isparta from being connected to the centre for many years (Wikipedia, 2023). The process gained momentum when Atatürk listened to the demands of the people during his visit to Isparta on March 6, 1930, and ordered that the city be directly connected to the railway line (Haber32, 2014; Isparta Manşet, 2025). The 13 km branch line between Bozanönü and Isparta was completed in 1935–1936, and the station complex officially began operations (Atatürk Ansiklopedisi, 2021). The station's opening ceremony was held on March 26, 1936, by Prime Minister İsmet İnönü, and the press of the time particularly emphasized the contribution it would make to the economic development of the region (Milliyet, 1936; Ulus, 1936). With the suspension of services in 2001, the station and its associated structures fell into disuse; however, with the resumption of the "Lakes Express" services in 2019, the recreation and restoration process gained momentum (TCDD, 2014).

As part of the National Garden Project, registered buildings have been restored in accordance with their original structures; landscape areas have been enriched with rose and lavender gardens, walking paths, and cultural event areas (Isparta Belediyesi, 2022; TOKİ, 2023). The Restoration Building has been reinforced with minimal intervention, its roof structure has been renewed, its stone walls have been repaired using conservation techniques, and its interior has been adapted for gastronomic functions (Çevre & Şehircilik Bakanlığı, 2021). This transformation is noteworthy as one of the first applications in Turkey where an industrial heritage structure within an active train station has been converted into a restaurant-café (Tekin, 2025).

2.1.2. The Importance of the repair building in the collective city memory

Isparta Station is one of the symbolic structures of early Republican modernization and holds a strong emotional resonance in the city's memory. Social practices such as sending off soldiers,

journeys to distant lands, welcomes, and holiday gatherings have made the station a place of shared memory across generations (Eraydın, 2016).

The Repair Building has also been one of the important structures forming the functioning infrastructure of the station complex as part of this collective memory. As emphasized in the presentation, **Isparta Historic Train Station**:

- It is a symbol of the modernization of the Republic (Anadolu Ajansı, 2023).
- It has architectural heritage value and is unique with its cut stone facade and wooden truss roof structure (Kültür & Turizm Bakanlığı, 2013).
- It is a centre of collective memory and an emotional symbol of nostalgic journeys (Eraydın, 2016).
- It represents the relationship between nostalgia and preservation, as it was registered in 2002 and underwent a comprehensive restoration process (Çevre & Turizm Bakanlığı, 2013).

The conversion of the Repair Building into a restaurant has both kept this collective memory alive and turned the space into a social meeting point.

2.2. Research Method

This study uses the Isparta Train Station Building and its surroundings as its material. The primary objective of the study is to examine in detail the restoration and repurposing process of the Isparta Station 1936 Renovation Building, which is considered industrial heritage, from the perspectives of architecture, interior architecture, and landscape architecture. The study discusses how conservation approaches and the relationship of reuse were established during the conversion of the building into the “Millet Bahçesi Gar 1936 Cafe & Restaurant” and how this process contributed to the city's memory and social dynamism.

Multiple site visits conducted as part of the study examined the building's unique physical characteristics, the condition of its load-bearing system, its spatial layout after restoration, and its relationship with the National Garden landscape. During these visits, both the level of preservation of structural elements and current usage patterns were observed (Çevre & Şehircilik Bakanlığı, 2021). In addition, qualitative data was collected on the needs related to the building's current function, user behavior, usage intensity, capacity planning, and space requirements arising from its operation through interviews with the operating company, Gaymakçı Ltd. Şti. (Tekin, 2025). In order to establish the theoretical framework of the study, TCDD archive records, historical newspaper articles (Milliyet, 1936; Ulus, 1936), local news sources (Haber32, 2014), municipal documents (Isparta Belediyesi, 2022), and cultural heritage inventories (Ministry of Culture and Tourism, 2013) were examined. In addition, national and international literature on the repurposing of industrial heritage structures was reviewed, and UNESCO's current methodological approaches to the preservation of cultural heritage were also evaluated (UNESCO, 2015). This multi-layered methodological approach allowed for a comprehensive assessment of the restoration process of the Repair Building in terms of its architectural, cultural, and functional dimensions by considering both field-based observational findings and historical-theoretical knowledge.

Within this scope, there are four key issues involved in the project design and implementation process. (1) Integrating the structure with National Garden in terms of its relationship with the

environment and landscape design, (2) Reinforcing the structure's load-bearing system and preserving its original architectural elements, (3) The selection and use of materials used in the restoration phase of the building, energy efficiency, and the integration of natural light into the space, (4) Its social and tourist contributions, semi-open plan design, and the examination and interpretation of general architectural features such as the fixtures and furniture used. The relationship between conservation and use was examined within the framework of ecological sensitivity and sustainability.

3. Findings and Discussion

3.1. General Information

The transformation of the historic railway repair workshop into the “Gar 1936” gastronomy space was achieved by combining the preservation of the building's original spatial character with the technical requirements of contemporary use through a holistic design approach. An examination of the existing structure's fundamental characteristics reveals that its south-facing façade and rectangular floor plan measuring 13.49 × 24.96 m reflect a typical industrial warehouse form. The high-ceilinged vaulted roof, with its wide spans and steel support system, is an important element that increases both the functional and structural capacity of the building. The linear organization of the service units along the north-south axis has been preserved, while the main hall has been left largely open for flexible use scenarios (Figure 1). This approach is consistent with the literature emphasizing the necessity of preserving the original spatial void in industrial heritage buildings (Ahunbay, 2011).



Figure 1. Post-restoration interior layout and positioning of the gastronomy unit (From the authors' archives)

In terms of spatial organization, the removable loft system resting on steel legs at the eastern end of the structure has both enhanced volume continuity and contributed to improved acoustic performance thanks to the gallery space it creates on the upper floor. This section integrates with service corridors, storage units, and staff areas, supporting the functional flow required by contemporary gastronomy spaces. Solid wood-metal combinations were preferred in most of the space, and seating arrangements were planned to accommodate both heavy user traffic and flexible seating needs (Figure 2). This arrangement represents a design decision parallel to the "original void + flexible interior" principle recommended in adaptive reuse projects (Ferretti, 2020).

When the plan data and photographs of the interior are evaluated together, it becomes clear that the transformation process was shaped not only by architecture but also by an experience-focused concept. The large communal dining area, loft, open kitchen section, and railway-themed display units within the interior stand out as elements that both reveal the historical narrative and lend functional diversity to the space. The wide-span facade windows bring in natural light from the surroundings, which is balanced by unique LED fixtures integrated between the ceiling trusses to achieve a homogeneous level of illumination. The literature emphasizes that lighting is critical in industrial buildings in terms of both atmosphere and function, and the application at Gar 1936 is consistent with this approach (Appl. Sci., 2020).

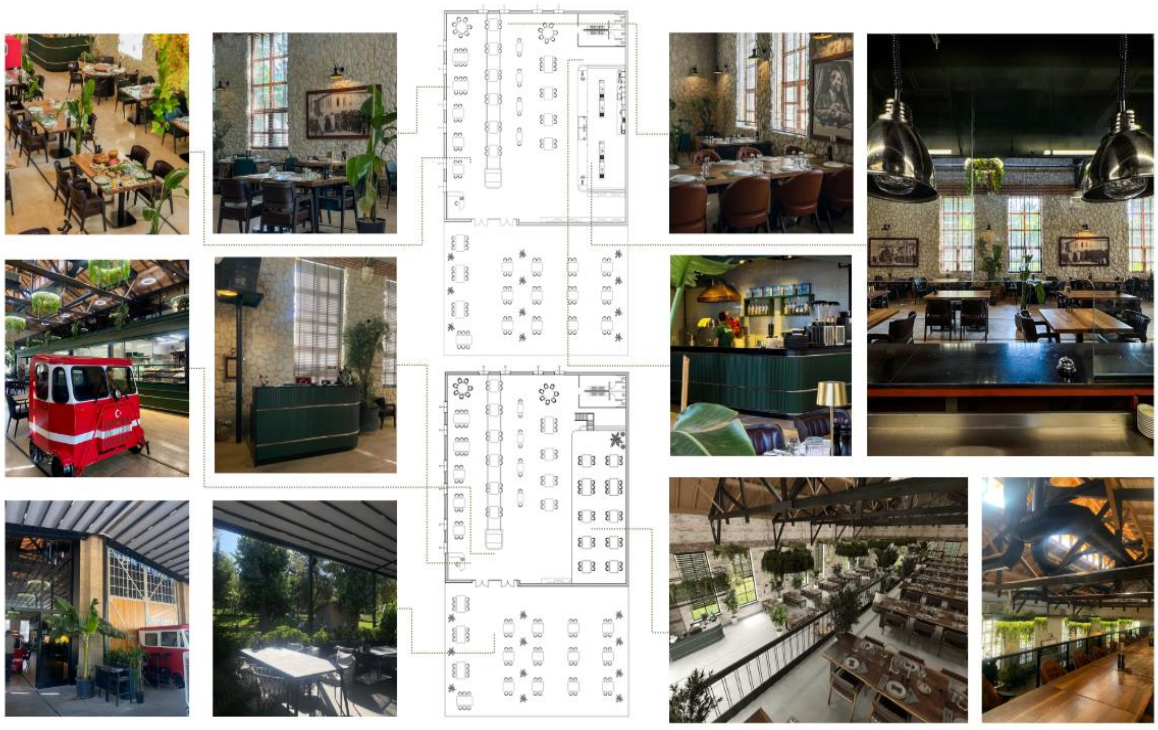


Figure 2. Analysis of interior photographs and plan schemes in terms of architectural integrity (From the authors' archives)

During the architectural interventions in the conversion process, the damage identified in the structure was first repaired. Roof deformations, corrosion in steel trusses, wood rot caused by water leaks, broken window panes, plaster fallout, and vandalism-related damage constituted the main problems identified in the damage analysis conducted prior to restoration. After these problems were addressed, an independent load-bearing loft system, an open kitchen layout,

flexible seating areas, and railway-themed display units were integrated into the structure during the spatial transformation phase. In the final stage, archival photographs, railway objects, and memory elements were placed within the space to make the building's historical identity visible; this application is also consistent with the principle of "narrative continuity" associated with collective memory theories in heritage spaces (Assmann, 2011).

When these findings are evaluated as a whole, it is evident that the 1936 transformation of the station was carried out in a manner consistent with contemporary approaches to preserving industrial heritage. The structure's load-bearing system, material character, and original spatial void have been preserved; new technical solutions that were necessary to implement have been kept to a minimum level so as not to overshadow the building's historical identity. Thus, the structure has both functionally adapted to its role as a gastronomy space and gained the status of a cultural focal point that carries the historical narrative into the future.

3.2. SWOT Analysis

The repurposing of the Repair Building has been comprehensively evaluated in terms of its strengths, weaknesses, opportunities, and threats. Among its strengths are the preservation of the registered structure, its reintegration into the social memory, the reinforcement of its historical fabric, and the transfer of cultural heritage to future generations (Kültür ve Turizm Bakanlığı, 2013). Weaknesses or threats particularly include roof deformation, water damage, wood rot, vandalism, and deterioration due to long-term disuse (TCDD, 2014). However, the high costs associated with restoration projects due to the need for original materials and specialized labor are also a significant threat (Stanley-Price, 2009). Opportunities include the building's potential to revive the city's memory, create tourism potential, produce social spaces, and improve the quality of urban life by integrating with the Millet Garden (Isparta Belediyesi, 2022). This analysis shows that the building has been transformed into a sustainable heritage structure in terms of identity, function, and economy.

3.3. Design Principles for Refurbishment

Four fundamental design principles were considered in converting the Repair Building into a restaurant: narrative and memory, social sensitivity, ecological approach, and the principle of minimal intervention. In line with the "narrative and memory" principle, traces of the building's industrial identity have been preserved in the spatial design, creating an environment where visitors can experience railway history. This approach is consistent with international literature that recommends preserving traces of original functions in cultural heritage spaces (Coulls, 1999). Under the scope of "social sensitivity," the structure has been turned into a focal point that contributes socially to the city with a business model integrated with the local community (Eraydın, 2016). In accordance with the principle of "ecological sensitivity," natural ventilation, local materials that reduce the carbon footprint, and sustainable practices have been preferred (UNESCO, 2015). Finally, the "minimal intervention principle" has been the fundamental approach to the restoration process; original stone walls, wooden trusses, and window openings have been preserved, and additions have been made with respect for the historical fabric of the building (ICOMOS, 2013).

3.4. Evaluation Criteria

During the restoration and adaptive reuse process of the Isparta Gar1936 Repair Building, the building's character, material authenticity, structural condition, and design decisions were evaluated within a holistic conservation approach. Current conservation approaches to

industrial heritage are based on preserving the original character and integrating the new function into the structure with minimal intervention (Glendinning, 2013; ICOMOS, 2013). In this regard, the spatial organization of the building, the integrity of the load-bearing system, the original material texture, and the re-functionalization decisions were analysed in physical, functional, and cultural dimensions. In the building and structure assessment, the spatial design reflecting the original functional traces, the reinforcement of the load-bearing system, and the level of preservation of floor coverings and wall materials were taken into account. The material analysis examined the preservation status of the original stone wall structure, wooden truss roof system, and metal frames, as well as the compatibility of newly added materials (Kültür & Turizm Bakanlığı, 2013). Finally, the design concept was evaluated within the framework of the principles of minimal intervention, ecological sensitivity, and the goal of generating social benefits in the conversion of industrial heritage into a gastronomic space (UNESCO, 2015).

Table 1. Assessment of the protection status of structural components and design success level

EVALUATION CRITERIA	SUBCATEGORY	DEGREE OF IMPORTANCE	SITUATION	SCORE (1-5)
Building and Structural System	Spatial Organization	High	Preserved	**GOOD(4)**
	Carrier System	Critical	Reinforced	**VERY GOOD (5)**
Material	Original Materials	High	Preserved	**GOOD(4)**
Energy efficiency	Insulation System	Middle	Renovated	**MEDIUM (3)**
Design concept	Industrial Heritage	Critical	Successful	**VERY GOOD (5)**

Original Materials:Roof Structure: Natural timber sourced from Bulgarian forests,Door: Wood–steel hybrid (or wood–steel combination),Flooring: Travertine and polished concrete,Terrace Paving: Andesite stone cladding (or andesite stone paving),Rail Tracks: Preserved in their original state,Wall Masonry: Local limestone

The criteria used in the evaluation of the structure were addressed in four main categories: structural integrity, material authenticity, energy efficiency, and the compatibility of the design concept with heritage values (Table 1). According to the presentation, the preservation of the spatial organization indicates that the building has a high degree of authenticity. The reinforcements made to the load-bearing system are important interventions that ensure the safe use of the building and are in line with the principle of “reversible and traceable intervention” mentioned in the literature (Stanley-Price, 2009).

In the material category, the preservation of the original stone wall masonry, wooden roof structure, and andesite rail tracks demonstrates that the building's original identity has been maintained. The insulation renovations carried out in the context of energy efficiency are a moderate level of intervention but are compatible with modern usage requirements. The design concept has been successfully implemented with a minimal intervention approach in transforming the industrial heritage into a contemporary gastronomy venue, achieving a “very good” rating (ICOMOS, 2013).

3.4.1 Furniture design and fixtures

The furniture layout of the Gar1936 restaurant-café building has been approached in a manner consistent with the approach of repurposing the building while preserving the spatial and material identity of its industrial heritage. The furniture used in the building's interior has been designed with a hybrid approach that both highlights the original texture of the stone walls and meets the needs of contemporary gastronomic spaces (Figure 3). The solid wood tables chosen for the seating areas reinforce the natural material character that harmonizes with the space's industrial past, while the leather-upholstered chairs offer both durability and comfort, providing an ergonomic solution suitable for restaurant use. (Çakır, 2019).

The fixed furniture used in the space also aims to highlight the originality of the structure. Wood-surfaced benches and fixed seating units integrated into the stone walls support material integrity, while the solid wood panels and metal details used in the design reinforce the industrial character. Such fixed fixtures draw attention by being applied without damaging the original texture, in line with the principle of "material and workmanship continuity" emphasized in the Nara Authenticity Document (UNESCO, 1994). In this context, it can be said that all the furniture and fixtures used in Gar1936 form a minimal yet characterful unity that supports the building's industrial heritage status.



Figure 3. Reinforcement placement in interior spaces and surface–reinforcement relationship (From the authors' archives)

3.4.2 Lighting and electrical solutions

The restaurant's lighting design is based on a dual-layered concept that aims to both reveal the historical atmosphere and provide modern comfort. Ring-shaped LED fixtures positioned between the ceiling trusses were selected for both general lighting and to create spatial depth, providing a light distribution that emphasizes the spaciousness of the industrial volume (Figure 4). The energy efficiency of LED-based solutions is consistent with the recommendations of the International Commission on Illumination (CIE) for sustainable indoor lighting (CIE, 2019). Therefore, the preference for LED usage in the building represents not only an aesthetic choice but also an energy-saving approach.



Figure 4. Lighting design in interior spaces and the solution for electrical fixtures within architectural integrity (From the authors' archives)

The building's electrical infrastructure has been modernized to meet the intensive usage requirements of the business. The newly added 250 kVA transformer ensures the restaurant's energy continuity and aligns with the concept of "technical integrity" emphasized by Hughes (2020), highlighting the importance of modern electrical systems in historic buildings from a safety perspective. The industrial-style spotlights used as wall sconces in the space provide accent lighting that highlights the texture of the stone walls. This enhances both the atmosphere and the spatial experience.

In addition to the lighting fixtures, the glass panel luminaires used support the gastronomic identity created after the restoration while establishing a rhythm appropriate to the high-ceilinged industrial structure of the space. This design approach complies with the principle of "combining functional and atmospheric lighting" recommended by the Illuminating Engineering Society (IES) standards (IES, 2018).

3.4.3. Landscape and environmental design

The Gar1936 area was redesigned to suit its function as a restaurant, while the landscape design took into account Isparta's climatic and cultural identity. The selection of plants that require low maintenance, are drought-resistant, and reflect the local character is fully consistent with sustainable landscape design literature. For example, the olive (*Olea europaea*), pachira (*Pachira aquatica*), banana plant (*Musa* spp.), and bird of paradise (*Strelitzia reginae*) used in the outdoor space are the right choices in terms of both visual continuity and climatic adaptation (Figure 5). This approach is perfectly in line with Thompson's (2011) emphasis on "ecological harmony with local plants" in his principles of sustainable landscaping. The exterior furnishings, natural stone surfaces, and wooden deck materials create a cohesive language with the interior space. This strengthens the relationship between the interior and exterior of the gastronomic space, offering users a seamless spatial experience. The seating areas used in the terrace sections are both comfortable and functional, designed in line with modern landscape design principles. The sustainability approach is one of the key determinants of the Gar1936 landscape design. Designed with goals such as preferring plant species that require little water, reducing the carbon footprint, and lowering maintenance costs, the outdoor space is compatible

with the environmental performance criteria recommended by the Sustainable Sites Initiative (SITES) (SITES, 2016).



Figure 5. The relationship between the building and its surrounding landscape and the role of plant arrangements in architectural integrity (From the authors' archives)

3.4.4 Energy efficiency and technical systems

During the refurbishment of Gar1936, technical systems such as energy efficiency, thermal insulation, natural lighting, sustainability, ventilation, and water management were addressed with a holistic approach. The aim was to achieve energy performance that both preserves the building's historical character and meets today's usage requirements. The technical solutions implemented after the restoration are consistent with international approaches to achieving energy efficiency in historic buildings. As emphasized in Historic England's (2018) Re-Use Guide, energy efficiency in historic buildings yields more sustainable results when achieved through “minimal interventions that respect the original material” (Historic England, 2018).

To improve energy efficiency in the building, insulation applications have been implemented on roof and wall surfaces to reduce heat loss. Existing window openings were restored without enlargement and double glazing was added to improve both thermal performance and interior comfort. Improving window performance in historic buildings is considered one of the fundamental interventions in terms of energy efficiency (Ünal & Yıldız, 2022).

The natural gas system in the building has been redesigned to provide both interior heating and the energy required for the kitchen's gastronomic functions. These applications have been implemented with solutions that increase energy efficiency without damaging the building envelope or interfering with the original wall texture (Eraydın, 2016).

As part of the restoration, thermal insulation was applied under the traditional Turkish roof tiles, breathable insulation materials were preferred for the stone walls, and the window frames were converted to double-glazed systems. Breathable insulation materials are widely recommended in historic buildings to preserve the moisture behavior of stone walls (Şahin & Korkmaz, 2020).

Transparent panels have been installed in the roof openings to increase the use of natural light, maximizing the benefit of daylight. Energy-efficient LED systems complement the natural light, while pendant lights placed between the metal trusses enhance the industrial atmosphere of the space (European Commission, 2020).

A sustainability approach has been adopted in technical systems; recyclable materials, low-energy lighting elements, and climate-appropriate landscaping solutions have been preferred. This approach is consistent with international sustainability criteria that recommend reducing the carbon footprint in adaptive reuse projects (Sustainable Built Environment, 2021).

The building's high-ceilinged industrial form supports passive ventilation, enabling reduced energy consumption by preserving natural air circulation. Although modern ventilation systems were used in the service areas, interventions were implemented without damaging the building's original roof structure (Passive House Institute, 2019).

The presence of a rainwater harvesting system around Gar1936 has ensured the irrigation of landscaped areas and the efficient use of water within the facility. Supported by a drilling system, this application is consistent with the approach of reusing local water resources that supports the sustainable water cycle (Water Europe, 2020).

The conservation approach applied to the structure is based on the internationally accepted principles of minimal intervention, authenticity, and reversibility in the adaptive reuse of industrial heritage buildings, and the historical integrity of the structure has been preserved throughout the restoration process. Interventions were only made where necessary; apart from addressing situations that threatened structural safety, new additions were avoided, and every element added to the structure was implemented using reversible systems that would not damage the original material. The injection-based repairs carried out on the surfaces of the stone walls strengthened the material texture of the structure, while the reinforcements made on the wooden and steel roof trusses were carried out in a way that left the historical traces of the load-bearing system visible, without any aesthetic additions. The preservation and renewal of the original steel doors, in particular, has been one of the most important elements in ensuring material continuity; industrial memory has been supported by avoiding modern cladding or covering applications. All additions made to the electrical, ventilation, and mechanical systems are removable and designed to be removed without damaging the structure in future restoration work.

This approach has made the building's intervention history readable while also providing flexibility for future usage scenarios. Decisions such as leaving the ceiling trusses exposed, preserving the original wall surfaces, and avoiding partition walls that compromise the building's volumetric integrity support the principle of “respect for authenticity,” which forms the basis of conservation ethics. This approach has made it possible not only to preserve physical elements, but also to sustainably carry the historical meaning, functional past, and spatial identity of the building into the future. When all these practices are evaluated together, it is clear that the conservation strategy used in the Gar1936 transformation represents a conscious and contemporary approach that is consistent with both national and international conservation documents (Historic England, 2025).

4. Conclusion and Recommendations

The repurposing of Gar1936 has created a prime example demonstrating that industrial heritage can be sustainably preserved in harmony with contemporary life. Throughout the restoration process, the building's spatial organization, structural system, original stone-and-steel character, and high-volume industrial structure were preserved and holistically integrated with its new gastronomic function. This transformation directly aligns with the principles of “cultural continuity and functional preservation” emphasized in adaptive reuse projects (Çalışkan, 2022).

This connection established between the building's past and present has strengthened Isparta's local memory and created significant public representation value in terms of collective memory. The transformation of the historic train maintenance workshop into a public focal point for social interaction has demonstrated that cultural continuity can be achieved not only through

physical preservation but also through functional and social participation. This situation parallels assessments made in recent studies that the integration of heritage areas into functions that are integrated with society is a fundamental condition for sustainability (Eraydın, 2016).

The minimal intervention approach adopted during the restoration process has made it possible to meet technical requirements without compromising the identity of the industrial heritage. Designing new additions to be removable, implementing them without damaging the original material texture, and carrying them out in a traceable manner are among the most up-to-date approaches recommended in conservation disciplines. This method complies with the "intervene only where necessary" principle defined in Historic England's (2020) guidance on minimal intervention in historic buildings (Historic England, 2020).

Energy efficiency improvements, such as natural lighting, ventilation, and insulation, were implemented without damaging the stone masonry or steel truss system, enhancing building performance while preserving the character of the industrial heritage. In particular, double-glazed window applications, breathable insulation materials, and roof openings that maximize sunlight are among the effective interventions that increase energy efficiency in historic buildings in recent studies (Ünal & Yıldız, 2022).

Furniture design, lighting solutions, landscaping, and outdoor furnishings are supported by recyclable and sustainable elements that harmonize with the building's unique material palette. The use of solid wood, leather, and metal details indoors, along with natural stone and local plant species outdoors, has created a strong sense of environmental integrity. This approach aligns with criteria recommended in sustainable built environment research for reducing carbon footprint and utilizing local materials (SBE, 2021).

In conclusion, the project presents a successful model demonstrating that the preservation and adaptive reuse of cultural heritage can be achieved in tandem with economic, socio-cultural, and environmental sustainability. The Gar1936 example has become an application that serves as both a regional cultural value and a national model, demonstrating that industrial heritage can be kept alive through proper conservation principles, minimal intervention strategies, and contemporary usage scenarios (Kutlu & Sürer, 2020).

Various additional strategies are proposed to transform Gar1936 into a more sustainable and environmentally resilient structure while preserving its industrial heritage. First, rainwater harvesting systems need to be developed. Collecting rainwater from roofs and storing it in underground or above-ground reservoirs for reuse in landscape irrigation will both reduce operating costs and alleviate pressure on water resources. This approach is recommended as one of the fundamental components of sustainable urban practices in the "Rainwater Harvesting Guide" prepared by the Ministry of Environment and Urbanization (ÇŞB, 2021).

Increasing solar-powered LED lighting solutions is an important step that will further enhance the building's energy performance. Generating electricity through low-incline photovoltaic panels installed on the roof will reduce the energy requirements of lighting systems while also lowering carbon emissions. Current research clearly indicates that such applications are an effective method for increasing energy efficiency in cultural heritage sites (Demirkan & Yılmaz, 2020).

The establishment of electric vehicle charging stations and bicycle parking areas around the station is important in terms of supporting sustainable transportation. This application will both reduce visitors' carbon footprint and strengthen the accessibility of the region. Studies on new

generation transportation policies emphasize that the transition to electric and micro-mobility vehicles in transportation improves urban environmental quality (Güler & Şahin, 2022).

Greywater recycling is an effective solution for reducing intensive water usage, particularly in food service establishments. Treating kitchen and sink water for use in reservoirs and landscape irrigation significantly reduces clean water consumption while also lowering operating costs. Current water management literature extensively discusses how this method is one of the most efficient systems for optimizing the water cycle (Köse & Arslan, 2021).

Finally, it is recommended that waste oil recycling be carried out systematically. Collecting used frying oil in special storage tanks and sending it to licensed biodiesel plants will both reduce environmental pollution and contribute to biofuel production.

Thanks and Information Note

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Retrieval-Augmented Generation (RAG) Based Artificial Intelligence (AI) Chatbots: A Case Study of St. Nicholaos

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Abstract

Large language models (LLMs) have paved the way for making AI-related tools accessible to ordinary users. A vast number of users benefit from LLMs using generative pre-trained transformers (GPTs). GPTs help create content, translate languages, integrate agents into daily tasks, and handle specific queries. GPTs usually operate in a chatbot format and enable users to interact with them easily without requiring advanced computer skills. They can process text, voice, and image data.

Currently, millions of people interact with chatbots to meet their specific needs, and the tourism industry has recently begun to emphasize their capabilities. Individual businesses and corporate companies use AI-powered chatbots to answer user inquiries, such as product comparison, price checking, route planning, or providing on-site feedback. However, there is a need for refinement in these chatbots. (1) Chatbots rely on pretrained datasets; therefore, their information may not always be up-to-date. (2) Chatbots are trained for general-purpose tasks, which means that they cannot perform well in domain-specific queries such as cultural heritage, food and beverages, or history of places.

This study adopts a retrieval-augmented generation (RAG) approach to open-source chatbots, which have great potential for revising and increasing their information capacity. RAG implementation highlights that ordinary chatbots struggle to answer questions regarding the St. Nicholaos and St. Nicholaos Church in Demre. Accordingly, a well-trained chatbot can answer specific questions more accurately and reduce the occurrence of hallucinations.

Keywords: Artificial ıntelligence, chatbots, cultural heritage, St. Nicholaos

1. Introduction

LLMs simply construct probabilistic responses for the user based on the text in their training data (Marr, 2024). These texts mostly depend on internet data and yet are prone to hallucination or false information. According to Huyen (2024), hallucination and inconsistencies are related to the probabilistic nature of AI. While inconsistencies occur when the model generates very different responses, hallucination refers to responses that are not grounded in facts (Huyen, 2024). Therefore, modern LLMs such as ChatGPT, Gemini, Llama, Claude, Mistral, Grok etc. are being used by millions of people in a day, yet they still provide false answers to users without even noticing them (Hsu, Tan & Stantic, 2024; Kırtıl, Çizel, Uzut & Uzun, 2024).

Three approaches are recommended to help foundation models respond more effectively to user queries: *Prompt engineering*, *fine-tuning* and *RAG* (Huyen, 2024). Prompt engineering is the process of optimizing input prompts to clarify the user's intent to the LLM (Ekin, 2023). Prompt engineering can be considered the first stage of interaction between the user and the LLM. The user should prefer a brief, concise and clear language while chatting with the foundation model. For example, the earlier versions of ChatGPT, such as GPT-3 was trained

only on text data, so the user should not expect knowledge about the physical world from it (Kublik and Saboo, 2022).

Fine-tuning requires the most technical knowledge and time among the three techniques. It requires machine learning skills because it is about model training. Fine-tuning involves training the LLM on a smaller, task-specific dataset (Özdemir, 2024). If the LLM has behavioral response problems, fine-tuning is recommended; simply, it is for form (Huyen, 2024). If the model works well but lacks information, RAG can help the model access relevant and necessary information (Huyen, 2024).

Table 1. Pros and Cons of RAG. (Adapted from Liu et al., 2023; Borgeaud et al., 2021; Gao et al., 2023)

Advantages of Using RAG	Challenges of Using RAG
Uses User's Specific Data (Customizable)	Two-Step Process (Complex)
Always Updatable	Possibility of Finding the Wrong Document (Retrieval Inaccuracy)
Reduces Hallucination	Potential for Slower Responses
Provides Citations	Context Length Limitations (Memory)
Cheaper & Faster (than Finetuning)	Requires Maintenance

The most critical contemporary problems about LLMs are the up-to-date information and context-specific tasks. Users struggle when they ask specific questions, or the LLM simply hallucinates. Specifically, the tourism and travel related LLMs need to be updated regularly, and the necessary information could be provided to the models via RAG. RAG can help the model to retrieve the necessary text, image or video-based information from a database. This database could be a separate domain, or basically could be located in the database of the provider.

2. Materials and Methods

This study prefers a RAG implementation to an open-source LLM. Open-source models allow users to intervene in the model and help enhance its response capabilities. We selected OpenAI's 'gpt-oss-20b' model as the foundational model and used AnythingLLM software for the interaction between user and chatbot.

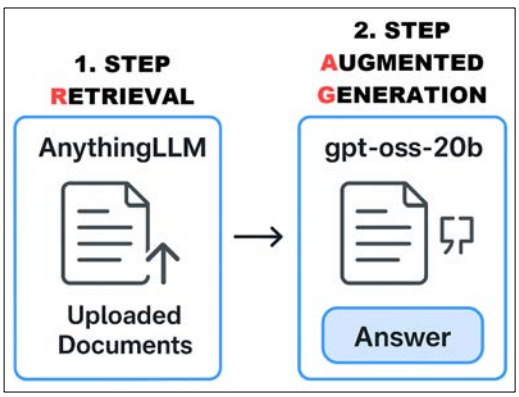


Figure 1. RAG Process Steps of the Study

The system prompt given to the chatbot was to behave like a travel chatbot: *"You are a travel chatbot designed for the tourism industry. You respond in Turkish or English languages based on the user's message. Speak in a warm and friendly tone, like a well-informed local guide. Your answers should be clear, detailed, and welcoming, but not overly academic or formal. For domain-specific questions look for the RAG-context."*

Our context was St. Nicholaos, which is located in Demre, Antalya, Türkiye. St. Nicholaos is a historical figure, and his church is a well-known cultural heritage site located in Demre. Domain-specific information from textbooks and local guides was carefully compiled, and a document of Questions and Answers was provided to AnythingLLM and stored in the vector database of the software.

3. Findings and Discussion

The findings indicate that the implementation of RAG increases the response accuracy of the chatbots. The same questions were asked to the models, and it was observed that the travel chatbot responded differently to these queries. The queries concerned several domain-specific questions regarding St. Nicholaos, a saint who once lived in Demre, Antalya, Türkiye.

Figures 2 and 3 depict questions about St. Nicholaos and the ancient harbour. It was seen that the chatbot without RAG says that there is no information about the topic (Figure 2a), and RAG-implemented chatbot highlighted the connection between Nicholas and the ancient harbour (Figure 2b).

Figure 3a and Figure 3b demonstrate the second query presented to the travel chatbot. The plain chatbot's response illustrates a clear example of hallucination (Figure 3a).

It provided an incorrect location for the church and an irrelevant narrative. On the other hand, Figure 3b gave an accurate answer regarding the user query. It gave the location and the story of the plakoma in correct and concise format. When more domain-specific questions were asked, the RAG-powered chatbot provided more accurate answers as long as the relevant information was present in its RAG context.

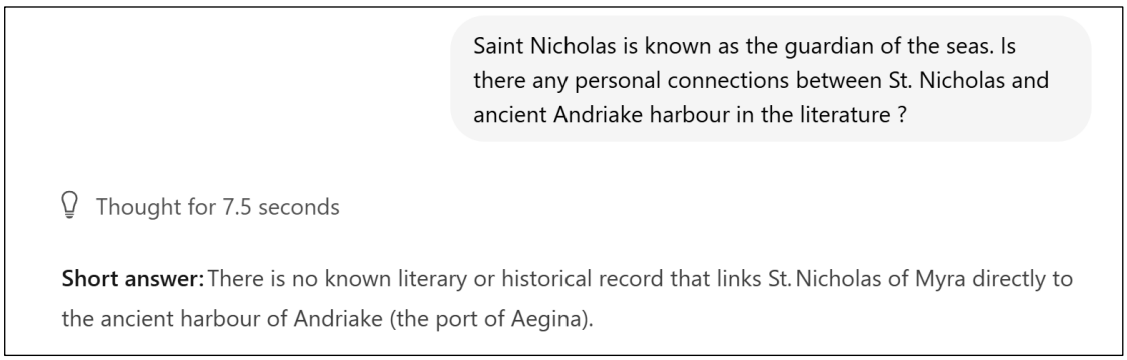


Figure 2a. Chatbot Answer Without RAG

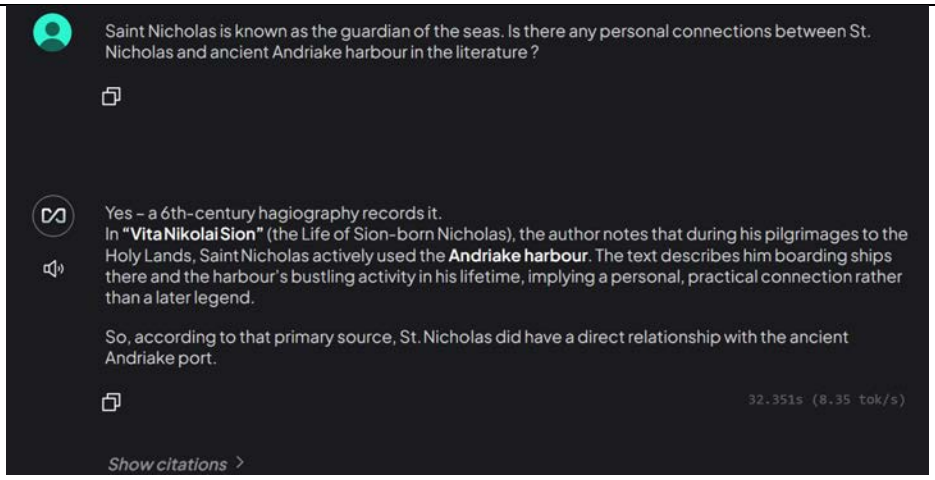


Figure 2b. Chatbot Answer With RAG

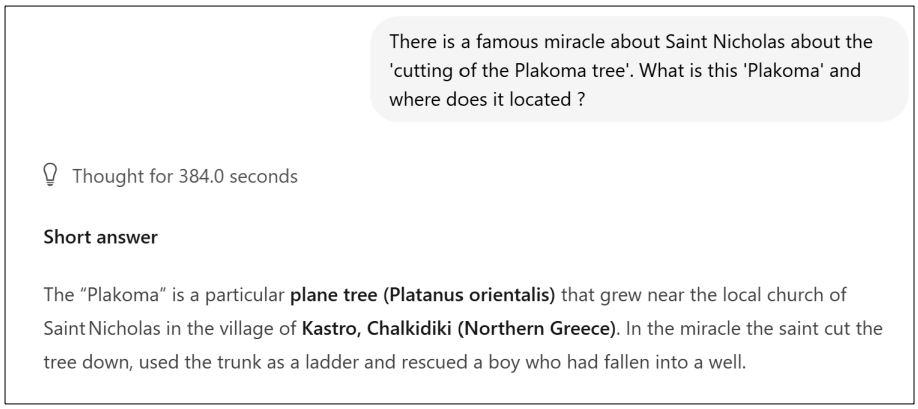


Figure 3a. Chatbot Answer Without RAG

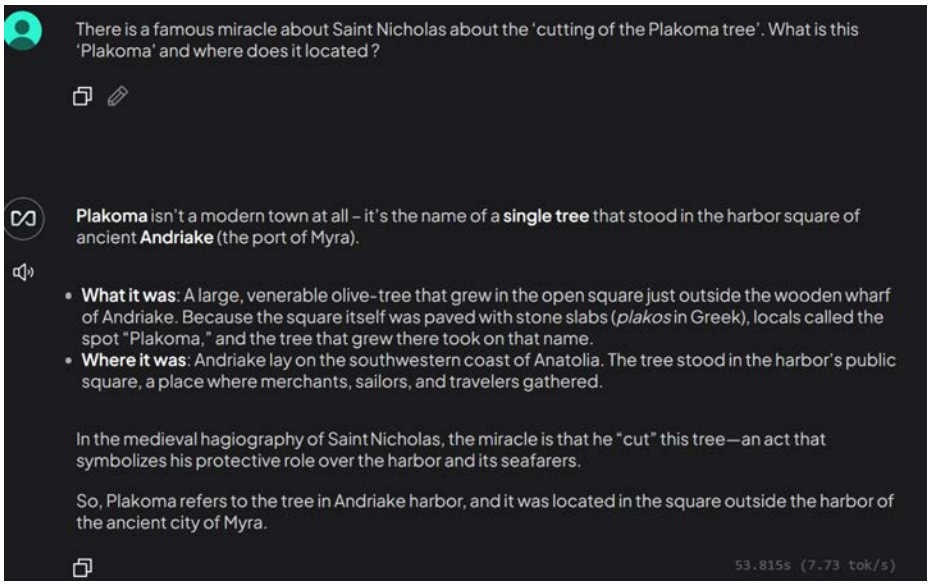


Figure 3b. Chatbot Answer With RAG

4. Conclusion and Recommendations

This study shows that RAG implementation significantly enhances the reliability of AI chatbots in tourism & travel contexts. Compared to the baseline model, the RAG-powered chatbot produced more accurate, consistent, and domain-specific answers regarding St. Nicholaos and the historical Demre region.

The findings underline key limitations of standard LLMs, especially their tendency to hallucinate when confronted with niche historical or cultural queries. This situation is apparent even in the most well-known and reputable chatbots. RAG mitigates these issues by enabling access to verified external sources, making it a useful tool for tourism professionals such as travel agencies, local tourist guides, and tour operators.

The study suggests broader integration of RAG-supported systems in destination marketing, cultural heritage interpretation, and tourism information services. Future research may test user experience, multimodal data integration (audio or video), and automated content updating to maximize the practical value of AI in tourism. AI-related tools are rapidly evolving, but their implementation with local tourism information needs to be followed up precisely.

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The article complies with national and international research and publication ethics. Ethics Committee approval was not required for the study. All authors contributed equally to the article

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Botanical Gardens Approach to Ecological Restoration of Abandoned and Derelict Lands

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Abstract

The conversion of land that has been damaged and isolated for various reasons into botanical gardens over time plays a very important role in terms of restorative and sustainable land use. In this study, the potential for transforming degraded and abandoned areas into botanical gardens has been evaluated in terms of ecological, cultural, and social aspects, using examples from different countries. From an ecological perspective, this transformation supports the recovery of physically or chemically degraded soil, provides opportunities for the formation of new habitats, and contributes to mitigating the effects of climate change. Culturally, abandoned industrial heritage areas are being repurposed, and the identity of these repurposed spaces is being preserved, thereby keeping the traces of the past alive while creating resilient urban and rural spaces that serve the needs of today. From a social perspective, it plays an important role in strengthening the connection between nature and humans, supporting collective lifestyles, and creating accessible green infrastructure. In conclusion, botanical gardens, which combine sustainable and restorative landscape planning and design principles with an interdisciplinary approach, offer multifunctional landscapes that are in harmony with nature. The redesign of abandoned and underutilised areas as botanical gardens offers opportunities to improve the ecological structure of their surroundings while also supporting countries' Sustainable Development Goals.

Keywords: Sustainable landscape planning, regenerative landscape, land use and land cover change, abandoned areas, botanical garden.

1. Introduction

Urban spaces and peri-urban zones that fail to renew themselves, cannot integrate with the urban fabric, and lose their functional continuity due to physical, economic, and socio-cultural transformations of the public realm often deteriorate into derelict or depressed areas (Özalp & Arslan, 2020; Fermancı & Kaya, 2020). According to Lefebvre (2013), in a city that is capable of continuously and autonomously regenerating itself, any community, system, or spatial unit that cannot adapt or renew becomes a component of urban decay and generates idle or abandoned spaces (Yılmaz et al., 2019). Such vacant or underutilized areas have become a widespread phenomenon globally. Even in today's highly developed cities, a considerable number of unusable, abandoned, and empty spaces still exist. These areas are often perceived negatively by residents and therefore tend to be overlooked. However, considering the spatial shortages experienced in rapidly expanding cities, it is evident that these urban voids remain largely undervalued (Tranick, 1986; Aydınlı & Kaya, 2020).

Yet, despite their negative characteristics, such idle areas possess significant potential for addressing spatial deficiencies and enhancing urban sustainability. Abandoned or functionally obsolete sites also offer valuable opportunities for ecological, social, and aesthetic reintegration of degraded urban fabric (Krzysztofik et al., 2015; Jin et al., 2021; Aydınlı & Kaya, 2020). In this context, adapting existing building stock and obsolete urban areas to new uses is crucial for

improving resource efficiency and minimizing urban emissions. These forms of "adaptive reuse" are widely recognized as core components of sustainable urban transformation and contribute to strengthening the ecological resilience of cities (İsmail, 2013; Kyaw et al., 2023). Restoring abandoned sites and disconnected infrastructure corridors through adaptive reuse enables the reestablishment of spatial continuity and promotes ecological, economic, and social revitalization (Ball, 1999; Nepravishta et al., 2019; Nepravishta, 2024).

Transforming such areas into botanical gardens through a sustainable approach can address the growing need for recreational environments in cities under pressure while simultaneously supporting the emergence of ecological networks. From this perspective, the conversion of derelict urban spaces into botanical gardens aligns with the principle of enhancing urban living quality through nature-based, ecologically sensitive design, providing the public with more comfortable and accessible environments (Yurtseven, 2020). Botanical gardens are institutions where plant species cultivated within an organized system are exhibited for public and educational purposes, while also supporting various scientific studies and meeting recreational needs (Heywood, 1987; Önder & Konaklı, 2011). Botanical gardens and arboreta, with their contributions to biodiversity, their capacity to host endemic and native species, and their embodiment of cultural values expressed through plant collections, represent some of the most exceptional examples of cultural landscapes (Aydın, 2006). Their biodiversity-enhancing function plays a significant role in urban landscape renewal and in taking action against climate change (Botanic Gardens Conservation International, 2025). Additionally, the transformation of abandoned lands into botanical gardens provides meaningful benefits in mitigating the urban heat island effect, offering an effective nature-based tool for climate resilience (Primack Çakmak & Çimen, 2014).

Materials and Methods

In this study, examples of degraded and functionally obsolete sites from various parts of the world that have been transformed into botanical gardens were examined. By investigating cases from different countries, the study aims to highlight sustainable scientific planning principles and contribute to the development of best practices for their implementation.

2. Findings and Discussion

2.1 Eden Project, UK

The Eden Project (Figure 1), located in the southwest of England, is widely regarded as one of the most significant examples of transforming a former mining site into a botanical garden through sustainable landscape planning principles (Atik et al., 2009; Emir & Yıldırım, 2024). In their study, Emir and Yıldırım (2024) note that approximately 15 hectares of the site previously operated as a kaolin quarry. The environmental degradation caused by the mining activities strongly influenced the scale of the project and the decisions made during the design process.

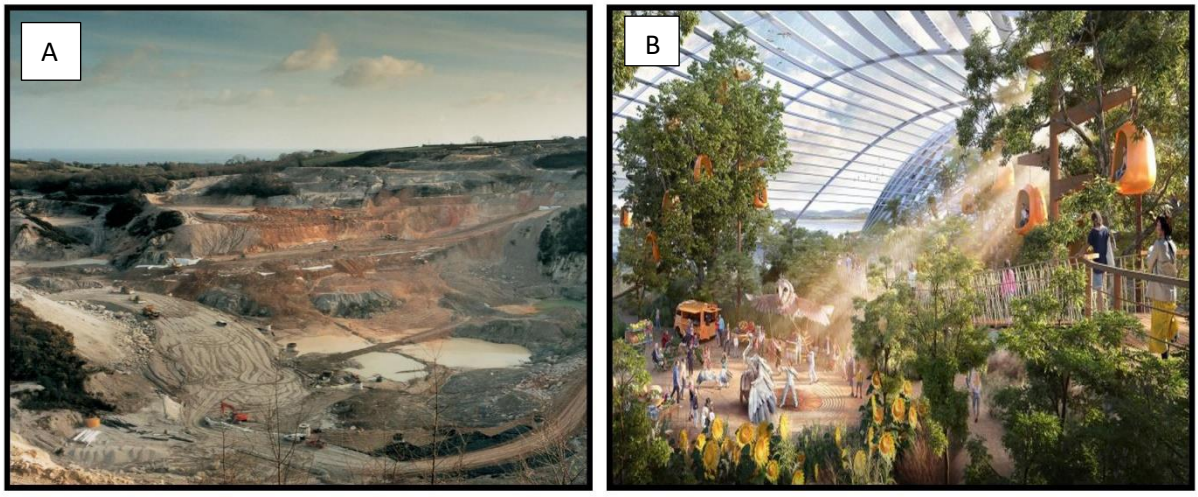


Figure 1. Former appearance of the Eden Project (A), and its current appearance (B) (URL, 1)

Through the geodesic dome designed by Richard Fuller, the project not only enabled vegetation to establish freely within the site but also ensured the environmentally compatible reuse of the former kaolin pits (Ural, 2022; Emir & Yıldırım, 2024). Figure 2 illustrates the geodesic dome and the associated landscape design interventions.



Figure 2. Visuals of the Eden Project (URL, 1).

The designed botanical garden aligns closely with biomimicry principles and has enabled the ecological rehabilitation of a previously degraded site. At the same time, the project incorporates systems for waste and water recycling, generates its own energy, and produces heat, thereby reducing the need for conventional fuel use (URL, 3).

2.2. Gardens by the Bay, Singapore

With its green city vision, the transformation of a disused area into a botanical garden for both international and local visitors has allowed the Singapore Botanic Gardens to host a wide range of rare plant species. The former and current appearances of the site are presented in Figure 3.

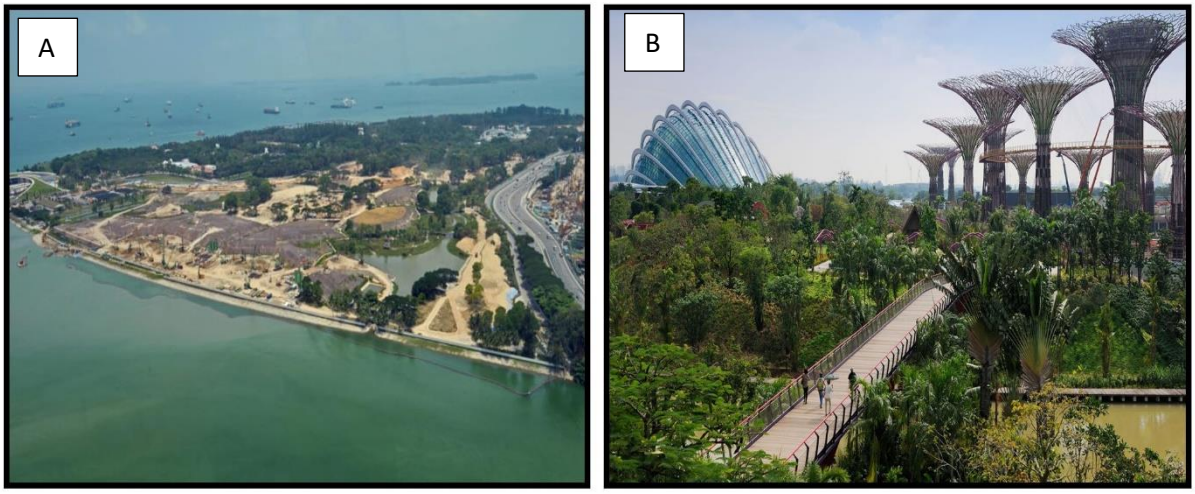


Figure 3. Former (A) and current (B) appearance of the project (URL, 2).

The project incorporates state-of-the-art technology, particularly through the integration of conservatories designed to optimize energy efficiency. These systems enable an approximate 30 percent reduction in energy consumption. The conservatories are constructed with a specialized glass coating that allows plants to receive the necessary amount of sunlight. The roof material is equipped with sensor-controlled movable sails that provide shading for the plants in cases of sudden temperature increases. Additionally, the water retained in the lakes, which serve as an extension of the marina reservoir, is purified by the plants, thereby contributing to water recycling (Davey, 2011; McNeill, 2022; URL, 2). The overall design features and large-scale views of the project are presented in Figure 4.



Figure 4. Various visuals from the Gardens by the Bay project (URL, 2).

2.3. South Coast Botanic Garden – Los Angeles, USA

The South Coast Botanic Garden, recognized as one of the first botanical gardens in the world to be established on a former sanitary landfill site, stands as a significant example of environmental remediation and ecological restoration. The area, which was initially subjected to intensive mining activities, began operating in the early 1900s, with extraction continuing until 1956. The land, severely degraded during this period, was later rehabilitated and gradually transformed into a restorative urban space that strengthened the interaction between nature and society. After the site was sold in 1956, it began to be used as the county's waste disposal area. Following its conversion into a botanical garden in 1961, the area has come to host more than

200,000 plant species (Faber, 2005; URL, 3). The former and current appearances of the site are presented in Figure 5.



Figure 5. Former (A) and current (B) appearance of the project (URL, 3).

Over time, the area transformed into a botanical garden has evolved into a major attraction. It aspires to serve as a model that encourages the restoration and reintegration of degraded sites for the benefit of future generations.

2.4. Pittsburgh Botanic Garden, Pennsylvania, USA

The Pittsburgh Botanic Garden, located in Pennsylvania, United States, occupies a landscape that functioned as a coal mining site during the 1920s. Mining operations conducted through the "room-and-pillar" technique led to the excavation of numerous tunnels across the area to access coal reserves. By the 1940s, large portions of the site were subjected to blasting in order to facilitate extraction, a process that resulted in the complete destruction of the native vegetation and the accumulation of substantial mining waste. Following the cessation of mining activities, efforts were initiated to rehabilitate the degraded land and transform it into a botanical garden (Edenborn et al., 2012; URL, 4). A visual representation of the site's former state is provided in Figure 6, while its restored condition following the botanical garden conversion is illustrated in Figure 7.



Figure 6. Former (A) and current (B) appearance of the project (URL, 4).



Figure 7. Visuals of the Pittsburgh Botanic Garden (URL, 4).

During the rehabilitation phase of the transformation into a botanical garden, analyses revealed the presence of toxic substances in the soil, including compounds similar to dissolved aluminum. It was also determined that the water bodies within the site had been contaminated by these toxic constituents as a result of previous mining activities. To mitigate this issue, lime beds were installed around the pond located within the newly established botanical garden. This intervention facilitated the natural purification of the water and supported the ecological restoration of the area, ultimately contributing to the formation of a renewed and livable ecosystem (URL, 4).

2.5. Zollverein Park – Essen, Germany

The Zollverein Coal Mine and Coking Plant in Essen, Germany, once the world's largest and a defining symbol of the Ruhr region's industrial heritage, was decommissioned in 1986. Following the closure of the adjacent coking facility, comprehensive efforts were initiated to repurpose and transform the site for contemporary use. Today, Zollverein stands as an internationally recognized example of industrial adaptive reuse and landscape regeneration. Visual representations of both the former mining complex and its current condition are provided in Figure 8 (Kaçar, 2016; URL, 5).



Figure 8. Former (A) and current (B) appearance of the project (URL, 5**)**

Through sustainable planning and adaptive reuse, the transformed recreational landscape has become a symbol of cultural revitalization and multifunctional urban regeneration, offering attractive spaces for culture, leisure, education, and work. Today, Zollverein represents both a

commemorative industrial heritage identity for the Ruhr region and a forward-looking model of spatial development (Eiringhaus, 2022; URL, 5).

Conclusion and Recommendations

This study highlights the potential of abandoned mining sites, derelict industrial areas, and other functionally obsolete landscapes to be reintegrated into the ecological system through sustainable landscape planning. The international examples reviewed demonstrate that long-term environmental degradation can be reversed when restoration strategies prioritize ecological integrity, biodiversity enhancement, and adaptive reuse.

Transforming degraded areas into botanical gardens provides not only ecological benefits but also social and educational value by creating spaces that reconnect communities with nature. The Eden Project, in particular, illustrates how a former mining site can evolve into a globally significant botanical complex, integrating energy-efficient systems, water recycling, and innovative design approaches. Such projects underscore the role of ecological rehabilitation in addressing the impacts of the climate crisis and promoting resilient landscape strategies.

Overall, the restoration of abandoned and degraded areas through botanical garden development presents a replicable model for sustainable futures. Expanding similar initiatives in Türkiye and worldwide will support environmental stewardship, enhance urban and rural resilience, and foster a stronger human–nature relationship for future generations.

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The Impact of Temporal and Spatial Changes in Land Use and Cover in Isparta City Center on Urban Ecosystem Services: a GIS-Based Analysis

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Abstract

Urbanization affects the supply of urban ecosystem services (UES) by rapidly changing the land use/land cover (LULC) pattern. This situation turns cities into fragile areas where more serious problems occur in terms of ecosystem services. This study aims to analyze how changes in land cover over time and across space in Isparta's city center affect Urban Ecosystem Services (UES). To do this, Land Cover/Land Use (LULC) change data from the Urban Atlas (UA), created by the European Commission's GMES/Copernicus Programme for 2012 and 2018, were used. In addition, the population change and future population analyses of Isparta city center were associated with Land Cover/Land Use (LULC) data. According to population estimates for the study area from 2012 to 2030, the area saw a growth of 47.11%. While UA cover land data indicates a 236.08% increase in the structural area, there is a decrease of 1.73% and 0.17% observed in the agricultural and forest lands that are part of the UES, respectively. As a result, approaches to the identification and protection of UES should be incorporated into urban planning studies to promote more resilient and sustainable cities. This study encourages the identification of UES for the ecological health of cities and sustainable urban planning and development.

Keywords: *Land use/land cover change (LULC), Urban Ecosystem Services (UES), Urban Atlas (UA), Isparta city center*

1. Introduction

The benefits that people derive from natural ecosystem resources (de Groot et al., 2012; Faber & van Wensem, 2012) or their direct or indirect contributions to human well-being are defined as ecosystem services (ES) (Gomez-Baggethun & Barton, 2013; Song et al., 2014). According to the Millennium Ecosystem Assessment (MEA) 2005, the conceptual framework of ES is defined as "Humans are integral parts of ecosystems and there is a dynamic interaction between them and the natural ecosystem; people with changing lifestyles direct changes in ecosystems both directly and indirectly and thus cause changes in their own welfare structures" (Yaman, 2025). Human ES supporting functions contribute greatly to human well-being due to their contribution to the daily survival of organisms on Earth (Song et al., 2014). Over the last 50 years, human well-being and the economy have undergone a process of sustainable development, but this has come at the expense of "increasing risks of non-linear change leading to deterioration of many ESs and increased poverty for some groups of people" (MEA, 2005). The primary causes of ES degradation are human activities such as urbanization, mining, forest activities, etc.

Urbanization represents a cultural and social evolution that accelerates the growth of urban centers, increases the number and distribution of urban communities, and promotes the agglomeration of nearby rural settlements (Bilozor et al., 2024). Urban ecosystem services (UES) are the values and benefits that internal ecosystems within a city provide to its inhabitants (Çoban & Yücel, 2018). UES classified its functions and components into 11 groups.

Table 1. Classification of important ecosystem services in urban areas and underlying ecosystem functions and components (Gómez-Baggethun & Barton, 2013)

Ecosystem service	Functions and components	Examples	Examples of indicators/proxies
Food supply	Energy conversion into edible plants through photosynthesis	Vegetables produced by urban allotments and peri-urban areas	Production of food
Water flow regulation and runoff mitigation	Percolation and regulation of runoff and river discharge	Soil and vegetation percolate water during heavy and/or prolonged precipitation events	Soil infiltration capacity
Urban temperature regulation	Photosynthesis, shading, and evapotranspiration	Trees and other urban vegetation provide shade, create humidity, and block wind.	Temperature decrease by tree cover×m^2 of plot trees cover (°C)
Noise reduction	Absorption of sound waves	Absorption of sound waves by vegetation barriers, especially thick vegetation	Leaf area and distance to roads
Air purification	Filtering and fixation of gases and particulate matter	Removal and fixation of pollutants by urban vegetation in leaves, stems, and roots	O3, SO2, NO2, CO, and PM10 µm removal multiplied by tree cover
Moderation of environmental extremes	Physical barrier and absorption of kinetic energy	Storms, floods, and wave buffering by vegetation barriers; heat absorption during severe heat waves	Cover density of vegetation barriers separating built areas from the sea
Waste treatment	Removal or breakdown of xenic nutrients	Effluent filtering and nutrient fixation by urban wetlands	P, K, Mg, and Ca given soil/water quality standards
Climate regulation	Carbon sequestration and fixation in photosynthesis	Carbon sequestration and storage by the biomass of urban shrubs and trees	CO2 sequestration by trees
Pollination and seed dispersal	Movement of floral gametes by biota	Urban ecosystems provide habitat for birds, insects, and pollinators	Species diversity and abundance of birds and bumble bees
Recreation and cognitive development	Ecosystems with recreational and educational values	Urban parks provide multiple opportunities for recreation, meditation, and pedagogy	Surface of green public spaces /inhabitant
Animal sighting	Habitat provision for animal species	Urban green spaces provide habitat for birds and other animals, and people like watching.	An abundance of birds, butterflies, and other animals valued for their aesthetic attributes

Urbanization leads to economic progress as well as numerous socio-economic and cultural benefits for city dwellers (Qiu & Lu, 2015), but it also brings with it many serious problems. Urbanization brings about problems such as loss of agricultural lands, degradation and destruction of natural and cultural landscape resources, and destruction of animal and plant habitats (Lin et al., 2023; Ersoy Tonyaloğlu & Kesgin Atak, 2020). Urbanization is one of the

most important factors causing significant changes in land cover and land use (LULC) structure worldwide (Gao et al., 2021; Zhang et al., 2022). The rapid expansion of urban areas over the last 30 years, on average twice the size of their populations (Angel et al., 2011; Seto et al., 2012), has accelerated LULC and changed the structure of ecosystems in the short term (Gómez-Baggethun et al., 2013) and affected the supply of UES. LULC, one-third to two-thirds of species in the world's most biologically diverse regions are at risk of future extinction (Myers et al., 2000). According to Seto et al. (2012), by 2000, 88% of global primary vegetation had disappeared in "biodiversity hotspots".

UES has a significant impact on the quality of life in urban areas, and preventing and controlling further deterioration of UES as a result of changing LULC with rapid urbanization has become an important issue. In particular, the protection of UES should be made a central concept of urban landscape planning and local policies in legal and administrative terms. In this context, the assessment of UES can potentially assist landscape and urban planners, local politicians, and ecological economics plays a vital role in advancing this effort as it deals with both economic benefits and natural capital, and the ecosystem functions or processes that produce them (Estoque & Murayama, 2012).

Geographic information systems (GIS) have become an important source of information for local politicians and planners to understand the causes and consequences of LULC dynamics of urbanization (Zucaro et al., 2024). In this study, the Urban Atlas (UA), an initiative developed by the European Union under the Copernicus Programme, was used. UA provides highly accurate maps of urban areas related to UES, such as residential areas, commercial and industrial zones, green spaces, water bodies, and transportation infrastructure, from 2012 to 2018. The UA dataset includes 27 land use classes mapped at a scale of 1:10,000 with a Minimum Mapping Unit (MMU) of 0.25 ha for urban areas and 1 ha for natural/semi-natural areas. The Minimum Mapping Width (MMW) is 10 meters (EEA, 2024). This study analyzed the impacts of land cover changes on the UES of the Isparta city center. For this purpose, LULC data from the Copernicus Land Monitoring Service for the years 2012 and 2018 were used. The pressures placed on ecological processes due to population growth and land use changes on the formation of ecosystem services in the Isparta city center were revealed. The results of the study provide important information for local policymakers to promote and develop sustainable land use planning that prioritizes UES.

2. Materials and Methods

2.1. Materials

This study was carried out in the city center of Isparta province, located in the Mediterranean region of Turkey. Isparta city center is in the north of the Western Mediterranean region, located in the Lakes Region between 30º 20’ and 31°33’ east longitudes and 37º 18’ and 38°30’ north latitudes (Isparta Provincial Directorate of Culture and Tourism, n.d.1). It has a surface area of 8,913 km2 and an altitude of 1,050 m (Isparta Provincial Directorate of Culture and Tourism, n.d.1), and is a settlement established on a plain (Aydemir & Cesur Durmaz, 2024). Today, the total population of the city center is 272,797, of which 133,680 are male and 139,117 are female. It has a total of 51 neighborhoods and 20 villages affiliated to the city center (Türkiye Population provincial district neighborhood village populations, 2025).

Rich vegetation is seen in the city of Isparta due to natural factors such as altitude, slope, aspect, and climate (Aydemir & Cesur Durmaz, 2024). It is possible to come across cedar, red

pine, black pine, hemlock, juniper, and oak trees in the forests, oak and shrubs in the mountainous and hilly areas, and cereals, fruit trees, vegetables, and legumes, as well as vineyards and rose gardens in the plains (Isparta Provincial Directorate of Culture and Tourism, n.d.2).

The city center is a settlement that stands out with its open green spaces. These include Ayazmana Park, Kızıldere-Gökçay Picnic Area, Milas Picnic Area, and Gölcük Lake Nature Park (Yazıcı et al., 2014). Findos, Kışla, and Gelincik Plateaus (Aydemir & Cesur Durmaz, 2024) are seen as important open green areas in the city center.

Gölcük Lake is a significant water feature within the city center. It is a crater lake located 5 km southwest of the Isparta city center. Gölcük Lake is circular in shape with a diameter of 1.5 km and a depth of 32 m (Isparta Provincial Directorate of Culture and Tourism, n.d.3). Gölcük Lake and its surroundings are surrounded by volcanic mountains and mixed forests.

Davraz Mountain, with a peak height of 2635 m, is among the important natural values located in the city center of Isparta. In addition to winter sports (skiing, snowboarding, etc.), many alternative tourism activities such as camping, mountaineering, nature walks, nature photography, etc. can be done on Davraz Mountain (Ceylan & Demirkaya, 2009).

Isparta city center has a very wide range of UES in terms of agriculture, forest, and water resources (Figure 1).

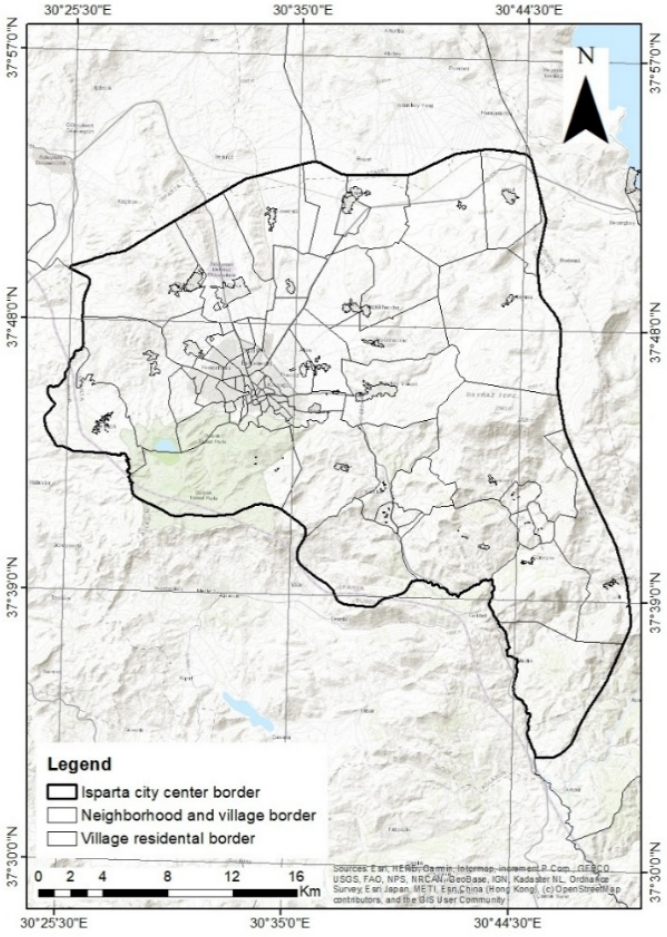


Figure 1. Isparta city center neighborhood and village boundaries

National and international literature, articles, and theses, publications from institutions and organizations, and maps and plans from institutions for digital mapping were reviewed. The maps and plans used are listed in Table 2.

Table 2. Maps and plans used in the study

Materiel	Source	Data date
Land Use/Land Cover (LULC)	European Commission's GMES/Copernicus Program https://land.copernicus.eu/en/products/urban-atlas	2012, 2018
Isparta City Center Settlement Borders	Open Street Map, https://www.openstreetmap.org/#map=11/37.7978/30.6417	
1/100,000 Antalya-Burdur-Isparta Environmental Plan	https://mpgm.csb.gov.tr/antalya-burdur-isparta-planlama-bolgesi-i-82219	2014
1/25000 scale Isparta Forest Management Map	Isparta Regional Directorate of Forestry	2021
1/25,000 scale STATİP Map (Problematic Agricultural Areas Identification and Improvement Project)	Ministry of Agriculture and Forestry, Isparta Provincial Directorate of Agriculture	2017
Population	Türkiye Population Province District Neighborhood Village Populations https://www.nufusune.com/merkez-ilce-nufusu-isparta	2012-2018

2.2. Methods

Isparta city center was chosen as the study area because the population growth in the city center has accelerated in recent years, and the resulting urbanization and change in land cover are clearly visible. Based on this, the impact of urbanization and population growth on the UES of Isparta city center was examined. Three stages were followed in the method of the study here. In this context, firstly, in order to reveal the temporal and spatial changes in land cover, the land cover change rates between 2012 and 2018 were examined in the Urban Atlas (UA) data set, which is part of the European Commission's GMES/Copernicus Program. In order to examine the current situation, the 2014 Antalya-Burdur-Isparta Environmental Plan and the UA land cover map were matched. Here, UA also enabled the identification of areas with UES value, such as parks, which are not included in detail in the land cover. Afterwards, the population changes and growth rates of the neighborhoods and villages in the Isparta city center between 2012 and 2018 were examined. The impact of population on UES was examined according to population projections between 2018 and 2040. The population estimate of Isparta province was made using the Compound Interest method. Finally, the effects of future urbanization on the UES are interpreted based on land cover change rates and population projections. The population estimates use the compound interest method:

$Ng = N2(1+r)n$

Ng: Future population estimate N2: Total population value in the reference year, n: Net year difference, r: Population growth rate. Here, the (1+r) value can be calculated by comparing two different time periods with known population sizes (Uğurlu, 2023).

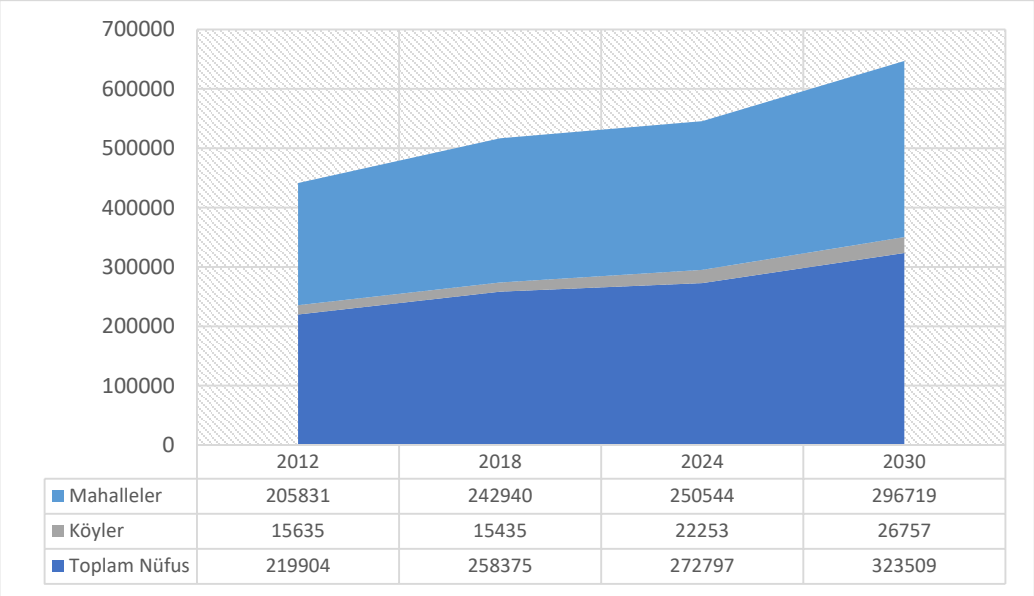
3. Findings and Discussion

3.1. Temporal change of the population in Isparta city center and the effect of UES

Urbanization is a process that causes changes in land cover from the urban center to the rural areas. This process is accelerated by the migration of people from rural settlements to urban areas. This situation poses the risk of a decrease or extinction in the amount of UES and production (Yılmaz Kaya & Uzun, 2020).

Isparta is a province that receives more immigration than it gives out. The main reasons for this can be said to be social and economic conditions, work, health, education, military service, etc. (Isparta Provincial Directorate of Culture and Tourism, n.d.4). The migration trend in Isparta province is seen as a population increase in Isparta city center and large districts such as Eğirdir and Yalvaç. One of the main reasons for the population increase in Isparta city center is the tendency to migrate from rural areas within the provincial borders to the city center (Isparta Provincial Directorate of Culture and Tourism, n.d.4). In addition, the increase in the orientation of people living in rural areas towards the service and industry sector, which is the main economic source of the city center, can be shown. The fact that Süleyman Demirel University, located in the city center, is home to civil servants, students, and the military can be cited as the main reason for the increase in population.

When the temporal population change effects in Isparta city center are examined, it is seen that the population rate in the city center increased linearly by 24.05% in total between 2012 and 2024. With the Compound Interest method, it is seen that the population will be 323,509 in 2030 (Table 3) and will continue to grow by 19% between 2024 and 2030 (Figure 2).



	2012	2018	2024	2030
Mahalleler	205831	242940	250544	296719
Köyler	15635	15435	22253	26757
Toplam Nüfus	219904	258375	272797	323509

Figure 2. Population growth indicator of the Isparta city center between 2012 and 2030

Population growth is observed in the neighborhoods and villages located in the city center of Isparta. Between 2012 and 2024, there was a 21.72% increase in neighborhoods and a 42.32% increase in villages. While the population growth in neighborhoods has been steady from 2012 to 2024, a variable population rate is observed in villages. A 1.28% decrease was observed in villages between 2012 and 2018, and a significant population increase of 44.17% was observed between 2018 and 2024. According to population projections for 2030, it is estimated that population growth will continue at 18% in neighborhoods and 20% in villages (Table 4). This situation shows that the urbanization rate of Isparta city center has increased

significantly along with the population growth. The population growth seen, especially in rural areas, is an indication of a large structural increase from the city center towards rural settlements. It shows that with the increasing population, the amount of UES and production will be seriously damaged, and the risk of extinction will be faced.

Table 4. Isparta province population increase percentage projection for 2012-2030

Years	Total Population	Villages	Neighborhoods
2012-2018	17,49	-1,28	18,03
2018-2024	5,58	44,17	3,13
2024-2030	19	20	18

3.2. Temporal land cover change of Isparta city center and its impact on the UES

In order to examine the impact of LULC temporal and spatial changes of Isparta city center on UES, the Urban Atlas (UA) data for the years 2012-2018 developed by the European Union within the scope of the Copernicus Programme were examined (Figure 3). With these data, the changing land dynamics and environmental changes on the UES of the LULC in the city center of Isparta were evaluated.

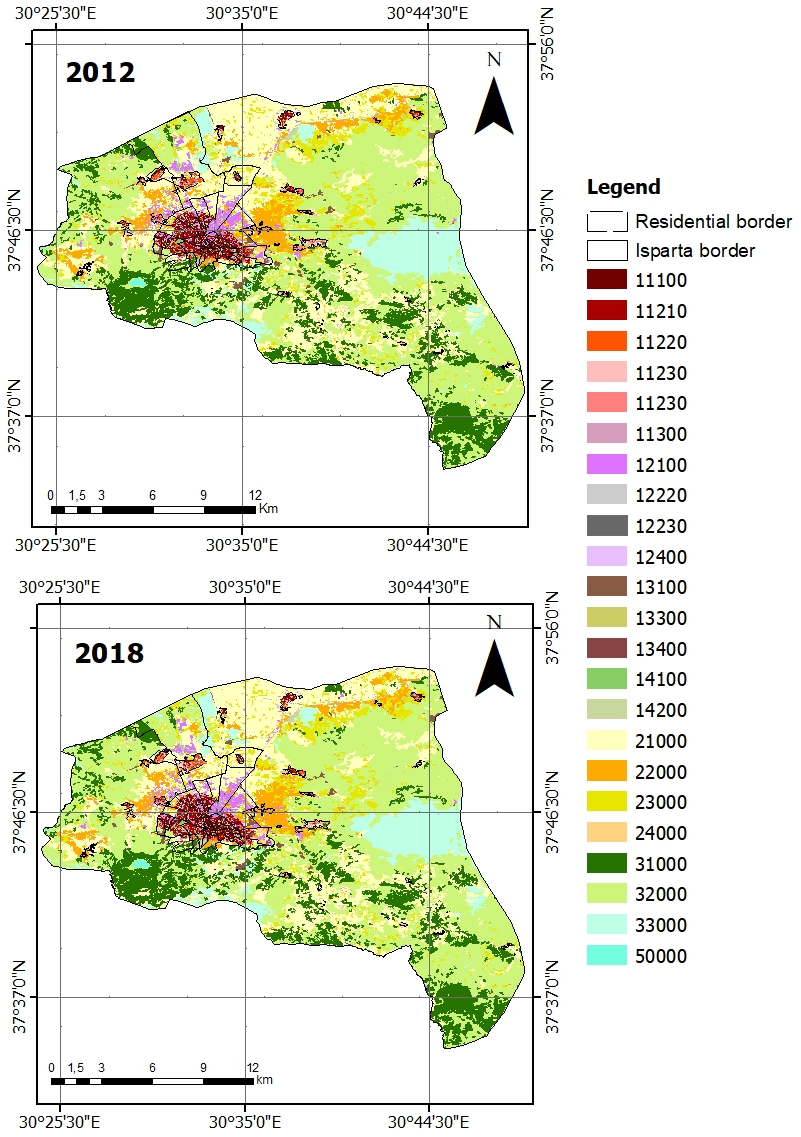


Figure 3. Isparta city center UA land cover and LULC data

When we look at the population data of the Isparta city center, we see an increasing trend. This situation can be shown among the important reasons for the acceleration of the LULC change in the city center. When the 2014 Antalya-Burdur-Isparta Environmental Plan is examined, that the population in the Isparta city center has increased and urban development areas have increased accordingly. Sav Town, Çünür neighborhood, and Akkent TOKİ areas are considered urban expansion areas. In the study conducted by Aydın and Polat (2021), it was predicted that 2,258 ha of development area would be proposed within the scope of the Environmental Plan, and the city of Isparta would be 5,967 ha of urban area. Today, it is seen that the residential areas of Çünür, Akkent, and Deregümü neighborhoods located in the city center of Isparta are increasing.

When looking at the UA LULC data for the years 2012-2018, different land categories and significant land changes are seen in the city center of Isparta. The most obvious change in land cover is the areas of industrial, commercial, and public units. In 2012, industrial,

commercial, and public units increased from 9,562,417 ha to 130,911,065 ha. The second largest increase was in construction areas, rising from 4,771,312 hectares to 26,788,151 hectares. It is the third largest land change in mining and waste sites, increasing from 2,877,877 ha to 4,057,454 ha. While the airport was 2,474,752 hectares in 2012, a land change of 4,380,037 hectares was observed in 2018. Contrary to the increase seen in structural areas, it decreased in agricultural and forest areas. While the total agricultural land was 14,285,140 ha in 2012, it decreased to 14,038,030 ha in 2018. In forest areas, the area of 6,498,478 ha decreased to 6,487,317 ha (Table 5).

Table 5. Isparta city center UA land cover data and 2012-2018 years LULC

		LULC (ha)		
UA Code	**UA Land Cover**	**2012**	**2018**	**Change (%)**
11100	Continuous urban fabric (S.L. : > 80%)	3,336,022	3,379,747	1.31
11210	Discontinuous dense urban fabric (S.L.: 50% - 80%)	9,481,491	9,557,247	0.80
11230	Discontinuous low-density urban fabric (S.L.: 10% - 30%)	2,202,417	2,310,883	4.92
11220	Discontinuous medium-density urban fabric (S.L.: 30% - 50%)	2,787,503	3,535,589	26.84
11240	Discontinuous very low-density urban fabric (S.L.: < 10%)	2,952,633	352,319	-88.07
11300	Isolated structures	126,323	1,239,913	881.54
				-2.45
12100	Industrial, commercial, public, military, and private units	9,562,417	130,911,065	1269.02
12220	Other roads and associated land	9,596,542	9,742,781	1.52
12230	Railways and associated land	2,064,567	2,064,567	0.00
12400	Airport	2,474,752	4,380,037	76.99
				520.71
13300	Construction sites	4,771,312	26,788,151	461.44
13400	Land without current use	1,925,297	2,053,098	6.64
13100	Mineral extraction and dumpsites	2,877,877	4,057,454	40.99
				243.61
14100	Green urban areas	1,369,666	1,478,116	7.92
14200	Sports and leisure facilities	4,877,213	1,069,249	-78.08
				-59.22
				236.08
21000	Arable land (annual crops)	1,637,705	1,601,331	-2.22
22000	Permanent crops (vineyards, fruit trees, olive groves)	3,290,071	3,188,745	-3.08
23000	Pastures	4,679,299	4,569,889	-2.34
24000	Complex and mixed cultivation patterns	4,678,065	4,678,065	0.00
				-1.73
31000	Forests	1,038,389	1,035,041	-0.32
32000	Herbaceous vegetation associations (natural grassland, moors...)	274,232	273,395	-0.31
33000	Open spaces with little or no vegetation (beaches, dunes, bare rocks...)	5,185,857	5,178,881	-0.13
				-0.17
50000	Water	1,065,452	1,065,452	0.00
				0.00

Population estimates using the compound interest method show that the population of the Isparta city center will increase by 2030. Similarly, the population data is increasing in the neighborhoods and villages located in the city center. Accordingly, when looking at the LCLU data for the years 2012-2018, when urbanization accelerated, urbanization accelerated. As urbanization rapidly increases in this direction, urban residents will face problems such as urban heat islands, noise pollution, increased urban waste, etc., where open green spaces, green corridors, air quality, etc., which increase the UES within urban areas, will decrease.

4. Conclusion and Recommendations

Many studies have been conducted on urbanization worldwide, and the findings show that urbanization will lead to the loss of ecosystem services such as regulating, supporting, and provisioning services (Sharma et al., 2023). Urbanization is not just a loss of energy resources but a worldwide problem. Zhang et al. (2017) found in their study that urbanization in Beijing-Tianjin-Hebei in China from 2013 to 2040 will decrease food production by 3.16%, carbon storage by 1.60%, and air cleanliness by 0.87%. They revealed that urbanization caused LULC changes among the main reasons for the decline in UES functions in the region. Estoque and Murayama (2012) studied the impact of LULC changes on UES in Baguio, Philippines, from 1988 to 2020. They revealed that urbanization will cause 34% deforestation by 2020. They emphasized that if deforestation continues at this rate during the urbanization-LULC change, ES will be significantly affected.

The impact of urbanization on LULC is important, enabling us to make inferences about the impact of changes in the land on UES. In this study, we demonstrated the feasibility of examining the population development of Isparta city center and its effects on the UES using data obtained from a remote sensing tool (UA cover land). In the study, while losses in forest and agricultural lands are observed in the city center of Isparta in the 2012-2018 UA cover land data, growth in built-up areas is observed with population growth. In the UA cover land data, the largest changes were detected in the built areas, respectively, industrial, commercial, public military, and private units (1269.02%), isolated structures (881.54%), and construction sites (461.44%). In agricultural areas, there is a 3.08% decrease in permanent crops, a 2.22% decrease in arable lands, a 2.34% decrease in pastures, a 0.32% decrease in forest areas, and a 0.32% decrease in herbaceous vegetation. This situation shows that rural settlements and agricultural lands have been opened to construction sites and structures. Considering the forest and agricultural lands of the Isparta city center, which provide various ecosystem services, as potential structural areas may lead to the loss of UES. Therefore, in this context, effective and ecologically based planning and regulations are needed to ensure sustainable long-term urban growth.

Thanks and Information Note

The article complies with national and international research and publication ethics. Ethics Committee approval was not required for the study. All authors contributed equally to the article.

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Cost/Benefit Analysis of Improvements in Recreational Areas (Case Study: Bursa Atatürk Forest)

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Abstract

Recreational areas, particularly those located near densely populated areas, meet the community's need for entertainment, recreation, and sports, which are among the most important social needs. To achieve the expected benefits from recreational areas, they must be well-planned and developed to meet evolving needs over time. The purpose of this study is to demonstrate the impact of three improvement scenarios developed to improve the service quality of the Bursa Atatürk Forest Recreational Area (AOMY) on the recreational active use value of the area. In each scenario, the study envisions new investments at the area, and visitors' willingness to pay for the area in its new state is determined using the Contingent Valuation Method (CVM). Costs for each scenario are also calculated using official unit prices. The results indicate that the three scenarios developed to improve the service provided by AOMY increased visitors' willingness to pay for active use by 52.70%, 29.80%, and 12.82%, respectively, compared to the current conditions of the recreation area, and by $4,227,293/yr, $2,348,443/yr, and $1,028,196/yr, respectively. In response to these increases, the additional total investment amounts for each scenario were calculated as $650,000, $899,071, and $278,000, respectively. These results demonstrate that the recreational use value can be significantly increased with the scenarios developed to improve the recreation area, and that investments made for this purpose are economically feasible. It can be argued that these results obtained for AOMY are also valid for other recreation areas under similar conditions.

Keywords: Natural resources, forest resources, valuation, contingent value determination, forest functions.

1. Introduction

Forest ecosystems serve numerous functions due to their characteristics. While various authors describe these functions in different ways, Eraslan (1982) grouped these functions under ten headings: wood production, hydrological, erosion prevention, climatic, public health, nature protection, aesthetics, recreation, national defense, and scientific. One of these is the recreational function, which helps people enjoy their free time both physiologically and spiritually.

In Türkye, all of the above-mentioned functions can be observed in forest areas, which are almost entirely owned by the state and operated by the General Directorate of Forestry (OGM). Recreational areas have been allocated in suitable locations, particularly around urban and settlement areas where the population is more concentrated, to meet the community's need for recreation, and recreational functions are actively carried out. According to 2024 statistics, there are a total of 1,935 recreational areas (forest parks) allocated from forest areas in Türkiye, 333 with accommodation and 1,602 without accommodation (OGM, 2024).

To ensure that forest resources are available to future generations without disturbing their

structure and capabilities, they must be managed within the framework of planned and sustainable forest management principles. For planning, yield and cost items must be accurately determined in terms of the function or functions to which resource values are allocated. Therefore, in forest areas designated as recreational areas, it is necessary to know the quantity and economic value of goods and services produced, in addition to cost items. However, because recreational services provided in recreational areas do not have a market price (the often symbolic entrance fees charged at the entrance to many recreational areas do not reflect the real value of the recreational service), the economic value of these services must be determined. In this sense, numerous studies have been conducted using methods developed on this area to reveal the economic value of services provided by natural resources that do not have a market price (Akesen, 1978; Akgüngör, 1997; Kaya et al., 2000; King & Mazzotta, 2000; Haab & McConnell, 2002; Belkayalı, 2009; Demirci, 2017; Deniz, 2020; Tang, 2009; Ayhan & Erkan, 2021). In this respect, methods have also been developed to estimate the economic value of recreational services produced in recreation areas, the most commonly used of which are the Travel Cost Method (TCM) and the Contingent Valuation Method (CVM) (Kaya et al., 2000). Estimating the economic value of recreational services is important in the identification, planning, and sustainable management of these areas. Furthermore, to assess the economic feasibility of additional expenditures and investments to improve recreational services in these areas, the economic value of the services provided through these additional investment is also needed.

The Atatürk Forest Recreation Area (AOMY) is an area managed by the Bursa Metropolitan Municipality (BBB) through allocation from the General Directorate of Forestry (OGM). Located very close to Bursa city center (2 km), the area receives 6.5 million visitors annually, according to 2019 records. It is also important to identify what can be done to increase the recreational services currently provided by this area.

This study aims to determine the active use value of the increased recreational services provided by AOMY, taking into account the characteristics of the area, using scenarios developed to increase the recreational services, and to analyze the costs and economic benefits resulting from each scenario. This paper was prepared by using the data collected in framework of the Master's thesis titled "Determination of Total Economic Value of Recreation Services in Bursa Atatürk Forest Picnic Area" prepared at Bursa Technical University, Institute of Graduate Education (Yıkıcı, 2022).

2. Materials and Methods

2.1. Materials

The research was conducted at the AOMY. Located within the borders of the Nilüfer district of Bursa province, 2 km from the city center, AOMY is a recreation area having 124 ha of surface. Registered as a Type A recreation area by the General Directorate of Forestry in 2002, AOMY was later transferred to the Bursa Metropolitan Municipality and is currently managed by this institution (Figure 1). According to meteorological data for the period 1928-2024, the average temperature in the study area is 14.7 ºC and precipitation is 708 mm (MGM, 2025). The predominant vegetation in the recreation area consists of black pine (*Pinus nigra*), oak (*Quercus robur*), and Turkish red pine (*Pinus brutia*). AOMY offers ample parking, picnic areas, kiosks, restrooms, a country restaurant, a country coffeehouse, a barbecue, a gazebo, an observation deck, a dishwashing area, a children's playground, an adventure park, a sports field, a paintball field, a cable car line, and a place of worship to meet visitors' needs.

The research material consisted of a survey of visitors to AOMY, relevant official records and reports, and other document.



Figure 1. Map showing the location of the Atatürk Forest Recreation Area (AOMY)

2.2. Methods

The study was conducted using face-to-face interviews in different locations and locations on different days of the week, at different times of the day, during the June-December 2020 period, a period when visits to the area were concentrated. In this study, the active use value of three different hypothetical scenarios developed to increase recreational services provided at the AOMY, presented in Table 2, was calculated using the CVM method. The hypothetical scenarios were developed to determine the economic value of the recreational services that would be increased through alternative investment instruments to better utilize the existing potential of the recreation area. As required by the method, the developed scenarios were explained in detail to visitors, the additional recreational services that would be provided for each scenario if the investments envisioned in the scenarios were introduced, and the maximum amount that visitors were willing to pay (payment intentions) for each scenario, independent of the current entrance fee to the recreation area, was determined using the payment card technique.

In addition, costs were calculated for each hypothetical scenario (Table 1), using the market unit prices for 2020, prepared by the Turkish Ministry of Environment, Urbanization and Climate Change for use in calculating architectural and engineering service fees. The recreational active use value and costs for each hypothetical scenario developed for the recreation area were calculated for the year (2020) in which the data were collected (the surveys were conducted) (Table 2). To minimize the potential negative effects of inflation (in Turkish Lira) in interpreting the results obtained from the study, the results are given in US Dollars ($). In 2020, when the study was conducted, 1 $ = 7₺.

To determine the total recreational economic value for the current condition and the developed scenarios, visitors' willingness to pay (the maximum amount they are willing to pay) was used. For that, the average per capita willingness to pay (OÖDE) was calculated using Formula 1. Then, the total willingness to pay (TÖDE) was estimated using Formula 2, taking into account the annual visitor number. Then, recommendations were developed by evaluating the calculated active usage value and investment cost for each hypothetical scenario together.

(1) $$O\ddot{O}DE = \frac{\sum_{i=1}^{n} \ddot{O}DE_i}{n}$$

(2) $$T\ddot{O}DE = O\ddot{O}DE * YOZS$$

In the formulas, ODDE: average of willingness to pay per person (₺), ODE_i: willingness to pay of the i^{th} person (₺), n: number of participant in the survey, TÖDE: total willingness to pay or total economic value (₺), and YOZS: annual number of visitors.

The number of surveys to be conducted was calculated as n= 91, taking into account a 95% confidence level (Z=1.96), a 10% acceptable error rate (D=10), the total annual number of visitors as the main population (N=6,548,872), and the probability of the measured characteristic being present or absent in the main population (p=0.5 and q=0.5) (Kalıpsız, 1988). However, in our study, we surveyed 201 people, taking into account sample sizes in similar studies.

Table 1. Payment card (for 2020 prices)

Maximum amount that can be paid as entrance fee ($)								
1	2	3	4	5	6	7	8	9
0,43	0,71	1,00	1,43	2,14	2,86	3,57	4,29	Other

3. Findings and Discussion

The findings of the study are presented under two main headings: findings regarding the general characteristics of AOMY visitors and findings aimed at determining the additional economic value visitors attribute to the hypothetical scenarios developed for the recreation area.

3.1 Findings Regarding Some Visitor Characteristics

17% of the visitors were female, and 83% were male. Of the surveyed visitors, 49% were between the ages of 40 and 65, and 46% were between the ages of 66 and 79. Based on these results, it can be said that a significant portion of the visitors (95%) are between the ages of 40 and 79. Furthermore, it was understood that a significant portion of the respondents (67%) visited the area with their families, while 28% visited the area with a group of friends. Consistent with this result, a large portion of the respondents (91%) arrived at the area in their private cars.

When examining the visitors' educational levels, 13% had primary school, 30% had high school, and 56% had undergraduate or graduate degrees. These results reveal the striking conclusion that more than half of the visitors have a university degree. When looking at the visitors' marital status, the percentage of those who are married is 77%. This result suggests that the recreation area appeals primarily to families. 67% of the visitors' monthly income is less than $357, and 90% is less than $714. These figures suggest that visitors generally

comprise low-income individuals. Recreational areas typically receive visitors during the holidays. The study results also show that 72% of visitors use the AOMY during their holidays. It can be said that these general findings regarding the visitors obtained in our study are similar to the literature information (Pak, 2003; Ateşoğlu, 2008; Yılmaz, 2016; Demirci, 2017; Kalfa, 2018).

3.2. Findings Regarding Theoretical Scenarios

The net contribution amounts and rates provided by three scenarios developed to increase the recreational value of the AOMY were calculated compared to the current situation. First, investment costs were calculated based on unit prices for each scenario (Table 2). As can be seen in the table, the total investment costs for each scenario were calculated as $650,000, $899,071, and $278,000, respectively. Then, using information obtained through the survey, the maximum amounts visitors were willing to pay per person and in total for recreational active use value (willingness to pay) for the three different improvement scenarios developed for the AOMY were calculated using Formulas 1 and 2 (Table 3). Table 3 also shows that the developed scenarios produced 52.70%, 29.28%, and 12.82% more active use value compared to the current situation, respectively.

Table 2. Hypothetical scenarios and their estimated costs (based on 2020 prices)

Scenarios	Planned Buildings and Facilities	Cost ($)
Scenario I	Bungalow houses (30 units), infrastructure and superstructure arrangement of the tent camping area, glamping tents (50 units)	650,000
Scenario II	Therapy forest infrastructure and superstructure facilities (100,000 m^2), wildlife park infrastructure and superstructure facilities (200,000 m^2), sports complex (21x40 m basketball-volleyball-tennis), new walking-biking path (3 km), mountain bike track (5 km)	899,071
Scenario III	Restaurant (250 m^2), teahouse (150 m^2), children's playground (for ages 3-5/5-7 and above), amphitheater, walking-biking path (3 km), sports complex (21x40 m. basketball-volleyball-tennis), stove (for lighting fires) and seating areas, pergola (2 units), observation terrace (2 units), parking lot (for 150 vehicles), picnic tables (50 units), water pipeline (1 km)	278,000

Table 3. Willingness to pay per capita and total for active recreational use in AOMY for hypothetical scenarios ($)

Hypotetical scenarios	Average of willingness to pay per capita ($/yr)	Total willingness to pay per capita ($/yr)	Contribution rate provided by improvement (%)	Total contribution of the improvement ($/yr)
Current situation	1.22	8,021,926	-	-
Scenario I	1.87	12,249,219	52.70	4,227,293
Scenarios II	1.58	10,370,369	29.28	2,348,443
Scenarios III	1.38	9,050,124	12.82	1,028,196

When Tables 2 and 3 are evaluated together, it can be seen that: i) the investment costs calculated for each scenario are significantly below the total additional recreational active use value generated by the scenarios, ii) the contribution amounts presented in Table 3 are for one year and, considering that these values will be generated annually throughout the investment lifespan, the contribution amount will be quite high.

A review of previous studies on the subject reveals that; Pak (2003) examined the average per capita visitor willingness to pay for active recreational use value for two different scenarios for seven recreational areas, calculating amounts between $0.48 and $0.89 for the first scenario and between $0.52 and $0.95 for the second. Ateşoğlu (2008) also calculated the average per capita visitor willingness to pay for planned recreational developments as $0.65 in a study. For Belkayalı's (2009) scenario for the improvement of Yalova Thermal Springs, the average visitor willingness to pay per person was calculated as $5.10. The results obtained in these studies are consistent with ours, and the partial discrepancies in the calculated figures may be due to the characteristics of the study areas. Similarly, in a study by Talay et al. (2010), a higher average willingness to pay per person was calculated at $19.75 for a scenario envisioning improvements to Göreme National Park. This may be due to the high recreational resource values of the national park in question.

4. Conclusion and Recommendations

The primary purpose of recreational areas is to provide recreational services. Each recreational area requires a number of physical improvements and, consequently, economic investment expenditures to provide this service. It is also expected that, over time, new plans, changes, and additional investments will be made in the operation of recreational areas, taking into account visitor demands. Based on this understanding, scenarios developed to increase the current active recreational use value in the AOMY have revealed a need for this purpose. Indeed, it has been determined that the current total active recreational use value of $8,021,926/yr at the recreation area can be increased to $12,249,219/yr, $10,370,369/yr, and $9,050,124/yr, respectively, under the three additional investment scenarios developed. These amounts represent the additional contributions of the scenarios, respectively, at $4,227,293/yr, $2,348,443/yr, and $1,028,196/yr. However, these contribution amounts will only be achieved with additional investment costs of $650,000, $899,071, and $278,000 for each scenario,

respectively. Furthermore, although these additional revenues are annual, the investment costs will be incurred only once and can be used throughout the life of the investment. While these results demonstrate that additional investments in recreational areas can significantly increase active recreational use value, it would be beneficial to demonstrate the economic feasibility of such additional investments using a method similar to that used in this study.

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Spatiotemporal Distribution and Impacts of Tornadoes in Alanya (2004–2024)

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Abstract

Tornadoes in Alanya are atmospheric vortices with high rotational speeds that typically form between the ground and the cloud base, frequently occurring along the coastal strip between Antalya and Anamur. These tornadoes usually develop independently of supercell storms, yet they can cause significant damage to greenhouses, tourist facilities, and infrastructure. However, scientific records of such events are limited. Due to the difficulty of detecting surface tornadoes with radar, the spatial and temporal variations of tornadoes in Alanya have not been adequately documented. This study compiled and analysed tornado events in Alanya from 2004 to 2024, identifying 44 waterspouts and one land-based tornado. Most waterspouts formed up to 5 km offshore, with those within 500 metres causing property damage and injuries. The highest number of tornadoes occurred off the coast of İncekum. Of the 16 damaging tornadoes, 76.5% were in the western part of the Alanya peninsula, while 23.5% occurred in the east. Seasonally, 49% of tornadoes were observed in autumn and 33% in winter, with October, September, and January being the most frequent months. These findings show that although tornadoes in Alanya are short-lived, they pose significant risks to coastal areas and infrastructure.

Keywords: Tornado, waterspout, ESWD, Alanya.

1.Introduction

Tornadoes are atmospheric vortices that develop between the earth and the cloud base, characterised by high rotational speeds. Due to their rapid onset, powerful destructive effects, and difficulty of prediction, they are considered among the most dangerous convective weather events (Kahraman et al., 2017). In Türkiye, the area with the highest frequency of tornado occurrences is the Antalya–Anamur coastline. A significant proportion of tornadoes in this region are not associated with supercell storms; rather, tornadoes that develop over the sea, often referred to as waterspouts, reach land and cause considerable damage. Tornadoes observed off the coast of Alanya, although sometimes attracting tourists due to their visual impact, pose a serious natural hazard because of the damage they cause to greenhouses, tourism facilities, and coastal infrastructure.

Globally, tornadoes are among the most destructive types of severe convective storms, with wide-ranging impacts on agricultural production, settlements, transport systems, and economic activities. It is reported that the strongest tornado categories are responsible for approximately 75% of global fatalities and material losses (Kantamaneni et al., 2017). While most tornadoes occur in the USA, tropical, and mid-latitude regions, they have also emerged as a difficult-to-predict and increasingly impactful natural hazard in Europe in recent years (Antonescu et al., 2017).

The spatial distribution of tornadoes in Türkiye is not homogeneous. Although they occur in various regions of the country, factors such as sea surface temperatures, the frequency of cyclonic system passages, topography, and atmospheric instability play a decisive role in tornado formation. According to the European Severe Weather Database (ESWD) records for the 2000–2020 period, a total of 520 tornado events have been reported in Türkiye, 47% of

which occurred along the Mediterranean coast (Bayraktar & Çiçek, 2022). The literature indicates an increase in both the frequency and intensity of tornadoes, particularly in the last decade, attributed to atmospheric processes related to climate change as well as increased observation and recording capacity (Bayraktar, 2023; Bayraktar & Çiçek, 2022; Groenemeijer & Kühne, 2014; Kahraman & Markowski, 2014).

The Antalya coastline is one of the most active areas in Türkiye for tornadoes due to its location and physical characteristics. Kumluca, Finike, Kemer, Manavgat, and especially the Alanya region are areas where tornadoes occur frequently. The 2017 Kumluca tornado caused extensive damage to agricultural land and greenhouses, while the tornadoes in Antalya on 24 and 26 January 2019 led to significant material losses and casualties (Güvel & Akgül, 2023; Bayraktar, 2023). These examples clearly demonstrate the region's vulnerability to tornado hazards.

Understanding the formation mechanisms of tornadoes and accurately identifying their spatial and temporal distribution is of great importance in developing disaster prevention strategies and risk management. Although tornado research in Türkiye has increased in recent years, data limitations remain a significant issue. Therefore, international databases such as ESWD and remote sensing techniques have become fundamental components of scientific research conducted in tornado-prone areas such as Alanya (Bayraktar, 2023).

This book chapter, titled “Spatial-Temporal Distribution and Impacts of Tornadoes in Alanya (2004–2024)”, aims to comprehensively examine the trends, spatial concentration areas, formation times, lifespans, and effects on agricultural and tourist infrastructure in Alanya and its surroundings. By holistically evaluating ESWD data, local newspaper archives, and social media records, the current status of tornado hazards in the region and the future risk outlook will be revealed.

2.Materials and Methods

In this study, data on annual tornado observations in the Alanya region were collected from the European Severe Weather Database (ESWD, n.d.), local newspaper archives, and social media platforms. All collected data were compiled into a database containing the spatial and temporal characteristics of the tornadoes.

The database includes the following fields: written location data, distance from the coast (in metres), impact area (coast, land, or both), latitude, longitude, observed hour, date, day, month, year, tornado duration, damage status, observation status, and reporting status. These data were used to understand and assess the local impacts of tornadoes.

To define the characteristics of the tornadoes, basic descriptive statistics such as total, average, maximum, minimum, and range were calculated. The statistical data were visualised and explained using simple two-dimensional graphs. Figure 1 shows a close-up view of the Alanya coastline and the city of Alanya.

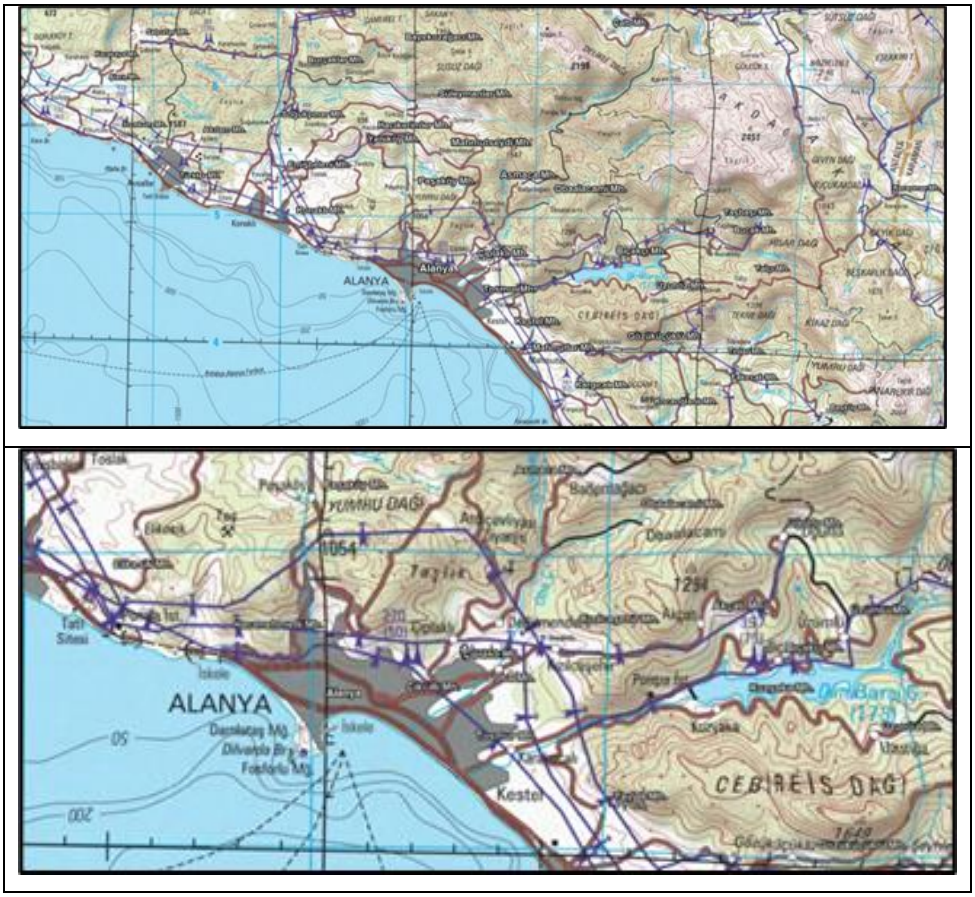


Figure 1. Location map of the study area.

3. Results

Regarding tornado observations, the highest number was recorded in İncekum (24%, 11 observations), while moderate numbers were observed in Kleopatra, Okurcalar, Konaklı, and Avsallar (5–6 observations each). Fewer observations occurred in Mahmutlar, Demirtaş, Payallar, and other small neighborhoods (2–5 observations) (Figure 2). This distribution indicates that tornadoes are more frequently observed in areas closer to the coast and in regions with high concentrations of tourist beaches, which is related to the interaction between sea and land and the greater availability of observation opportunities.

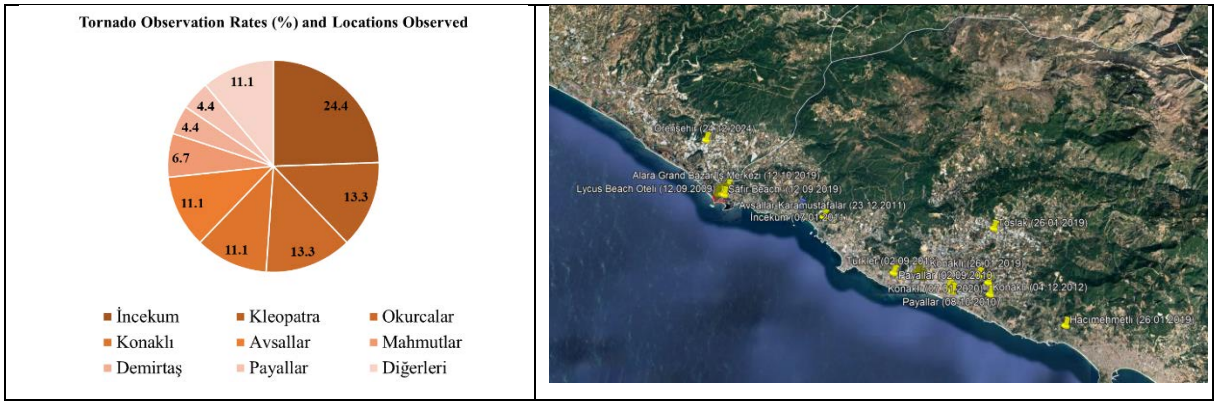


Figure 2. Tornado observation rates and observed locations

According to Figure 3, tornadoes caused damage in 42% of cases, while 58% did not result in any damage. This shows that tornadoes caused significant damage in some regions, but in most cases, their impacts were limited. In the agricultural sector, greenhouses, being outdoors, sustained the most damage, while structures at tourism facilities and hotel beaches were damaged, windows were shattered, and sunbeds were blown away and destroyed. In residential areas, there was generally light structural damage and local injuries.

Situation	Count	Percentage (%)
Damage present	19	42
No damage	16	58

Damage type	Prominent Period	Impact
Agriculture	2010-2012	Most frequent and severe damage in agricultural greenhouses
Tourism facilities	2004-2010	Hotel beaches, sunbeds, beach umbrellas, facility windows
Residential/Settlement	2010-2012	Light structural damage and injury

Figure 3. Distribution of tornado damage status and by damage types

Tornadoes were mostly observed in areas close to the coast (0–5 km). In more distant regions, observations were rare, irregular, and limited to certain years. No tornado observations were made more than five kilometers from the coast (Figure 4). This distribution shows that waterspouts are generally related to the sea surface, and the likelihood of observation increases with proximity to the coast. Tornadoes primarily form on the sea surface near the coast, and the probability of seeing them decreases rapidly with distance from the coast. On average, tornadoes occur approximately 2 km from the coast.

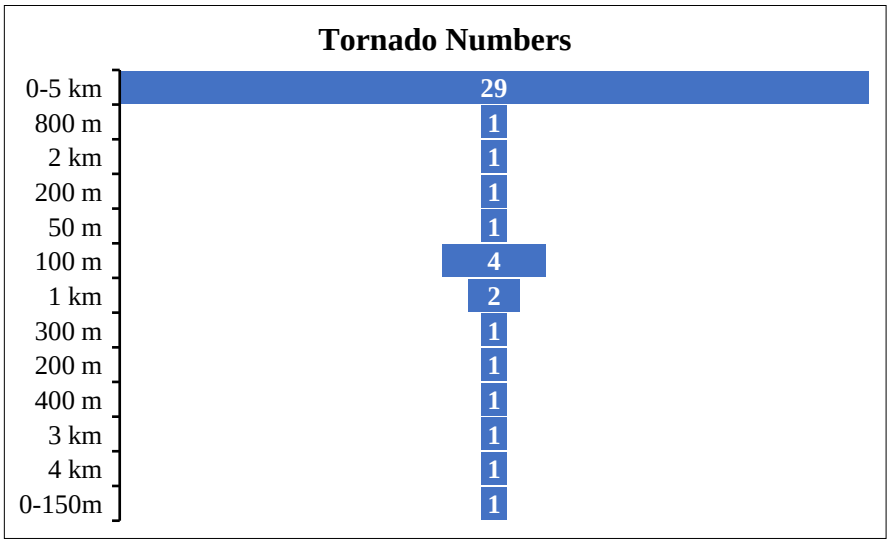


Figure 4. Distribution of tornado distances from the coast

When examining the annual variation in tornado numbers, a slight decrease of about 0.065 tornadoes per year was observed over time. This indicates a small downward trend in tornado numbers. However, this decrease is very minor, and the observed changes are not large enough to constitute a significant trend. Therefore, while there is a slight annual decline in tornado numbers, it cannot be considered statistically significant or a distinct trend (Figure 5). This suggests that changes in tornado numbers follow a more random and irregular pattern.

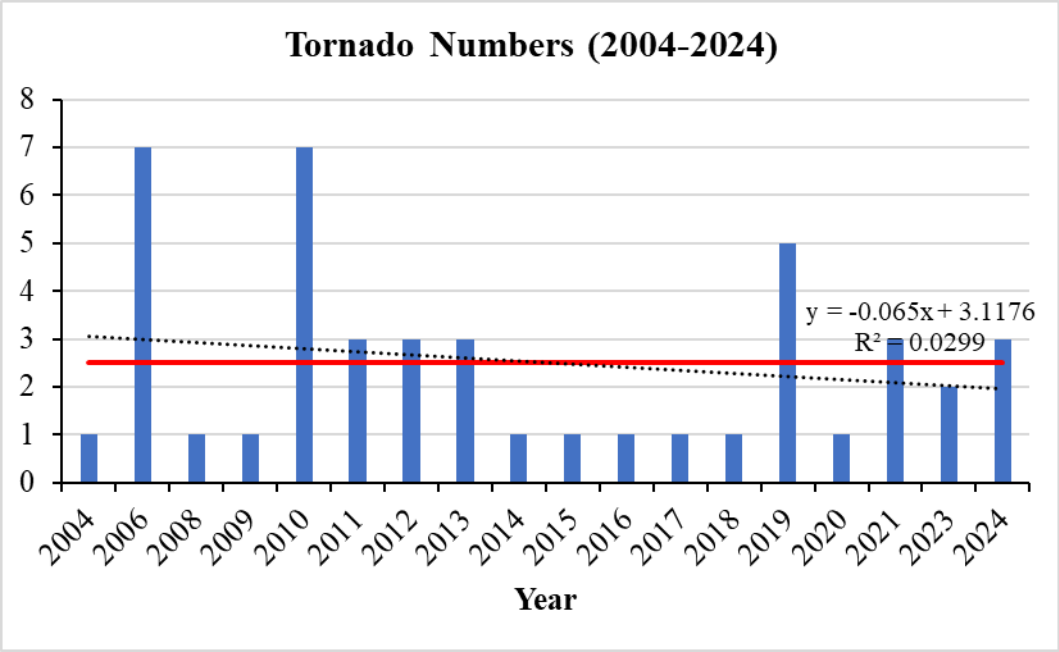


Figure 5. Year-to-year variation in tornadoes

Starting in January, a general downward trend in tornado numbers is observed. This decrease shows significant variability during the summer, with tornado numbers reaching their minimum in August. However, beginning in September, there is a noticeable increase, peaking in October (Figure 6). This suggests that seasonal variations in tornado activity play an important role at different times of the year.

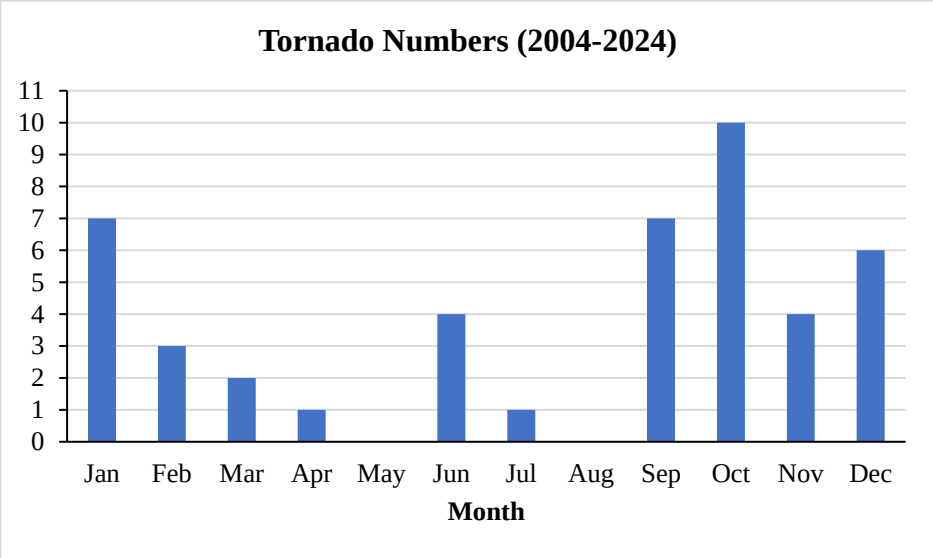


Figure 6. Monthly variation in tornadoes

According to the data, 32 out of 45 tornado observations (71%) occurred at a specific hour. Tornadoes are generally more frequent in the morning. This suggests that high atmospheric instability and energy buildup in the morning promote tornado formation. In the evening and nighttime, tornado frequency decreases as the atmosphere becomes more stable or energy is lost. These findings clarify the distribution of tornadoes at different times of day (Figure 7).

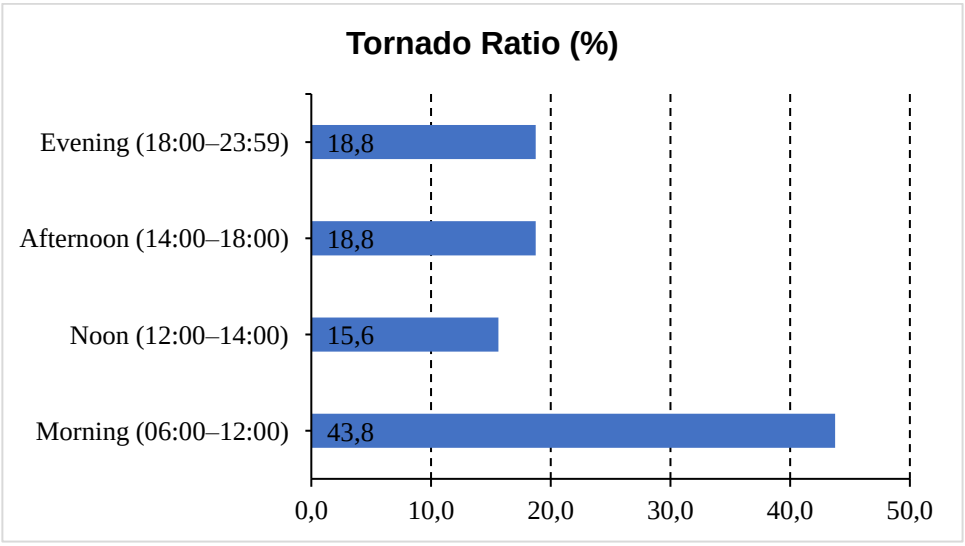


Figure 7. Distribution of tornadoes by different times of day

When examining 10 tornado observations with duration data, the shortest tornado lasted 0.5 minutes (2015), while the longest lasted 15 minutes (2010 and 2019). Since 2012, tornado lifespans have become increasingly longer. The average tornado duration is approximately 8 minutes. The observed duration of tornadoes ranges from 0.5 to 15 minutes. This indicates that tornadoes typically form and dissipate within 30 seconds to 15 minutes, but in recent years, this duration has been increasing (Figure 8).

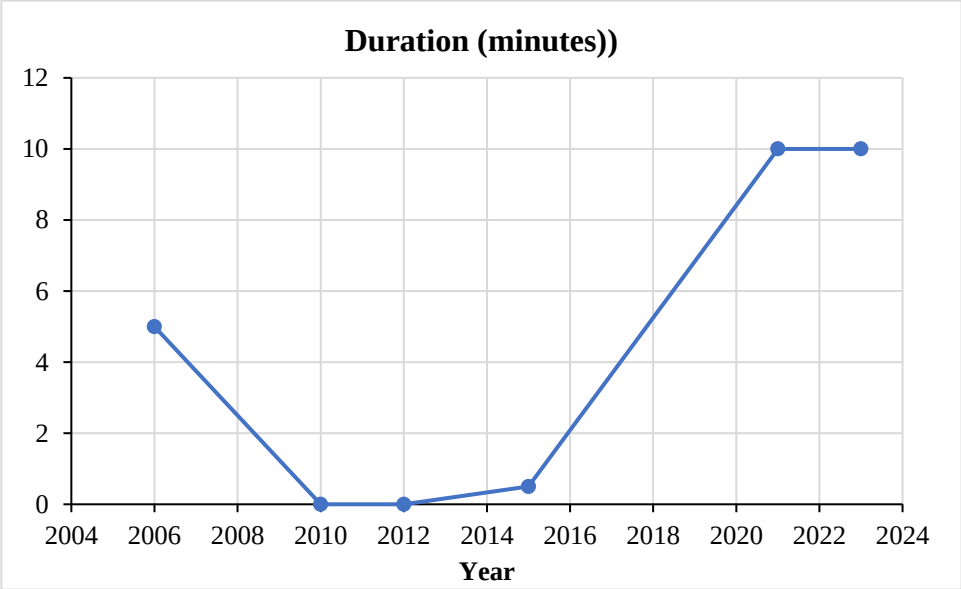


Figure 8. Distribution of tornado durations by year

Tornadoes observed in Alanya between 2004 and 2024 were analyzed in two main periods. In the first period (2004–2014), non-damaging tornadoes were observed more frequently but irregularly, while damaging tornadoes were rare and also showed an irregular distribution. Non-damaging tornadoes were more common in some years and less frequent in others. Damaging tornadoes occurred infrequently (Figures 9 and 10).

In the second period (2015–2024), non-damaging tornadoes became more widespread and regular, while damaging tornadoes increased in some years but generally showed variable frequencies (Figures 9 and 10).

Seasonally, non-damaging tornadoes were most frequently observed in September and October, while damaging tornadoes showed irregular intensity at the beginning of autumn and winter. The heatmap of non-damaging tornadoes reveals a more distinct seasonal pattern, whereas damaging tornadoes display a more scattered distribution (Figures 9 and 10). This suggests that damaging tornadoes are more unpredictable and irregular.

Month	2004	2006	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2023	2024	Total
Jan					2	1								1	1				5
Feb							1												1
Mar																		1	1
Apr																			0
Jun					1														1
Jul														1					1
Sep				1	1														2
Oct	1	1			1						1								4
Nov																			0
Dec						2	1									1			4

Figure 9. Heatmap of tornadoes causing damage by year and month

Month	2004	2006	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2023	2024	Total
Jan					1			1											2
Feb								2											2
Mar																		1	1
Apr														1					1
Jun		1											1						2
Jul																1			1
Sep		2	1		1				1										5
Oct		3					1			1		1					1		7
Nov														1		1	1	1	4
Dec														1					1

Figure 10. Heatmap of tornadoes not causing damage by year and month

4. Conclusion and Recommendations

In this study, the spatial and temporal characteristics of waterspouts that occurred in Alanya between 2004 and 2024 were compiled and analyzed. The findings show that tornadoes in the Alanya region are concentrated in specific areas and display distinct seasonal variations. The 44 waterspout events and 1 landspout event recorded in Alanya over 21 years provide important insights into the distribution of tornadoes across Türkiye.

Most waterspouts in Alanya were concentrated offshore from İncekum and in the neighborhoods of Konaklı, Payallar, and Okurcalar, where more material damage and injuries were reported. Waterspouts in the 500-meter wave-break region and nearby sea areas caused environmental damage, with an average lifespan of 5 minutes. This concentration has been linked to increased tornado frequency in coastal areas during periods of rising sea surface temperatures, as noted by Bayraktar & Çiçek (2022). This suggests that tornadoes are more likely to form when sea surface temperatures are higher. Specifically, the areas where waterspouts form tend to correspond to regions of lower pressure compared to their surroundings, while damaging tornadoes generally form ahead of strong low-pressure systems over the Mediterranean and associated cold fronts.

The fact that tornadoes typically last between 30 seconds and 15 minutes complicates their predictability, highlighting the need for more data collection to improve meteorological forecasts.

Of the tornadoes observed in Alanya, 76.5% occurred on the western side of the Alanya Peninsula, while 23.5% occurred on the eastern side. This spatial distribution indicates that local wind dynamics and thermal differences between land and sea are key factors influencing tornado formation in the region. Regarding seasonal distribution, 49% of tornadoes were observed in the fall and 33% in the winter. The highest number of tornado events occurred in October. This seasonal pattern aligns with findings from Groenemeijer & Kühne (2014) and Bayraktar (2023), which show that most tornadoes in the Mediterranean and Aegean regions occur during the fall (October, November) and winter months.

Although a general decrease in tornado numbers was observed across Türkiye between 2004 and 2024, a notable increase has occurred since 2018. This rise suggests that climate change may significantly affect tornado frequency and intensity. The increase in tornado duration after 2012, along with the occurrence of damaging tornadoes in the wave-break region and nearby sea areas, provides important clues about how environmental factors are altering tornado dynamics.

Thanks and Information Note

The article was prepared in accordance with national and international research and publication ethics. Ethics Committee approval was not required for this study.

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Germination Characteristics of *Nicotiana glauca* Graham

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Abstract

Nicotiana glauca Graham is a fast-growing, poisonous, invasive plant with a cosmopolitan distribution. It continues to invade many areas outside its natural habitat by spreading through various means and self-pollinating. It is also found growing as an exotic species in our country. N. glauca has high toxicity due to its primary alkaloid, anabasine, and all parts of the plant are poisonous to living organisms. It threatens biodiversity by altering the nutrient cycle in the soil, soil properties, and interspecies interactions, and by competing with native species as a result of its allelopathic effect. Given these characteristics, combating this species is a priority. Determining the environmental factors that affect the germination of this species is important for developing effective control methods. There are no studies conducted specifically in Turkey on determining the seed characteristics of this species. In this study, N. glauca seeds were collected from Haykıran Village, Menemen-Izmir, and stored at +4 °C. The 1000-seed weight of the seeds was determined. Germination studies were conducted in germination cabinets at 24 °C under light and dark conditions. The seed and germination characteristics of N. glauca were investigated to establish control of the species. An Independent Samples T-test was applied using SPSS (v27). The 1000-seed weight was found to be 0.0400 g. Germination studies showed that the germination percentage of seeds in light conditions was higher (81.7%).

Keywords: Invasive plant, *Nicotiana glauca*, germination

1.Introduction

Nicotiana glauca Graham exhibits a cosmopolitan distribution due to its tolerance to environmental conditions and aggressive spread (Hernández, 1981; Alharthi et al., 2021). It grows naturally in northwestern Argentina and Bolivia (Goodspeed, 1945; Issaly et al., 2020). It also has an exotic distribution in our country (Hernández, 1981).

N. glauca is a fast-growing and competitive species that grows as a woody shrub or small tree and can reach a height of approximately 6 m (Blamey & Grey-Wilson, 1993; Brandes, 2001). Its hairless leaves are elliptical or lanceolate (DiTomaso & Kyser, 2013; Moore, 1972). The flowers are greenish-yellow in color and appear in numerous loose clusters (Parsons, 1907; Moore, 1972). (Figure 1). The main alkaloid present is anabasine, and all parts of the plant are poisonous (Jeffrey, 1959; Ayenew et al., 2018). The fruits are ellipsoid, 7-10 mm capsules (Blamey & Grey-Wilson, 1993; Moore, 1972). It has a high reproductive and dispersal capacity due to the large number of seeds produced (Hernández, 1981). A single tree can produce up to 1,000,000 seeds per year (DiTomaso & Kyser, 2013). Seeds ripen from September to October (PFAF, 2025). The species self-pollinates or cross-pollinates via

birds, producing abundant viable seeds (Ollerton et al., 2012). The seeds are also adapted to hydrochoric dispersal (Brandes, 2001).

N. glauca anabasin has high toxicity due to its primary alkaloid and is poisonous to living organisms (DiTomaso & Kyser, 2013; Hassen et al., 2014). It has been reported to cause cleft palate formation in offspring during animal pregnancy and poisoning when consumed; poisoning in humans due to unconscious consumption and indiscriminate collection with other plants, sudden respiratory failure, impaired skeletal muscle homeostasis, increased menopausal effects, and acute toxicity upon skin contact (Panter et al., 2000; Furer et al., 2011; Ntelios et al., 2013; Musso et al., 2019; Kear et al., 2020). An example of this situation in our country is a case of difficulty breathing due to unconscious consumption (Yalçınlı & Kıyan Güçlü, 2018).

N. glauca is an invasive exotic species that threatens biodiversity by competing with native species (Ayenew et al., 2018; Profiro & Braga, 2020). Its high water consumption harms native species and negatively affects local plant growth and distribution by altering nutrient cycling in the soil, soil properties, and species interactions (Brandes, 2001; Profiro & Braga, 2020; Assaeed et al., 2021). They displace native species, leading to erosion and flooding (DiTomaso & Kyser, 2013). In Mediterranean ecosystems, they disrupt soil mycorrhizal functions, contributing to increased degradation (Rodríguez-Caballero et al., 2020).

N. glauca has an allelochemical effect on native species, adversely affecting biodiversity. It has been reported to have an allelopathic effect on the germination and seedling growth of *Medicago sativa* L., *Triticum aestivum* L., and *Juniperus procera* (Alshahrani, 2008; El-Kenany et al., 2017).

It is classified as invasive due to its adaptability to changing environments, its role as a pioneer species in degraded areas, its rapid growth, and its high reproductive potential (Vélez-Gavilán, 2023). It has been used as an ornamental plant in many countries in the past and has spread in frost-free arid and semi-arid regions (Hernández, 1981; Brandes, 2001). In this context, it has settled uncontrollably in a wide range of habitats, including building ruins, roadsides, abandoned areas, courtyards, dunes, historic building walls, degraded areas, urban waste areas, quarries, landscaped areas, riverbanks, meadows, and wooded areas, in the form of ruderal shrubs or trees (Brandes, 2001; Pérez, 2009; DiTomaso & Kyser, 2013). Due to these negative characteristics, attention has been drawn to the need to combat this species (Ayenew et al., 2018; Profiro & Braga, 2020; Sayari et al., 2021).

Mechanical, cultural, biological, and chemical control methods are available for weed control. It has been stated that mechanical control cannot be used due to regrowth, cultural control cannot be used due to regrowth and toxicity in grazing, and biological control cannot be used as there is no biological agent available yet. However, it has been indicated that successful results can be achieved with chemical control using glyphosate, triclopyr, and imazapyr herbicides (Venegas & Pérez, 2009; DiTomaso & Kyser, 2013).

The cosmopolitan and invasive *N. glauca* continues to spread in Turkey (Hernández, 1981; Profiro & Braga, 2020). Determining the ecological and physiological characteristics of *N. glauca* is important for developing effective control methods (Florentine et al., 2006; Batlla & Benech-Arnold, 2014). The lack of information on environmental factors affecting the germination characteristics of *N. glauca* seeds makes it difficult to develop effective control methods for the species (Florentine et al., 2016). Although there are studies in the literature

on determining seed characteristics, there is no study specific to Türkiye. Within this scope, the study investigated the effects of light and temperature factors on the germination of *N. glauca* seeds. The seed characteristics of *N. glauca* were also examined in the study as a basis for controlling the species.

2. Materials and Methods

Materials

In this study, mature seeds of *N. glauca* were collected in 2024 from Haykıran Village, Menemen-Izmir, and stored at +4 °C in Eppendorf tubes (Figure 1). A digitally controlled germination chamber (Lovibond TC 140 G-Liebherr, Dortmund/Austria) and an analytical balance (Radwag AS 220.R2, Radom/Poland) were used to determine seed characteristics and for germination studies.



Figure 1. N. glauca seed collection area and flowers

Method

Removing and storing seeds

The *N. glauca* seeds used in the study were collected during the ripening period. The seeds from the dried capsules were transferred to Eppendorf tubes after sorting and cleaning and stored at +4 °C (Figure 2).



Figure 2. Dried *N. glauca* capsules

Weight of 1000 seeds and germination

According to STA (2021) rules, randomly selected seeds were mixed, and the 1000-seed weight was calculated using Equation 1 based on 800 (8x100) seeds.

$$1000\text{-}unit\ weight = \left(\sum x_i/8\right) \times 10$$ Equation (1)

x_i : Average of repetitions

Germination tests were conducted in germination chambers at 24 °C under light and dark conditions (Brandes, 2001; Intrieri et al., 2004; Florentine et al., 2006; Fabricante et al., 2015; Florentine et al., 2016). For each randomly selected treatment from the samples, 400 seeds (100*4 replicates) were used according to the Randomized Block Design with 1 origin (Izmir) at 1 different temperature level (24 °C), 2 different light levels (light-dark), and 4 replicates, totaling 8 (1*1*2*4) experimental units (petri dishes). To slow evaporation, the Petri dishes were covered with transparent stretch film (Baskin & Baskin, 2014). The seeds were checked every 2 days for 28 days, and distilled water was added to those lacking moisture. Seeds with roots exceeding 2 mm and showing geotropism were considered germinated (Fabricante et al., 2015). The germination percentage (GP) was calculated using Equation 2, and the average germination time (AGT) was calculated using Equation 3 (Baskin & Baskin, 2014).

$$ÇY(\%) = \left(\sum n_i/N\right) \times 100$$ Equation (2)

$ÇY$: Germination Rate (%)

n_i : i. number of sprouts per day (count)

N : Total number of seeds tested (pieces)

$$OÇS = \left(\sum (t_i \times n_i)\right) \div \left(\sum n_i\right)$$ Equation (3)

$OÇS$: Average germination time (days)

t_i : The time elapsed since the start of the test (days)

n_i : t_i number of seeds germinating per day (count)

Statistical Analysis

An arc-sin transformation was applied to the germination percentage values obtained as a result of seed germination. The transformed data were subjected to an Independent Samples T-test using SPSS (v27). The significance level is 0.05.

3. Findings and Discussion

1000-piece weight

Studies indicate that the average weight of seeds is 0.0685 g and that 25 seeds weigh 0.0001 mg (Brandes, 2001; Barakat et al., 2019). In our study, the weight of 1000 seeds were found to be 0.0400 g. The ability of seeds to adapt to various conditions and spread through various means such as birds, water, humans, animals, wind, and gravity, as well as their very small size and light weight, increase their invasion capacity (Ollerton et al., 2012; Hernández, 1981; Brandes, 2001).

Seeding

The germination of *Nicotiana* seeds varies from species to species depending on light requirements. Some species require light for germination and can only germinate in the dark after specific stratification processes; other species do not require light and can germinate in the dark. In this context, light and temperature are environmental factors that have a significant effect on the germination of *N. glauca* seeds (Honing, 1930; Florentine et al., 2006; Florentine et al., 2016). It has been stated that a constant temperature of 25 °C in light and dark environments is favorable for germination in *N. glauca* seeds, which show tolerance to varying temperature ranges (Honing, 1930). In this study, germination experiments were conducted at 24 °C under light and dark conditions to determine the germination characteristics of N. glauca seeds.

At the end of the germination period, the germination percentages and average germination times of the seeds were found to be 81.7%–6.6 days in light conditions and 70.0%–10.3 days in dark conditions, respectively. Accordingly, it was determined that seeds in light conditions had a higher germination percentage and a lower germination time. The low germination period indicates a higher germination rate of the species in light conditions (Baskin & Baskin, 2014). In the literature, germination percentages were 100% in Brandes (2001) at 20 °C/15 °C day-night application, close to 100% in Florentine et al. (2016) at 30/20 °C with a 12-hour/12-hour light/dark combination, Fabricante et al. (2015) found 95% at a constant temperature of 25±1 °C, and Machado et al. (2008) found 84% with gibberellic acid application to pre-washed seeds.

The T-test revealed a significant difference between germination percentages (Table 1).

Table 1. T-test in N. glauca seeds

	Levene's Test for Equality of Variances		t-test for Equality of Means						
	F	Sig.	t	df	Sig. (2-tailed)	Mean Diff.	Std. Error Diff.	95% Confidence Interval of the Difference	
								Lower	Upper
Eq. variances assumed	,213	,660	2,589	6	,041	8,01000	3,09348	,44053	15,57947
Eq. variances not assumed			2,589	5,982	,041	8,01000	3,09348	,43513	15,58487

In some species, seeds germinate more readily in light than in darkness (Baskin and Baskin, 2014). The higher germination percentage obtained in light conditions in our study is consistent with studies in the literature (Intrieri et al., 2004; Florentine et al., 2006; Florentine et al., 2016).

It has been observed that the color of cotyledons formed in germinating seeds is pale yellowish green in dark conditions and green in light conditions (Figure 3). This can be explained by the fact that seedlings growing in the dark form small, non-green cotyledons as

a result of a negative relationship between germination in the dark and the amount of chlorophyll in the tissues during seed maturation (Cresswell & Grime, 1981; Sajib et al., 2023).

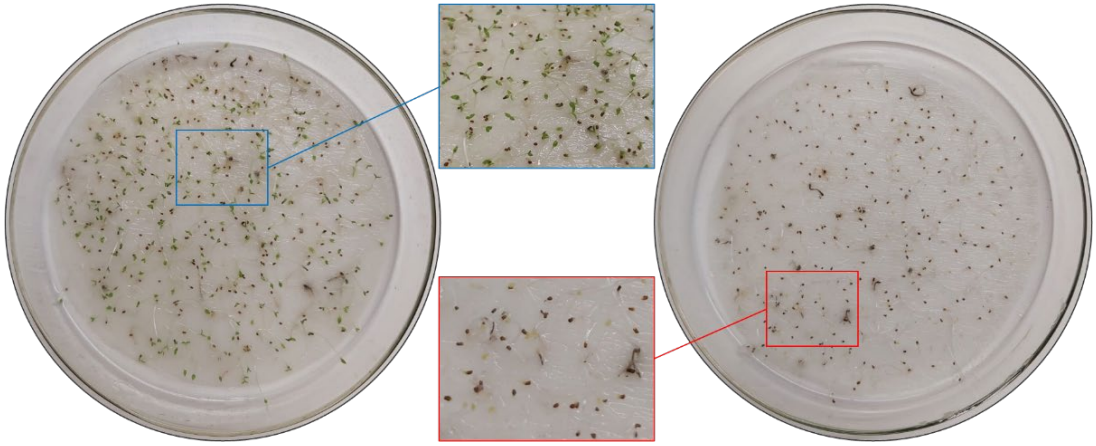


Figure 3. Germinating seeds: light environment (left), dark environment (right) (15th day of the test)

4. Conclusions and Recommendations

To effectively control invasive plants, it is necessary to understand the environmental factors that influence their germination. *N. glauca* is an invasive plant that threatens biodiversity. It is also found in temperate regions of our country. In this study, the 1000-seed weight of *N. glauca* seeds was determined. In addition, the effect of light and dark environments at a temperature of 24 °C on germination was investigated. The 1000-seed weight of the seeds was found to be 0.0400 g. As a result of the germination studies, a higher germination rate (81.7%) was obtained in the light environment. It was observed that the cotyledons did not turn green in the dark environment.

Given the invasive nature of *N. glauca*, which is widespread in our country, studies should be conducted on the ecological and physiological characteristics of the species to determine its distribution and take proactive measures to combat it. Due to the toxicity of *N. glauca*, target groups such as livestock farmers, herbalists, environmental associations, and consumers should be made aware of the issue.

Thanks and Information Note

The article complies with national and international research and publication ethics. All authors contributed equally to the article.

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Effects of Improper Pruning on Urban Ecosystems: A Case Study from Van

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Abstract

Pruning is a fundamental maintenance practice that directly influences the healthy development of ornamental plants and the functioning of urban ecosystems. However, unskilled or improper pruning can lead to irreversible damage in plant physiology and disrupt essential ecosystem services in cities. This study aims to identify and classify the most common pruning mistakes observed in Van province, present illustrative examples, and propose solutions from the perspective of urban ecosystem management. Field observations were conducted through on-site visual inspections and photographic documentation. The pruning errors were categorized under five main headings: timing errors, form-deforming cuts, unnecessary or excessive pruning, incorrect branch selection, and tool-related damages. The findings revealed that such mistakes negatively impact plant vitality and urban ecosystem balance, reduce flowering performance, and increase susceptibility to diseases. In conclusion, the study emphasizes that pruning practices should be performed by qualified experts to ensure sustainable urban landscape and ecosystem management, and suggests localized guidelines for improved pruning in Van's urban environments.

Keywords: Pruning errors, ornamental plants, urban ecosystem, Van, maintenance techniques.

1. Introduction

Plant material is among the fundamental components of landscape architecture, carrying aesthetic, functional, and ecological value. To sustain plant design in a healthy manner and preserve the vitality of landscape spaces, sustainable maintenance practices are essential. Within these practices, pruning is more than an aesthetic operation; it is a technical intervention that respects the physiological needs of the plant (Brickell & Joyce, 2017; Mikolajski, 2012).

In general terms, pruning is a systematic procedure aimed at removing unwanted, dead, diseased, senescent, or crossing branches to promote balanced and healthy plant development. Through appropriate pruning, plants maintain their aesthetic form and benefit more effectively from environmental factors such as light, air, and water (Hobson, 2007). Especially today—when urbanization and building density are increasing—regulatory

practices like pruning are increasingly needed to ensure that ornamental plants can continue their growth in a controlled way.

Pruning also constitutes a deliberate intervention in a plant's natural form and directly affects growth, development, flowering, and fruiting processes. The appropriate method varies according to plant species, age, season, and environmental conditions. When performed at the right time and with the right technique, pruning protects plant health, strengthens aesthetic form, and enhances harmony with the surrounding environment (HP Trade, 1989).

In landscape applications using ornamental plants, pruning is a key tool for maintaining spatial order, establishing visual foci, and ensuring that spaces present a tidy appearance throughout all four seasons (Önder & Akbulut, 2011). However, pruning influences not only individual plant health but also the functioning of the urban ecosystem and the ecosystem services it provides.

Although pruning is carried out for diverse purposes, serious errors may occur due to lack of technical knowledge, poor timing, improper cutting techniques, or the use of methods unsuitable for the species. Such mistakes can lead to short-term aesthetic deterioration, long-term declines in plant health, and weakening of urban ecosystem sustainability (Mikolajski, 2012). In practice, common pruning errors include out-of-season pruning, topping (when topiary is not intended), overly frequent or excessive pruning, misuse of tools, and failure to protect wound surfaces. These errors result in problems such as form distortion; reduced or lost flowering; dieback and increased fungal diseases; and declines in key urban ecosystem services, including shading, microclimate regulation, and carbon sequestration (Hobson, 2007).

Applied with correct technique and knowledge, pruning supports healthy plant development. Conversely, improper practices cause significant disruptions both in plant physiology and in urban ecosystem functions.

Situated in a continental climate zone, the province of Van experiences hot, dry summers and long, harsh winters. These climatic characteristics make ornamental plants particularly vulnerable to external stressors. Frost risk, drought, UV radiation, and sudden temperature fluctuations are among the principal environmental factors that increase plant stress. In this context, accurately determining pruning time and applying techniques suited to local climate conditions are of critical importance. Moreover, the impacts of pruning mistakes should be considered not only at the individual plant level but also in terms of their adverse effects on the integrity of Van's urban ecosystem.

2. Materials and Methods

This study aims to identify pruning errors observed on ornamental plants in the province of Van and to analyze their impacts on plant physiology, aesthetics, and landscape integrity. It also seeks to contribute to the dissemination of sustainable pruning practices within the discipline of landscape architecture.

Study design. The research follows a mixed, practice-oriented design comprising field observations, visual documentation, expert consultations, and literature-based analysis, as outlined below:

- **Field surveys.** Photographic, on-site observations will be conducted in areas with dense ornamental plantings, including Van Merkez (central district), Edremit, and Tuşba.
- **Visual documentation.** Pruning errors on different plant species will be recorded and classified, with "before–after" comparisons where feasible.
- **Expert opinions.** Semi-structured interviews will be carried out with landscape architects, agricultural engineers, and municipal maintenance teams.
- **Analysis.** The collected evidence will be evaluated against the relevant literature to assess the causes and consequences of pruning errors.

Beyond diagnosing current problems, the study aims to support improvements in practice by proposing recommendations at the levels of training, regulation, and implementation, thereby contributing to enhanced landscape quality in Van.

3. Results

3.1. Pruning Errors Observed on Ornamental Plants in Van

Pruning practices on street trees and ornamental plantings are frequently carried out ad hoc—driven by immediate needs and on-site constraints—rather than under a planned landscape management strategy. Field observations in Van indicate that pruning errors stem from three primary sources:

3.1.1. Errors Driven by Power Transmission Lines

The interweaving of urban power lines with median strips, parks, sidewalks, and residential frontages increases the risk of contact between trees and electrical infrastructure. To mitigate this risk, pruning is often performed untimely, haphazardly, and in violation of arboricultural principles. While such interventions may appear to reduce safety concerns in the short term, they negatively affect plant physiology over the long term, distort canopy architecture, and create conditions conducive to stress-induced pest and disease outbreaks (Harris, Clark & Matheny, 2004).

3.1.2. Errors Stemming from Urban Planning Constraints

Van's urban fabric—characterized by narrow streets and intersections—restricts the growing space of trees. As maturing canopies obstruct shopfronts, signage, or sightlines, requests submitted by business owners to relevant authorities often lead to pruning decisions guided by short-term user satisfaction rather than by principles of urban forestry. This approach deforms natural tree form, diminishes aesthetic value, and limits ecosystem services such as shading and microclimate regulation.

3.1.3. Errors Due to Gaps in Physiological and Species-Level Knowledge

Field personnel responsible for pruning frequently lack sufficient knowledge of species' morphological traits and physiological needs, leaving practices to individual discretion. This knowledge gap leads to arbitrary pruning detached from technical standards. When species-specific growth habits are ignored, branch balance is disrupted, wood decay is promoted, and plant life span is shortened.

3.1.4. Errors in Pruning Timing (Early vs. Late)

In continental climates such as Van, pruning timing is critical for plant health. The optimal window is generally mid-winter to late winter, when plants are fully dormant and before early spring bud-break. However, observations show that pruning often disregards this biological rhythm.

- **Early pruning.** When conducted in late autumn or early winter—before full dormancy—active sap flow may be disrupted. Wounds remain exposed longer and tissues become vulnerable to low temperatures, frost, and desiccating winds. Consequently, increased frost cracks, cambial injury, and branch dieback have been recorded in regional plantings.
- **Late pruning.** When performed after bud-break in spring or during the active growing season, pruning significantly depletes plant energy reserves. Cuts made during flowering and leaf-expansion reduce photosynthetic capacity, lower flower and fruit yield, and predispose plants to pests and diseases under stress. Moreover, heavy pruning during this period often triggers "water-sprout"/epicormic shoot flushes, degrading natural crown form and increasing long-term maintenance costs.

4. Conclusions and Recommendations

Systematic observations in Van, combined with comparisons to the literature, indicate that current pruning practices in urban ecosystem management contain substantial deficiencies in knowledge, planning, and implementation. In particular, the neglect of species-specific physiological traits, improper timing, and the prioritization of aesthetic concerns over ecological realities lead to severe degradation of plant health, a decline in urban ecosystem services, and the emergence of an artificial landscape appearance.

The findings further show that pruning errors are not limited to individual operator mistakes; at the institutional level, gaps in training, supervision, planning, and monitoring help entrench these errors. The consequences extend beyond plant health to the integrated functioning of urban ecosystems. For example, prematurely senescing plants lose their natural shading function; bird habitat diminishes; and carbon sequestration capacity declines. This weakens urban ecosystem services—such as microclimate regulation, biodiversity support, and carbon storage—and results in inefficient use of public resources.

A core result of this study is that pruning in Van is often conducted according to generic rules of thumb rather than species-appropriate standards. Applying the same geometric forms to different species disrupts natural growth rhythms. In this regard, Brickell and Joyce (2017) emphasize that species-appropriate pruning is essential not only aesthetically but physiologically; Mikolajski (2012) underscores the need to account for each plant's biological cycle before pruning. Field evidence suggests that these principles are not yet sufficiently applied in Van.

Bringing together the literature-based analysis and the local field findings, the following integrated recommendations are proposed for a sustainable, science-based pruning regime:

1. **Expand Training and Certification Programs**

   Local authorities and practitioners should implement comprehensive pruning curricula that combine theory with live, hands-on demonstrations. Programs must cover technical,

aesthetic, and ecological principles. A certification system should be instituted, and uncertified personnel should not be allowed to prune in public spaces.

2. **Prepare Species-Specific Pruning Guides**

   Pruning manuals tailored to Van's climate, soils, and native/commonly used flora should be produced and made accessible to municipal units, landscape firms, and professional bodies. Guides should incorporate flowering phenology, dormancy periods, and disease susceptibility as physiological parameters.

3. **Adopt Timing-Sensitive Pruning Calendars**

   To prevent timing errors critical to plant health, species- and site-specific pruning calendars should be established and followed in the field. Pruning should be avoided during periods with frost risk; winter pruning must be carried out only under expert supervision.

4. **Establish Supervision and Monitoring Mechanisms**

   The effectiveness and outcomes of pruning—and their effects on ecosystem services—should be assessed regularly. A municipal "Landscape Monitoring and Evaluation Unit" can maintain digital visual records, integrate citizen reports, conduct field audits, and publish periodic performance reviews.

5. **Increase Public Awareness**

   Communication should highlight that pruning has ecological and ecosystem-level consequences beyond aesthetics. Informational campaigns—posters, social media, local media—can improve public understanding and support for correct practices, helping cities achieve both visual quality and biological sustainability.

6. **Balance Ecological and Aesthetic Objectives**

   Pruning decisions must be evaluated through the lens of ecosystem services—biodiversity, microclimate, carbon sequestration, wildlife support—not solely visual order. In some locations, allowing more natural forms can benefit biodiversity; the goal should shift from a uniformly "manicured" look to "ecological fit."

In conclusion, the pruning assessment conducted for Van offers a transferable model for cities in Türkiye with similar climatic and floristic conditions. Sustainable urban ecosystem management is only possible with an approach that respects nature, is grounded in scientific knowledge, and balances aesthetic and ecological aims. Actions taken within this framework will directly shape not only today's landscapes but also the urban ecosystem quality bequeathed to future generations.

Thanks and Information Note

The article complies with national and international research and publication ethics. All authors contributed equally to the article.

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Topiary Art as A Tool for Developing Urban Identity and Tourism Potential in Van

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Abstract

Green spaces—and the aesthetic and functional contributions of their elements—play as crucial a role in shaping urban identity as cultural heritage, collective memory, lived experience, and natural features. In this context, topiary—the art of pruning plants into sculptural forms—has emerged as a striking practice in both historical and contemporary urban landscapes. This study examines how topiary can contribute to the urban identity and tourism potential of the city of Van. Rooted in Ancient Rome, topiary today features prominently in global exemplars such as Versailles and English gardens, where it serves simultaneously as a marker of cultural identity and a draw for visitors. Although Van boasts powerful cultural and natural assets—Lake Van, Van Castle, Akdamar Church, and the Van Cat—these identity cues are not yet sufficiently reflected in its existing urban green spaces. The research employs literature review, global and local case studies, current-state analysis, and design proposals. Findings indicate that topiary can endow Van's urban landscape with distinctiveness, aesthetic value, and ecological function; further, when integrated with local symbols, it can strengthen residents' sense of belonging. The study concludes that targeted topiary installations at city gateways, squares, and tourist focal points could enhance Van's brand value and increase its appeal as a destination.

Keywords: Topiary art, urban identity, cultural landscape, tourism potential, landscape architecture, urban green space.

1. Conceptual Framework: The Role of Urban Identity and Green Spaces

Cities are not merely settings for shelter and economic activity; they are identity fields where societies project cultural, social, and aesthetic values. An urban identity is shaped by historical heritage, the natural environment, socio-cultural structure, and approaches to planning, design, and management. The principal arenas where these identity components become visible and experiential are public open and green spaces (Lynch, 1960). Parks, squares, promenades, and thematic gardens function as focal points where residents gather, strengthen their sense of belonging, and construct the city's visual memory.

In the landscape architecture context, green spaces carry not only ecological and functional value but also contribute to urban identity through aesthetic and symbolic dimensions (Maciocco, 2008; Bianconi & Filippucci, 2019). Street furniture, sculptures, planting design, and artistic practices such as topiary emerge as visual elements that reinforce a place's character. While these components visually define urban identity, they also deepen users' perception and experience of space (Henckel, Thomaier, Könecke, Zedda, & Stabilini, 2013).

The role of art in urban landscapes extends beyond aesthetics. By conferring recreational value and improving environmental and life quality—along with touristic appeal—art supports sustainable development policies. In particular, cultural-landscape interventions and artistically designed green spaces create attractions for visitors and bolster residents' pride and sense of belonging (Durey, 2023; Pizzi & Weiss-Sussex, 2011). Within this frame, topiary integrated into landscape settings should be seen not only as a support for identity formation but also as a tool for enhancing tourism potential.

Topiary—defined as the artistic shaping of plants through pruning and training—traces its origins to Ancient Rome. As noted by Pliny (1st century CE), Roman villa gardens conceived topiary as "living sculptures" (Ruemler, 2004). Using species such as cypress and boxwood, geometric and figurative forms served not only aesthetic aims but also signified power, order, and cultural prestige (Brook & Brady, 2003).

Persisting in medieval monastic gardens, topiary reached a zenith during the Renaissance and Baroque periods. In the 16th and 17th centuries, aristocratic gardens in Italy and France produced some of the most emblematic examples of the art (Hadfield, 1971). From this era onward, topiary evolved from a horticultural practice into a cultural signifier and an integral component of urban aesthetics.

One of the strongest demonstrations of topiary's contribution to identity and tourism is the Gardens of Versailles in France. Designed by André Le Nôtre, these gardens—through geometric compositions and symbolic plant forms—offer an aesthetic experience while serving as a cultural emblem of French monarchical grandeur (Pizzi & Weiss-Sussex, 2011). Now inscribed on the UNESCO World Heritage List, Versailles welcomes millions of visitors annually, illustrating the tight integration of topiary and tourism.

English gardens, by contrast, developed a more naturalistic and romantic interpretation of topiary. From the 17th century onward, places like Levens Hall have preserved topiary collections that blend with rural aesthetics, functioning as both elements of cultural memory and significant tourist attractions (Brook & Brady, 2003). Together, these examples show that topiary is a multidimensional urban art form that yields aesthetic, economic, and cultural benefits.

Today, topiary is used across cities on every continent—from Europe to Asia, Africa to the Americas—in thematic parks and tourist precincts. In doing so, it supports urban identity and acts as a universal component of cultural landscapes (Njoku, 2020; Rashidova & Lapteva, 2023).

Located in eastern Türkiye, Van is a city with strong natural and cultural assets that shape a robust regional and national identity. Lake Van—the world's largest soda lake—provides not only ecological value but also the city's principal tourism anchor (Gürbüz, 2012). The natural landscapes around the lake serve as recreational foci for residents and as aesthetic–cultural magnets for visitors.

Van's historical fabric is equally rich. Van Castle and Akdamar Church are among the most important heritage sites reflecting the city's multilayered past, conferring a distinctive character (Şahin & Alp, 2010). The Van Cat has become a cultural icon that enhances the city's recognition nationally and internationally (Altunok et al., 2011). Collectively, these features attest to Van's strong geographic, historical, and cultural identity.

Yet these identity cues are not sufficiently reflected in the city's green spaces. Parks, squares, and roadside plantings often consist of ordinary, non-distinctive layouts, showing limited integration with local symbols (Sevik & Çetin, 2016). As a result, opportunities to strengthen urban identity and enhance tourism potential remain underutilized (Bianconi & Filippucci, 2019).

In this context—given its Roman roots and successful deployment in global exemplars such as Versailles and English gardens—topiary emerges as an innovative solution for Van (Brook & Brady, 2003; Ruemler, 2004). By combining aesthetic and symbolic value, topiary has the potential to bring distinctiveness to green spaces that currently lack identity.

Aim of the article. This study proposes integrating topiary with Van's cultural motifs (the Van Cat, carpet patterns, tulip forms) to enhance the quality and identity of urban green spaces (Durey, 2023; Pizzi & Weiss-Sussex, 2011). In this way, the urban landscape becomes not only a recreational realm but also a cultural venue bearing identity and tourism value.

Application framework. Proposed topiary interventions can be implemented at city gateways, main squares, and tourist focal points (Van Castle, Akdamar, Lake Van waterfronts). Designs integrated with local motifs are expected to elevate the city's brand value and create a strong attraction for both residents and visitors.

2. Materials and Methods

This research employs a qualitative-dominant design to examine how topiary art can contribute to urban identity and tourism potential in the city of Van. The study proceeds in four stages:

2.1. Literature Review

First, a comprehensive review was conducted on the historical development of topiary, global applications, and the nexus between urban identity and tourism. Both classical works (e.g., Lynch, 1960; Hadfield, 1971) and recent academic studies (Brook & Brady, 2003; Sevik & Çetin, 2016; Rashidova & Lapteva, 2023) were examined to establish the theoretical foundation. The review also situates Van's green-space issues within a global frame of reference.

2.2. Case Studies (Global and Local)

Second, global exemplars where topiary supports urban identity and tourism—such as the Gardens of Versailles, English gardens like Levens Hall, and contemporary mosaiculture—were analyzed to distill transferable design principles and good-practice criteria for Van. Selected Turkish examples, though limited, were also reviewed, alongside an assessment of local public perceptions, to extract context-specific insights.

2.3. Current-State Analysis

Third, the condition of Van's urban green spaces was evaluated through direct observation, photographic documentation, and content analysis. Parks, squares, roadside landscapes, and tourist precincts were examined for aesthetic, functional, and identity dimensions. Findings indicate that these areas often display standardized, non-distinct layouts with limited integration of local symbols. On this basis, leverage points for topiary interventions were identified.

2.4. Design Proposals

Finally, insights from the literature review, case studies, and current-state analysis were integrated to formulate Van-specific topiary design proposals. These include forms inspired by local cultural symbols—such as the Van Cat, traditional carpet motifs, and the inverted tulip. The proposals are envisioned for strategic locations (city gateways, main squares, and tourist focal areas), with the expectation that they will enhance urban identity and increase tourism appeal.

3. Findings

3.1. Plant Species Used

Success in topiary depends on selecting dense-foliaged, finely branching, evergreen, and pruning-tolerant species (Ruemler, 2004). Van—situated in Eastern Türkiye—has a continental climate with long, cold winters, dry summers, and high diurnal/seasonal temperature ranges. These conditions are decisive for plant selection in urban green spaces. Species chosen for topiary must therefore combine pruning tolerance with adaptation to Van's climatic extremes (Alp, 2007).

Suitable species

1. *Buxus sempervirens* L. boxwood / common box/ Şimşir

• **Traits:** Small leaves, tight texture, slow-growing evergreen shrub.

• **Suitability:** Cold-hardy under Van's continental conditions; the classic choice for formal topiary.

• **Use:** Geometric forms in parks, plazas, and ceremonial entrances.

2. *Taxus baccata* L. English yew/ Porsuk

• **Traits:** Evergreen, shade-tolerant, long-lived; dark green foliage with refined texture.

• **Suitability:** Performs best in sheltered urban sites in Van; highly tolerant of pruning—good for detailed, figurative work.

3. *Ligustrum vulgare* L. wild/European privet/ Adi Kurtbağrı

• **Traits:** Fast-growing, densely branching shrub with high pruning tolerance.

• **Suitability:** Cost-effective, durable option for medians and roadsides in Van.

• **Use:** Hedges, edging, and simple geometric topiary.

4. *Cupressus sempervirens* L. Italian cypress/ Servi

• **Traits:** Narrow, columnar, emblematic conifer.

• **Suitability:** Serves as a strong identity marker in religious, historic, and touristic settings.

• **Use:** City gateways, memorial landscapes, historic precincts.

5. *Juniperus* spp. junipers/ Ardıç

• **Traits:** Evergreen, drought-tolerant, with diverse forms and textures.

• **Suitability:** Well adapted to Van's dry summers.

• **Use:** Functional and aesthetic roles across streetscapes and open spaces.

6. *Berberis thunbergii* DC. Japanese barberry/ Kızamık Çalısı

• **Traits:** Seasonal color variation adds visual richness.

• **Suitability:** Though only moderately suited to topiary shaping, it contributes strong color/texture contrasts in parks and gardens.

In sum, climatic hardiness, pruning compatibility, and aesthetic diversity guided species selection for Van. Boxwood and yew are the strongest candidates for classical topiary; privet and Italian cypress provide functional and symbolic contributions in public realms; junipers and Japanese barberry offer climate-fit alternatives that enrich texture and color.

3.2. Aesthetic, Ecological, and Socio-Cultural Functions

Topiary's leading contributions to Van can be articulated in three dimensions:

- **Aesthetic functions.** Geometric forms, figurative "living sculptures," and animal silhouettes heighten visual appeal in urban settings. For Van, proposed motifs include the Van Cat, *Tulipa sylvestris* L. (Van lalesi), *Fritillaria imperialis* L. (crown imperial), and the Lake Van silhouette, which materialize local cultural memory in space (Brook & Brady, 2003).
- **Ecological functions.** Dense foliage can mitigate noise, modulate microclimate, and improve air quality; in streets and squares, topiary plantings can also provide shading and wind attenuation (Sevik & Çetin, 2016).
- **Socio-cultural functions.** In botanic gardens, event venues, and tourist hotspots, topiary generates identity and brand value, contributing to the urban economy. In Van, this role is expected to be most pronounced around Akdamar Island approaches, Van Castle forecourts, and similar destinations (Njoku, 2020).

4. Contemporary Practices and Potential for Van

In recent years, topiary has moved beyond aristocratic gardens and become commonplace in shopping centers, hotel landscapes, city parks, and tourist attractions (Rashidova & Lapteva, 2023). Mosaiculture—using climbers and bedding plants trained over steel armatures—offers alternative techniques to traditional pruning, delivering faster and often more impactful results.

For Van, our assessment indicates the following priority settings for application:

- **City gateways:** "Welcome" compositions and Van Cat figures that elevate brand value.
- **Squares and promenades:** Geometric forms and cultural symbols integrated with local motifs.
- **Tourist precincts:** Aesthetic interventions reflecting local identity along the Lake Van waterfront, around Akdamar Island, and at the Van Castle environs.

- **University campuses and parks:** Especially the Van Yüzüncü Yıl University shoreline, which can serve as a pilot zone for identity-expressive designs.

5. Discussion: Contributions to Aesthetics and Identity Formation

Topiary adds a distinctive, dynamic visual appeal to urban landscapes. Plant compositions designed as geometric forms, animal figures, or cultural emblems can transform ordinary green spaces into unique aesthetic venues (Ruemler, 2004). In Van, topiary installations in parks and squares would introduce an artistic layer to an otherwise monotonous landscape palette, thereby enhancing the city's visual quality.

A central contribution of topiary is the materialization of place-specific values. Interpreting Van's symbols—such as the Van Cat, the inverted tulip, or carpet motifs—in living plant form makes local identity visible and strengthens belonging. This deepens residents' emotional bond with urban spaces and supports the internalization of space as "place" (Lynch, 1960; Pizzi & Weiss-Sussex, 2011). In this sense, topiary functions not merely as a landscape aesthetic, but as a tool for identity building.

Iconic, attention-grabbing landscape elements are also fundamental to tourism differentiation and attraction. World-renowned exemplars like the Gardens of Versailles and Levens Hall demonstrate topiary's touristic potential (Brook & Brady, 2003). In Van, well-placed topiary would increase the aesthetic appeal of tourist areas and contribute to national and international promotion. In the age of photography and visual media, such signature elements generate strong imagery that amplifies the city's recognizability (Durey, 2023).

The success of urban design interventions depends not only on aesthetic merit but also on public participation and acceptance. Community buy-in is critical to the long-term sustainability of topiary projects in Van. Involving residents in the design process, foregrounding local symbols when selecting figures, and ensuring community stewardship in routine maintenance will improve durability and success (Sevik & Çetin, 2016; Rashidova & Lapteva, 2023).

6. Conclusions and Recommendations

Findings indicate that topiary is feasible for Van's urban green spaces and can yield aesthetic, ecological, and socio-cultural benefits. In particular, interpreting local symbols—such as the Van Cat, the inverted tulip, and stylized references to Lake Van—as topiary can help urban spaces acquire a stronger identity. Beyond aesthetics, topiary can support noise mitigation, microclimate moderation, and visual quality, thus directly improving quality of life in Van (Ruemler, 2004; Sevik & Çetin, 2016). Incorporating sculptural plantings that feature high-color-impact, native or locally characteristic species—e.g., motifs inspired by the *Fritillaria imperialis* L. (crown imperial) —is expected to further reinforce urban identity.

For future research and practice, pilot implementations in different districts are recommended—particularly at gateways, squares, and tourist focal points—to monitor effects over time. Public awareness programs and participatory processes should be used to strengthen social ownership of the aesthetic and identity dimensions. Multi-stakeholder collaboration among universities, local authorities, and civil society organizations will be key to sustaining these efforts (Rashidova & Lapteva, 2023; Durey, 2023).

To scale adoption, topiary should be embedded in urban design standards for Van. Inclusion of topiary in municipal development plans and green-space guidelines will enable systematic, city-wide application. Recognizing topiary as an identity asset within tourism strategies can elevate Van's brand value and contribute to its national and international visibility (Brook & Brady, 2003; Pizzi & Weiss-Sussex, 2011).

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Assessment of the Ecotourism Potential of Döşemealtı District, Antalya Province

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Abstract

Ecotourism is defined as a sustainable form of tourism that prioritizes the active participation of local communities in the tourism development process and emphasizes the preservation of natural and cultural heritage, in line with development policies and fundamental principles. The district of Döşemealtı has preserved numerous tangible cultural and historical sites that bear the traces of different civilizations throughout history and shed light on the present day. Sites such as Karain Cave, Kocain Cave, the Ancient Döşeme Road, the ancient city of Ariassos, the ancient city of Termessos, and Evdirhan are significant in terms of historical and cultural value. In addition, Termessos National Park, Kırkgöz Lake, and the surrounding natural landscape elements constitute the fundamental natural values that increase the district's ecotourism potential. The main objective of this study is to evaluate the ecotourism potential of Döşemealtı district from a landscape architecture perspective and to contribute to spatial planning processes. The study examined the district's cultural and natural features in detail, identified areas with tourism potential, and conducted a literature review on the relevant areas. Based on these data, a SWOT analysis was performed to systematically reveal the district's strengths, weaknesses, opportunities, and threats in terms of ecotourism. The findings of the analysis formed the basis for developing spatial planning recommendations aimed at increasing ecotourism potential. In this context, preserving the natural and cultural landscape, ensuring ecological continuity, encouraging the active participation of local communities in the process, and directing tourism activities in a planned manner were identified as strategic priorities for the district's sustainable ecotourism development. As a result, the findings of the study offer recommendations for the effective use of Döşemealtı district's ecotourism potential and the protection of its landscape values.

Keywords: Döşemealtı, ecotourism, tourism potential, cultural values, natural values.

1. Introduction

From the past to the present, ecotourism has become a type of tourism that generates significant economic, social, and ecological contributions in natural areas. By offering powerful experiential opportunities in natural settings, it provides visitors with the chance to learn about natural and cultural values, emphasizing the conservation of biological diversity and the importance of local culture. The common point among the definitions of the concept of ecotourism, first used by Kenton Miller in 1978, is that it is a tourism approach that aims to develop methods of benefiting from the environment without harming it, to ensure that the local people share in the tourism revenues without disrupting their cultural fabric, and to protect the environment and increase local prosperity in natural areas. Although similar to nature tourism, ecotourism differs in that it focuses on preserving cultural heritage as well as natural values, providing income-generating activities for local communities, and education. The International Ecotourism Society (TIES) defines ecotourism as “environmentally sustainable and socially beneficial travel to natural areas”; in this context, ecotourism is mostly carried out in sensitive, unspoiled, and protected areas, in the form of small-scale and low-impact activities. These

activities aim to educate visitors on environmental and cultural issues, protect natural and cultural values, promote the direct economic development of local communities, and encourage respect for different cultures and human rights. It is stated that ecotourism will provide multiple benefits when planned and managed by local communities in line with the principles of protecting the health of the local environment, preserving and promoting the cultural structure, and meeting community needs; thus contributing to more ecotourists learning about different environments and increasing environmental awareness on a global scale (Akın & Gül 2020).

Research conducted worldwide shows that ecotourism is rapidly rising among tourism sub-sectors and has become one of the most dynamic areas: UNEP (United Nations Environment Programme) findings show that ecotourism ranks high among tourism types, while WTO (World Tourism Organization) projections reveal a steady increase in both tourist numbers and total mobility. Indeed, according to WTO data, spending on ecotourism travel is growing at a rate approximately five times faster than the global average for other types of tourism, corresponding to an annual increase of 20%. In the context of this global trend, Turkey ranks among the top 10 most visited countries in the world according to statistics compiled by the World Tourism Organization, maintaining a strong position as a destination with a 3.5% share of the global tourism market and a 6.8% share of the European market. Turkey's high natural and cultural diversity and its product structure that can be spread across four seasons have the potential to further strengthen this position in the context of high value-added and sustainable ecotourism (Ünal Ankaya et al., 2018).

Turkey has high potential for nature sports and ecotourism thanks to its historical and cultural richness and natural beauty; therefore, there is a growing shift towards tourism models that are spread throughout the year and generate higher added value, rather than relying solely on summer tourism. Under the heading of ecotourism, the country offers a wide range of activities, including highland tourism, bicycle tours, ornithology (bird watching), photo safaris, river sports (canoeing and rafting), agro-tourism (farm tourism), botanical tours, horseback nature walks, camping and caravan tourism, cave tourism, mountain tourism, and nature walks are carried out under the heading of ecotourism; this diversity demonstrates that ecotourism offers Turkey a sustainable tourism alternative that spans all four seasons (Ünal Ankaya et al., 2018). In this context, the combination of high biological diversity and strong cultural landscapes (mountain pasture systems, ancient road networks) in the country provides a comprehensive foundation for the development of ecotourism products, while the product diversity provided by national parks and natural sites, long-distance hiking routes, and rural accommodation practices; should be supported by science-based planning, carrying capacity applications, and regular monitoring and evaluation mechanisms in the face of risks such as seasonality, visitor density, forest fires, and drought.

The focus area of this study, Döşemealtı district in Antalya province, offers a unique foundation for developing a nature-based and culture-focused ecotourism destination with its karst cave systems (Karain, Kocain, Öküzini), geo-ecological focal points (Kırkgöz Lake, Güver Canyon), and cultural heritage assets (Termessos, Ariassos; Evdir/Kırkgöz Han; Döşeme Yolu) to develop a nature-based and culture-focused ecotourism destination. However, the development dynamics triggered by the organized industrial zone (OSB), unplanned urban sprawl, and deficiencies in infrastructure/visitor management are the main factors that undermine the balance between conservation and use. Although the district is attractive due to its proximity to the Antalya metropolis and the accessibility provided by the E-24 (Antalya–Burdur–Ankara)

and D-650 (Antalya–Denizli) highways, the protection of ecological thresholds and the establishment of fair value chains with the local economy are of critical importance.

The aim of the study is to develop a comprehensive framework that can bring together nature-based conservation goals and local socio-economic development goals under one roof in Döşemealtı. In this regard, the district's natural and cultural values were systematically evaluated using a SWOT (Strengths-Weaknesses-Opportunities-Threats) analysis; planning decisions and management recommendations were developed taking into account ecological thresholds, accessibility, and spatial integrity principles. Methodologically, the Antalya–Burdur–Isparta Planning Region 1/100,000 scale Environmental Plan sheets (O24–O25–N24–N25) were georeferenced in a GIS environment and verified with current satellite data. and the existing land use and spatial relationships were analyzed through digitization and area calculations. The findings show that, when integrated with the principles of carrying capacity, safety, and visitor management, ecotourism-focused product and route design can simultaneously enhance environmental sustainability and local socio-economic benefits in Döşemealtı. The following sections of the study present planning decisions and management-monitoring recommendations in light of these findings

2. Material and Methods

2.1. Material

The settlement, named after Kırkgöz Lake which feeds the Düden Waterfall, was established in 1934 as Kırkgöz–Yeniköy when families from the Kızılcadağ area of Korkuteli settled there. Later, it grew into a village with the settlement of 60 Turkish families from Cyprus in 60 housing units built by the then Governor of Antalya, Haşim İşcan, and the transition of the Yörük nomads living in the region to a settled life. Located approximately 20 km from Antalya on the Antalya–Burdur highway, the settlement was established in the 1970s with the Döşemealtı Subdistrict Directorate and included Duacı, Kirişçiler, Kevşirler, Başköy, Odabaşı, Selimiye, Dereli, Çıplaklı, Kızıllı, Ekşili, Karaveliler, Killik, Camili, Ahırtaş, Bıyıklı, Kömürcüler, Yağca, Çığlık, Nebiler, Yukarı Karaman (now Düzlerçamı), Yeşilbayır, Dağbeli, and Bademağacı. Although the municipalities of Dağbeli and Bademağacı were established in 1973, it retained its status as the center due to its proximity to Antalya. Kırkgöz–Yeniköy established its municipal organization on December 17, 1977, when its population reached 2,711, and was named “Döşemealtı Town.” The name “Döşemealtı” comes from the approximately 4 m wide paved stone road that passed through the Derbent Pass and connected the cities of Pamphylia and Pisidia in ancient times, and continued to function during the Byzantine, Seljuk, and Ottoman periods. The local people named the pass through which the road passed “Döşeme Boğazı” (Paved Pass) and the plain below the road “Döşemealtı” (Under the Paved Road). For many years, the district had an economic structure based on agriculture, relying on the production of cotton, olives, wheat, barley, corn, oats, sesame, onions, citrus fruits, and various vegetables and fruits, as well as small and large livestock farming and Döşemealtı carpet weaving. Today, Döşemealtı has become urbanized and one of the central districts of Antalya. With the establishment of the Organized Industrial Zone, employment has shifted predominantly to the industrial sector. (Döşemealtı Beldiyesi. Döşemealtı Tarihçesi, 2025).



Figure 1. Underfloor location

2.2. Method

The O24, O25, N24, and N25 sheets of the 1/100,000 scale Environmental Planning Map for the Antalya–Burdur–Isparta Planning Region, published by the Ministry of Environment, Urbanization, and Climate Change, have been obtained; These sheets were placed on a 1/100,000 scale sheet index using the "Georeferencing" tool in ArcMap, and after ensuring their spatial accuracy, archaeological sites, wildlife protection/development areas, national parks, and reservoirs were digitized. In the second stage, a comprehensive literature review was conducted to identify natural and cultural values in the study area, an inventory of these values was created, and the identified areas were marked on Google Earth satellite images. In the final stage, these areas located in Google Earth were transferred to the ArcGIS environment and integrated by overlaying them with the digitized environmental plan. Thus, both the protection statuses defined in the official plan sheets and the literature-based natural and cultural landscape elements were brought together in a single GIS database. This methodological process is visually represented in Figure 2, which shows the digitized environmental layout plan in the ArcGIS environment, and Figure 3, which shows the Google Earth-based positioning and data integration.

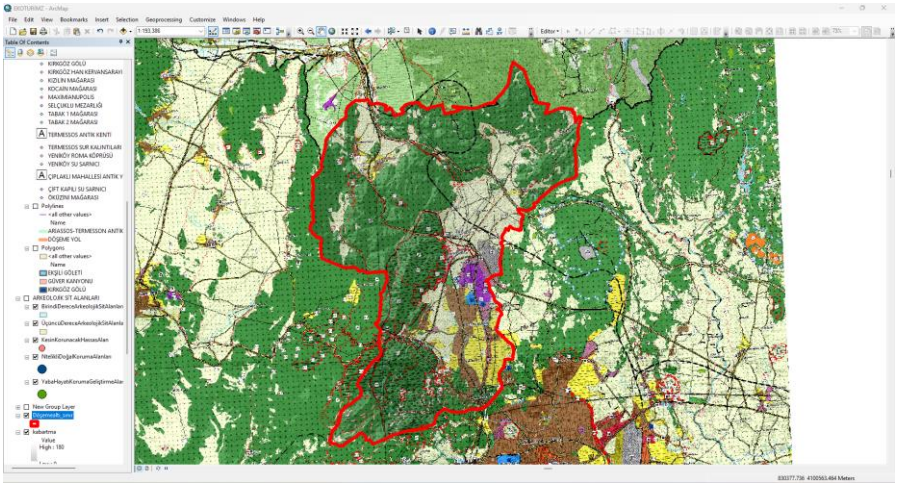


Figure 2. Revised environmental layout plan

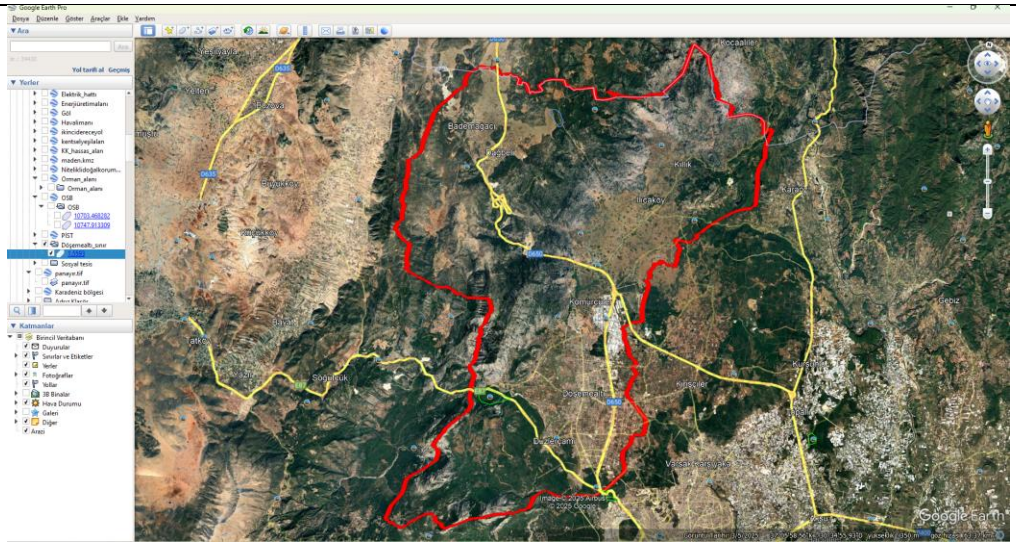


Figure 3. Work area

3. Findings

When examining the integrated natural and cultural values map presented in Figure 4, it is evident that Döşemealtı district exhibits a high level of diversity and density in terms of natural and cultural landscape elements. A total of 12 natural values (8 caves, 1 lake, 2 canyons, and 1 national park) and 30 tangible cultural values have been identified in the district. It is understood that natural focal points are concentrated in the forest-karst belt, mainly located in the northern and western parts of the district; Termessos National Park, Kırkgöz Lake, Güver Canyon, and the Karain, Kocain, Öküzini, Boynuzluin, Çarkin, Kızılın, and Tabak I-II caves constitute the main components of this belt. In contrast, cultural focal points are located more in the district center–southern band and along the Döşeme Yolu and Ariassos–Termessos axes; caravanserais, cisterns, mounds, and rural architectural elements form a holistic cultural landscape fabric. This spatial pattern is consistent with the natural and cultural value inventory presented in detail in the findings section, revealing that the ecotourism potential of Döşemealtı district has a multi-focused, integrated, and layered structure.

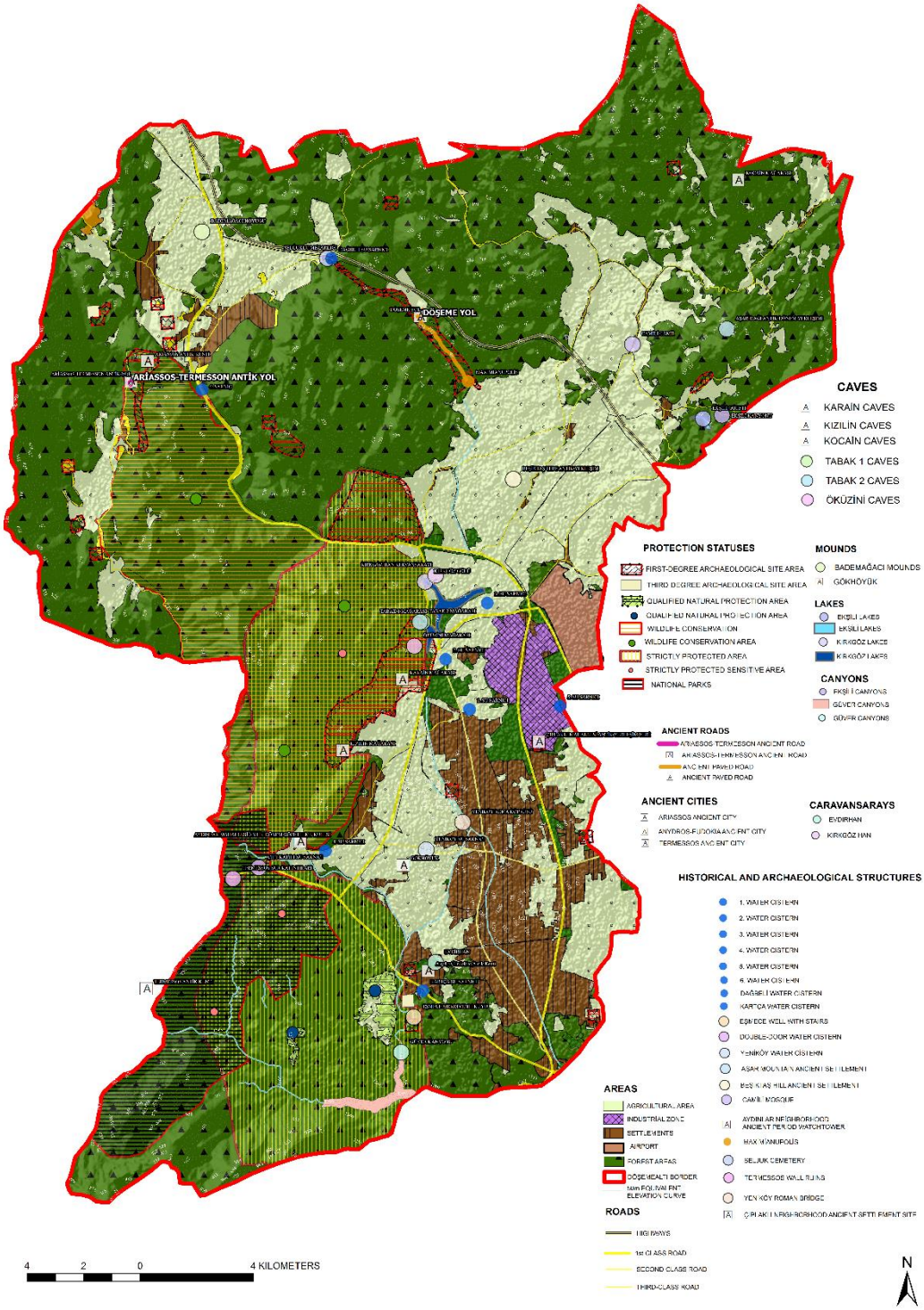


Figure 4. Digital background

Table 1. Natural Values Map

NATURAL VALUES		
ECOTOURISM VALUE	**NAMES**	**COORDINATES**
CAVES	1. Boynuzluin Caves	-
	2. Çarkini Caves	-
	3. Karain Caves	37° 4'40.00"K 30°34'15.00"D
	4. Kizilin Caves	
	5. Kocain Caves	37°13'56.42"K 30°42'42.82"D
	6. Öküzini Caves	37° 5'20.27"K 30°34'34.31"D
	7. Tabak-1 Caves	37° 5'47.42"K 30°34'47.24"D
	8. Tabak-2 Caves	37° 5'47.68"K 30°34'43.83"D
LAKES	9. Kirkgöz Lakes	37° 6'33.35"K 30°34'53.11"D
CANYONS	10. Güver Canyons	36°57'36.32"K 30°33'53.71"D
	11. Ekşili Canyons	37° 9'30.70"K 30°42'6.70"D
NATIONAL PARKS	12. Termessos National Park	-

As shown in the table above, a total of 12 natural values have been identified in the study area. Eight of these areas are caves, one is a lake, two are canyons, and one is a national park.

Table 2. Cultural Values Map

CULTURAL VALUES		
ECOTOURISM VALUE	**NAMES**	**COORDINATES**
ANCIENT CITIES	1. Anydros- Eudokias	36°59'6.00"K 30°34'36.54"D
	2. Ariassos	37°10'54.98"K 30°28'28.02"D
	3. Termessos Ancient City	36°58'57.41"K 30°27'53.81"D
CARAVANSARAYS	4. Evdir Han	36°59'17.62"K 30°34'47.63"D
	5. Kirkgöz Han	37° 6'40.35"K 30°35'8.60"D
MOUNDS	6. Bademağaci Mound	37°13'23.13"K 30°29'52.88"D
	7. Gökhöyük	37° 1'7.60"K 30°34'6.67"D
	8. Yeniköy Roman Bridge	37° 1'56.60"K 30°35'34.00"D
	9. Aydinlar Neighborhood Ancient Period Watchtower	37° 1'39.20"K 30°31'40.90"D
	10. Aşar Mountain Ancient Settlement	37°11'9.05"K 30°42'18.13"D

HISTORICAL AND ARCHAEOLOGICAL STRUCTURES	11. Çiplakli Neighborhood Ancient Settlement Site	37° 3’23.20”K 30°37’26.90”D
	12. Beşiktaş Hill Ancient Settlement	37° 8’26.80”K 30°37’4.90”D
	13. Camili Mosque	37°10’55.80”K 30°40’2.60”D
	14. Eşmece Staircase Well	36°58’16.00”K 30°34’13.70”D
	15. Seljuk Cemetery	37°12’47.33”K 30°32’50.85”D
	16. Termessos Wall Ruins	37° 1’2.05”K 30°30’3.18”D
	17. Maximianupolis	37°10’20.76”K 30°36’5.72”D
	18. 1. Water Cistern	37° 4’5.53”K 30°35’49.96”D
	19. 2. Water Cistern	37° 5’3.93”K 30°35’18.50”D
	20. 3. Water Cistern	37° 6’6.46”K 30°36’20.97”D
	21. 4. Water Cistern	37° 1’29.95”K 30°32’16.64”D
	22. 5. Water Cistern	37° 4’5.36”K 30°37’59.46”D
	23. 6. Water Cistern	37°10’22.55”K 30°29’44.78”D
	24. Dağbeli Water Cistern	37°12’47.06”K 30°32’57.01”D
	25. Kartça Water Cistern	36°58’45.98”K 30°34’28.41”D
	26. Yeniköy Water Cistern	37° 1’26.82”K 30°34’40.32”D
	27. Double-Door Water Cistern	37° 1’13.50”K 30°30’40.40”D
ROADS	28. Ancient Paved Road	37°11’34.42”K 30°35’0.54”D
	29. Ariassos-Termessos Ancient Road	37°10’32.84”K 30°28’3.29”D
POND	30. Ekşili Lake	37° 9’27.53”K 30°41’39.42”D

As a result of the research conducted, a total of 30 cultural heritage elements were identified in the study area, including 3 ancient cities, 2 inns, 2 mounds, 1 bridge, 1 watchtower, 3 ancient settlement areas, 1 mosque, 1 well, 1 cemetery, 1 wall remnant, 1 military garrison, 10 cisterns, 2 ancient roads, and 1 reservoir, totaling 30 cultural heritage elements.

3.1. Natural Values

3.1.1. Caves

3.1.1.1. Boynuzluin Cave

It is located 30–31 km north-northwest of the Antalya provincial center, approximately 1 km northeast of Karain Cave and approximately 250 m northwest of Öküzini Cave. The main entrance, which is currently closed, faces south; this orientation is considered to have provided

favorable conditions for settlement. The cave consists of a very small front room and three cavities. The main entrance opens into the first front room; from here, one passes into the second cavity, which serves as the main living area. This second cavity is divided in two by a wall built using the dry wall technique. Over time, the calcareous water dripping from the ceiling has cemented these walls, giving them the appearance of a massive dam. (Tay Project, 2025a).

3.1.1.2. Çarkini Cave

It is a natural cave located northwest of the Antalya provincial center; 1 km northwest of the Somaklı neighborhood of Yağca Village, 1 km west of the Kocaköy neighborhood, and 2 km south-southwest of the Karain Cave. It developed within Cretaceous limestones and faces southwest. The entrance elevation is approximately 500 m above sea level. (Kartal, 1999). It was declared a First Degree Archaeological-Natural Site Area in 1990. (Tay Project, 2025b).

3.1.1.3. Karain Cave

Located at 37°04′40.00″ N latitude and 30°34′15.00″ E longitude, Karain Cave is part of a cave complex near Yağca Village, 31 km northwest of the provincial center of Antalya in the Mediterranean Region. The cave developed on slopes formed during the uplift of the Anti-Taurus chain within the Katran Mountain massif, composed of Cretaceous limestone, and dominates a wide travertine plain that is a remnant of sea level rises. It is located approximately 150 m above the plain floor and 430–450 m above sea level (Yalçınkaya & Özçelik, 2012). This geomorphological location and the general character of the internal cavity system can also be visually observed in the interior view of Karain Cave in Figure 6, which reveals the morphology of the cave interior.



Figure 5. Worship point



Figure 6. Inside Karain Cave

Karain Cave, which housed human communities approximately 500,000 years ago, is one of the oldest known settlements in Anatolia. Excavations show that the cave was continuously inhabited throughout all stages of “primitive human” life; in addition to bones belonging to species that are now extinct in Anatolia, such as elephants, hippopotamuses, lions, and giraffes, numerous animal remains have been found (Döşemealtı Belediyesi Tarihi Yerler, 2025 b.). As a result of studies conducted at various intervals between 1946 and 1973 by Prof. Dr. İ. Kılıç Kökten, it was understood that the area was continuously inhabited during the Paleolithic (Stone Age), Neolithic, Chalcolithic, and Early Bronze Ages. In Classical times, based on the inscriptions and votive niches on the walls, it was determined that the cave was used as a place

of worship and sacrifice; the spatial arrangement that embodies this sacred use is exemplified in Figure 5, which shows the worship area. This multi-layered archaeological accumulation provides important data on the vegetation, animal communities, and climatic characteristics of the Pleistocene period of the Quaternary. Remains of species such as hippopotamus, rhinoceros, and elephant, along with fossils of Neanderthal humans from the Middle Paleolithic and Homo sapiens fossilis from the Upper Paleolithic, are evaluated within this framework. Excavations have been ongoing since 1985 under the leadership of Prof. Dr. Işın Yalçınkaya. When viewed in conjunction with Figures 5 and 6, Karain Cave serves as a key focus for understanding the paleo-environmental and cultural history of the region, both in terms of archaeological stratification and sacred space organization

3.1.1.4. Kizilin Cave

Kızılin Mağarası, Antalya ili Döşemealtı ilçesi Yağca Mahallesi sınırları içerisinde yer almakta Kızılin Cave is located within the boundaries of Yağca Neighborhood, Döşemealtı District, Antalya Province, with GPS coordinates 37°03.357′ N and 30°32.776′ E. Following the current road route, the cave is approximately 1.6 km from the center of Yağca Neighborhood and 3.5 km from the Karain settlement. Furthermore, the area in question is located within the boundaries of the Antalya Düzlerçamı Wildlife Development Area (Kartal at all., 2018). Figure 8 shows the spatial relationship of Kızılin Cave with Yağca Neighborhood, Karain settlement, and other caves in the surrounding area based on these coordinates.

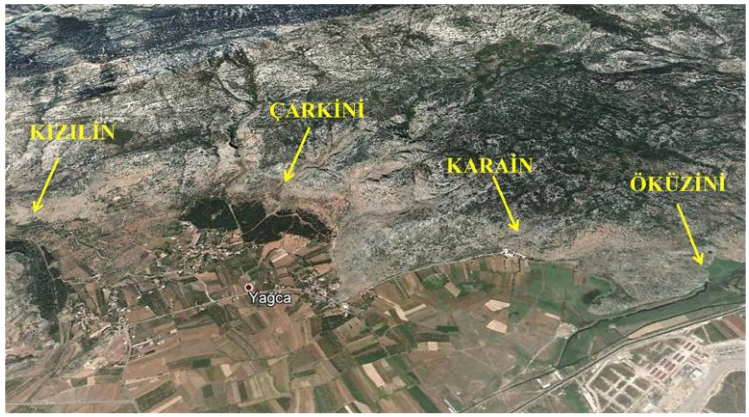


Figure 8. Kızılin and surrounding settlement areas (Kartal, 2025)

3.1.1.5. Kocain Cave

Kocain Cave is a natural cave located at coordinates 37°13′56.42″ N and 30°42′42.82″ E, approximately 45 km north of the Antalya provincial center, on Hisardağı (İndağı) at an elevation of 1,171 m. The cave is approximately 600 m long, with an entrance width of 35 m and an internal width of 75 m; the ceiling height varies between 50 and 60 m, and it consists of a single, very large main hall. Declared a first-degree Archaeological and Natural Site in 1990, the cave contains a large cistern dating back to the Roman period, and traces of walls belonging to a building complex dating back to the Roman Empire can be seen in front of the cave entrance (Öztürk, 2015). The monumental stalagmites and other speleothem formations inside the cave can be seen in Figure 9, which shows the Kocain Cave stalagmite in detail, while the wide entrance and single-hall interior layout can be seen in Figure 10, which reflects the cave entrance. The cave, which has some of the widest galleries in Turkey, offers a more impressive atmosphere than other examples, especially with its entrance section. It is difficult to reach; it

can be difficult to exit by car, and access by public transport is limited. The cave is suitable for beginner-level training and exploration for cave research communities and provides sufficient facilities for camping and sporting activities. However, considering the steep topography and interior morphology shown in Figures 9 and 10, activities must be planned in accordance with safety and protection rules.



Figure 9. Cocaine cave stalactite



Figure 10. Entrance to Kocain Cave

3.1.1.6. Öküzini Cave

The cave is located approximately 32 km northwest of the Antalya provincial center, north of Yağca Village, and 1.5 km north-northeast of Karain Cave. The old Antalya–Burdur highway passes very close to the cave. Geological studies show that the cave was first formed by river erosion and later expanded by natural collapses. Due to nearby water sources, the area was inhabited during the Paleolithic Age. In recent years, its location near a travertine plain has made the cave easily accessible, leading to a rapid increase in damage. The site was registered as a 1st-degree Archaeological and Natural Site Area in 1990 (Tay Project, 2025c).

3.1.1.7. Tabak Cave

Tabak 1–2 Caves are located approximately 200 m above the Kırkgözler Spring, 1 km from the Döşemealtı junction on the old Antalya–Ankara highway. The coordinates of Tabak 1 are 37°05′47.42″ N, 30°34′47.24″ E, while the coordinates of Tabak 2 are 37°05′47.68″ N, 30°34′43.83″ E. The cave begins with a gallery sloping down at an angle of approximately 30° and covered with scree stones at the bottom; this gallery continues as the main branch. From the middle section of the gallery, a second main branch diverges from a point reached by climbing approximately 4 m on the right side. Human skeletons have been found in both branches, and anthropological evaluations date these remains to the Late Roman–Byzantine period (Tay Project, 2025d).



Figure 11. Sport caving in the Tabak cave

The cave system does not show active flow, but small pools of water are observed in places. The spatial distribution and accessibility concept of the Cave System I and Cave System II presented in Figure 11 supports this situation, revealing that the cave's proximity to the main road, the closed/old industrial area in the vicinity, and the occasional intervention of security units (gendarmerie) have made camping difficult. The presence of cave branches with separate entrances and a sinkhole at the same location can be seen on the map, along with the marked entry points and karstic collapse formations. Layers I and II are more challenging caves compared to Kocain Cave. The narrow entrances observed in Figure 11, the slope and fracture lines in the gallery passages, and the need for SRT and additional technical equipment in some sections are confirmed by these morphological features; the suitability of the chimney technique at the entrances can also be related to these morphological features. The system, which is suitable for caving training for sporting purposes due to its structural characteristics, is shown on the figure together with the lake in its immediate vicinity; it is understood that the area around this lake is only partially suitable for camping, as steep slopes, karstic rock, and different rock types significantly complicate both climbing and progressing inside the cave. In this context, Figure 11 provides a framework that visually represents the technical caving potential of the Tabak I–II cave system and its limitations in terms of camping/recreational use at a spatial scale.

3.1.2. Lakes

3.1.2.1. Kirkgöz Lake

On September 2, 2022, it was registered as a "Natural Site – Qualified Natural Conservation Area" (Çevre Şehircilik Ve İklim Değişikliği Bakanlığı, 2023). Kırkgözler forms one of the largest source systems of the Taurus Mountains, which have a large catchment area (Isparta–Burdur–Korkuteli). These sources discharge from karstic limestones at an elevation of 300 m along a zone of approximately 1 km. A significant portion of the water that forms a large wetland is drawn for the Kepez Hydroelectric Power Plant; some of it re-enters the underground on the upper plateau via the Düden and karstic waterways within permeable travertine masses.

The large underground water reserves of the Taurus Mountains appear in the form of both terrestrial and marine sources (subaerial and submarine outlets) in the vast area between the Boğaçayı River and Kemerağzı. The relationships between the sources can be evaluated by monitoring changes in chloride ion (Cl^-) concentrations. Studies by the 13th Regional

Directorate of the State Hydraulic Works (DSİ) have shown that the Kırkgöz sources share similar hydrogeochemical characteristics with the Düden Waterfall, İskele, Kemerağzı, Arapsuyu, Mağara, and Duraliler sources. Special importance should be given to the protection of the Kırkgöz system, which is understood to be hydraulically and chemically related to many springs (Çevre Şehircilik Ve İklim Değişikliği Bakanlığı, 2025).

3.1.3. Canyons

3.1.3.1. Güver Canyons

Güver Canyon is located on the Antalya–Korkuteli highway, within the boundaries of Döşemealtı district and within the Düzlerçamı Wildlife Development Area. Estimated to have formed over approximately 1 million years, the canyon is approximately 2 km long, 30 m wide on average, and 115 m deep; three separate streams flow through it (Mansuroğlu at all., 2021).

3.1.3.2. Ekşili Canyons

It is located 680 meters east of Ekşili Reservoir, under the Ekşili–Hatipler highway. It is known locally as the “Kiremit Oluk Canyon.” (Antalya Kültür Envanteri, 2025).

3.2. Cultural Values

3.2.1. Ancient Cities

3.2.1.1. Anydros - Eudokia Ancient City

Eudokias is located 17 km northwest of Antalya city center on the Antalya-Korkuteli highway. The plain where Yukarıkaraman stands today (Düzlerçamı Plain) formed the western edge of the Pamphylia Plain in ancient times, making the ancient city essentially a Pamphylian settlement. Records from travelers and researchers indicate that the ancient-Byzantine settlement at the site of today's Yukarıkaraman was a large settlement. The ruins are concentrated in an area bounded by Evdir Han to the north, the old Antalya road to the east, Uzunkuyu Kahvesi to the south, and the Kuruçay stream/floodplain to the west. The ruins at the site generally date to later periods (Late Roman and Byzantine eras). The ancient city of Eudokias, covering an area of approximately 52 hectares, measuring approximately 800 m north-south and approximately 650 m east-west, was centered around a main street paved with stones, of which not even the slightest trace remains today. According to information provided by Spratt and his colleagues, the city's main public buildings were arranged around this main street. The most prominent feature of the settlement is the water channels carved into the bedrock, which have retained their functionality from the Late Roman period to the present day. In addition to the profane structures, the most magnificent architectural remains to survive to the present day is the prostylos temple built in the Corinthian order, located southwest of Evdirhan (Antalya Valiliği, 2025).



Figure 12. Anydros-Eudokias Ancient City Ruins (Google Earth, 2024)

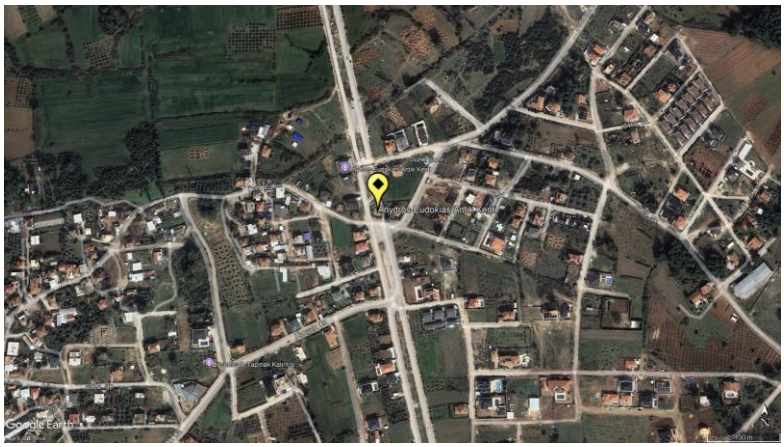


Figure 13. Google Earth satellite image (03/05/2025)

3.2.1.2. Ariassos Ancient City

Ariassos, one of the cities of the Pisidia Region, is located approximately 50 km north of Antalya, west of the Çubukbeli Pass, and near the village of Akkoç. The city's official founding is dated to 189–188 BC, associated with the campaign of Manlius Vulso and the Peace of Apameia. Coin minting continued from the 1st century BC until the Gallienus Period (253–267 AD). In Late Antiquity, it was known as part of the Pamphylia Province and as a bishopric center until the 12th century. Ariassos, which was allied with other Pisidian cities, earned income from transit fees and taxes thanks to its strategic location, but was abandoned after the Byzantine period. The city plan reveals necropolis areas from east to west, city walls, a monumental city gate, a possible columned street, and the main city fabric settled on terraces on the northern slope. Its main structures are the city gate, mausoleum-type tombs, walls, Roman road, aqueduct, nymphaion, bouleuterion, gymnasium, baths, and theater. The largely intact monumental three-arched city gate at the head of the valley leading into the city is known to have been used during the Severus Alexander period (Kültür Portalı Antalya Gezilecek Yerler (2025 a).



Figure 14. Ariassos Ancient City (Türkiye kültür portalı, 2025)

3.2.1.3. Termessos Ancient City

Termessos is located approximately 35 kilometers northwest of Antalya, within the boundaries of Güllük Mountain Termessos National Park. The city is built on mountainous terrain, starting at an elevation of 908 meters above sea level and reaching 1,254 meters (Kürkçü, 2016).

Termessos, an important ancient city founded by the Solymians, who are believed to be descendants of the Luwians, one of Anatolia's oldest peoples, is particularly noted in historical sources for the Termessians' strong defense against Alexander the Great's siege of the city in 333 BC, refusing to surrender. One of the most striking examples of archaeological sites preserved within a forest setting, the city is located within the boundaries of Güllük Mountain (Termessos) National Park, which bears the same name. With its rich vegetation, wildlife, and endangered species, it is essentially a botanical garden and open-air zoo. The city's ruins begin with the Hellenistic-era walls located near Yenicekahve on the Antalya–Korkuteli highway and continue up to the summit of Mount Güllük. Following the path that ascends towards the city after the parking area, on the right side, the steps and monumental entrance of the Ionic temple built during the reign of Emperor Hadrian can be seen. Climbing southward from the section where the lower city walls and water channel are located, the Gymnasium, whose first floor is still partially standing, and the columned street with shops lined up behind it to the southwest can be seen. In addition to this, important architectural structures of the period such as the theater, baths, agora, council building, numerous tombs and cisterns, the residence attributed to the founder, and various temples can still be seen today. Termessos attracts attention with its numerous temples and extensive necropolis areas; the variety of tomb types and the richness of the decorations reflect the artistic and cultural level of the city. The tomb of Alketas, one of the important commanders of the Alexander the Great period, dated 319 BC, as well as other tomb structures, are important in shedding light on the history of the city. One of the most striking artifacts from Termessos in the Antalya Museum is the “Dog Sarcophagus” displayed in the Sarcophagi Hall. The poetic inscription written by its owner, Rhodope, for her dog Stefanos gives this artifact unique importance (T.C. Kültür Ve Turizm Bakanlığı, 2025).

3.2.2. Mounds

3.2.2.1. Badem Ağacı Mounds

Bademağacı Mound is approximately 50 km from Antalya and approximately 20 km from the Bucak District of Burdur. Administratively, it is located within the boundaries of Bademağacı Village, Döşemealtı District, Antalya Province. The mound, located approximately 2.5 km from

the village, is about 5 km north of Çubukbeli, where the Burdur-Antalya Highway crosses the Taurus Mountains. The Bademağacı Mound was discovered in 1958 by James Mellaart during a surface survey conducted in the region. The mound, mistakenly named Kızılkaya, was identified as the Bademağacı Mound in research conducted by Refik Duru. Excavations at the mound were initiated in 1993 by a team led by Refik Duru and Gülsün Umurtak and continued uninterrupted until 2010. Although Neolithic finds in Antalya are mostly represented by mixed and insufficient finds from Paleolithic caves, the excavations at Bademağacı Mound have yielded information about the Neolithic period in Antalya. Given the abundance of settlements dating back to the Paleolithic Age, the reason for this decline in the Neolithic Age may be attributed to Antalya's rugged and rocky terrain, which is not suitable for agriculture. Consequently, it has been noted that Neolithic settlements are more prevalent in the northern part of the Taurus Mountains (Kivanç at all., 2017).

3.2.2.2. Gök Mounds

Gökhöyük is located approximately 29 km northwest of Antalya. It is situated on the canal bank between the villages of Yeniköy and Yağca, on the old Antalya-Burdur highway. Gökhöyük was discovered by Kılıç Kökten. In 1984, during the construction of a water canal, part of Gökhöyük was destroyed when earth was removed by machinery. The Antalya Museum conducted a surface survey and, in 1986, carried out excavations consisting of two boreholes over a period of 21 days. Gökhöyük is one of the Early Bronze Age settlements in Antalya. Most of the finds from Gökhöyük belong to the Early Bronze Age (Kıvanç at all., 2017).

3.2.3. Caravanserais

3.2.3.1. Evdir Han

Evdir Han, a Seljuk work, is located within the boundaries of the Döşemealtı district of Antalya province. As understood from its inscription, which has not survived to the present day, it was built in the early 13th century during the reign of I. İzzeddin Keykavus bin Keyhusrev. Measuring approximately 67x55 m, the caravanserai has a nearly square rectangular plan. Its walls are made entirely of cut stone, while its roof is constructed of rubble stone. Classified as a four-iwan caravanserai, the structure is notable for its projecting portal above the main entrance; however, the upper two corners of the portal are now destroyed. On the portal, within a thin outer border band, there is a thicker second border row consisting of infinite star motifs; the upper sections of both borders appear to be damaged. The third border band is decorated with geometric motifs. The doorway is in the form of a pointed arch, designed to give the impression that it is supported by small columns. There is a small mihrab on each side wall of the niche continuing inward, the upper part of the portal niche is designed with muqarnas filling, and the door ends with a flat arch. Around the inner courtyard of the caravanserai, pointed arches with cut stone masonry rest on thick cut stone pillars; pointed barrel vaults form the upper covering of the four iwans. The cells opening onto the arcades, which are enclosed spaces, stand out as units that complete the functional layout of the caravanserai Kültür Portalı Antalya Gezilecek Yerler, 2025 b).

3.2.3.2. Kirkgöz Han

Kırkgöz Han is located in the Pınarbaşı area of Döşemealtı district, one of the central districts of Antalya province. The han takes its name from Kırkgöz, the former name of Döşemealtı district. The name Kırkgöz originated from the large number of water sources in this region. The lake where spring waters accumulate, like Kırkgöz Han, also takes its name from here. It

is located at the 30th km of the Antalya-Burdur highway. Kırkgöz Han has a rectangular plan with dimensions of approximately 52.00 x 65.00 m. The han has an open courtyard and a closed hall section. The structure is oriented north-south, with rows of arcades on both sides of the 50.00 x 51.00 m inner courtyard. After the arcades and enclosed rooms, the open courtyard section in the middle forms a rectangular shape measuring 25 x 42 m. The enclosed section at the end of the courtyard, measuring approximately 15.00 x 50.00 m and featuring a rectangular plan, constitutes the winter section of the building, known as the hall. In terms of its general appearance, the building presents a typical example of a Seljuk caravanserai, extending from south to north, featuring a rectangular plan, a simple appearance, yet resembling a castle in appearance.

The interior layout of the caravanserai consists of units located around the courtyard. Behind the entrance iwan, in the middle of the south facade of the courtyard, there is an entrance iwan, flanked by two small enclosed spaces. Rows of arcades are located on the west and east sides of the courtyard. At the end of both arcade rows, on the north side, there is a small enclosed space. Behind these, covering the entire south facade, there is a winter, enclosed section (Yurdasever, 2011).

3.2.4. Historical and Archaeological Structures

3.2.4.1. Cisterns

Water, one of humanity's most important needs, and its supply have been among the foremost problems that humankind has had to solve since the earliest days of civilization. Throughout history, cities have generally been built near water sources. In later periods, cities located on fertile land but far from water sources developed architectural elements such as aqueducts, waterways, and open or closed cisterns designed to store water, in order to facilitate easy access to water (Güngör, 2017).

Cisterns are water storage structures developed as a result of research into the methods and forms of rainwater storage due to the lack of spring water and low groundwater levels, and their usage characteristics have evolved over time. The geographical location of the Döşemealtı Region, the ancient cities in the region, the ancient “Döşeme Boğazı” road, and the water cisterns built by the Yörük nomads on their migration routes are important cultural assets. The scarcity of water resources in high-altitude areas, despite these regions receiving abundant rainfall due to their characteristics and thus having favorable conditions in terms of water availability, necessitated the development of rational solutions for finding and storing water, thereby ensuring the continuity of life. It has been observed that the clusters of wells and cisterns seen in the Döşemealtı region are concentrated on or near ancient road networks that provided access to production and trade areas; this was done to solve the problem of finding and storing water needed during transportation. The architectural diversity and number of cisterns seen in the Döşemealtı plain are striking. While it is correct to associate the existence of numerous cisterns in a region where drought is almost a constant with animal husbandry, this is not sufficient. On the other hand, the absence of cisterns and wells of various models and densities in distant and nearby neighborhoods engaged in nomadic animal husbandry and having cultural ties to the region, with a few exceptions, demonstrates the uniqueness of the cisterns in the Döşemealtı plain. The region's distinctive “water storage structures” dating back to periods before nomadic life have been used to the present day, with some changes in form and volume and restoration when necessary (Öncü & Gül, 2023).

3.2.4.2 Yeniköy Roman Bridge

It was built in the 2nd century AD during the Roman period to carry water from the Kırkgözler Spring to the ancient city of Anydros. It is one of the smallest Roman-period bridges built in the ancient Pamphylia region (Antalya Kültür Envanteri, 2025).

3.2.4.3. Aydinlar Neighborhood Ancient Period Watchtower

It is a three-story watchtower built during the Hellenistic period in the 1st century BC. The tower was declared a Protected Immovable Cultural Asset in 1998 (Antalya Kültür Envanteri, 2025).

3.2.4.4. Ashar Mountain Ancient Settlement Site

In the Ahırtaş area of Killik Mahallesi, on a hill with two small peaks and an elevation of 980 meters, known locally as Asar Mountain, there is a mountain-fortress settlement dating back to the Roman period. Thanks to the forest road opened by the General Directorate of Forestry of the Republic of Turkey, it is possible to reach the summit by vehicle or on foot. The location offers a wide panoramic view overlooking Hatipler to the east, Ekşili Reservoir to the west, and Kocain Cave and Çubuk Beli to the northwest. Located on the Via Sebaste route, which starts from the ancient city of Perge and extends into Anatolia via the pass known as Klimaks in ancient times and Çubuk Beli today, Asar Mountain served as a strategic fortress settlement ensuring road safety during the Roman and Byzantine periods (Antalya Kültür Envanteri, 2025).

3.2.4.5. Çiplakli Neighborhood Ancient Settlement Site

It is a farm settlement inhabited until the Eastern Roman period in the 6th century. The remains of structures from the Hellenistic and Roman periods, a water well, an olive oil press, and a trapetum vessel are the ruins that have survived to the present day. It was declared a First-Degree Archaeological Site in 2002 (Antalya Kültür Envanteri, 2025).

3.2.4.6. Beşiktaş Hill Ancient Settlement

Beşiktaş Hill was founded in the 2nd century AD on a small hill 320 meters high in the southwest of Karataş Neighborhood (Antalya Kültür Envanteri, 2025).

3.2.4.7. Camili Mosque

It was built in 1871 during the Ottoman Empire. It is an example of early rural Ottoman architecture. Camili neighborhood takes its name from being the first settlement in the region to have a mosque. Camili Mosque is considered one of the early examples of mosque architecture belonging to the Yörük-Turkmen culture (Antalya Kültür Envanteri, 2025).

3.2.4.8. Eşmece Well With Stairs

It is located south of Karaman Neighborhood, which is part of Döşemealtı District in Antalya Province. It was established by the Antalya nomads. It was opened on the southern part of Güver Creek. Throughout history, it has been one of the important water sources visited by travelers on the highland migration routes along the Konyaaltı-Kepez-Döşemealtı route (Antalya kültür envanteri, 2025).

3.2.5. Roads

3.2.5.1. Ancient Paved Road (Antik Döşeme Yol)

The Derbent Pass, one of the important routes connecting the cities of Pamphylia and Pisidia in ancient times, continued to serve its purpose during the Byzantine and Seljuk-Ottoman periods, and was used as a migration route for Yörük communities until recent times. It is known that military lodgings were built at various times along this road, which maintained its transportation and transit function for approximately 2000 years, for the purposes of control and security. This ancient road, paved with flagstones, gave its name to the district of Döşemealtı. Locals refer to this road, which is approximately 4 meters wide and paved with stones, simply as "Döşeme," the strait through which it passes as "Döşeme Strait," and the flat area below the road as "Döşemealtı." Over time, the name Döşemealtı came to refer first to a group of villages in the surrounding area, then to the entire plateau, then to the subdistrict center, and finally to the district center (Döşemealtı Belediyesi Tarihi, 2025a). The road running along Döşeme Boğazı is still largely in good condition today. Built in a way that changes direction with frequent breaks and is supported by steps in places to suit the terrain, the road continues to climb and reaches a section where the passage narrows significantly and where there is an active cistern and various building remains. Here, the remains of a gate, which the road appears to have passed through, can be seen. The dense architectural remains, dating from different periods, suggest that this area may have been a strategic point for the transition from Pamphylia to Pisidia (Ercenk, 1992). In the Tabula Peutingeriana, a work written in the Middle Ages that describes Roman-era road routes, this road is shown as part of the route between Side and Laodicea. Accordingly, the ancient road, part of which was formed by Via Sebaste, starting from Side to Laodicea, and from there to the two major metropolises of the Asia Province, Ephesus and Pergamon, followed this route: Side – Aspendos – Syllion – Perge – Klimax (Döşeme Boğazı) – Komama – Kormasa – Themisonion – Laodicea – Ephesus – Pergamon. Therefore, it is accepted that the section of Via Sebaste between Perge and Döşeme Boğazı includes a part of the road that starts from Pergamon, passes through Laodicea, and reaches Side, which is believed to have been built by Manius Aquillius (129–126 BC), the first governor of Asia, Rome's first province in Anatolia. (Varsak Belediyesi, 2007).

3.2.5.2 Ariassos-Termessos Ancient Road

It was built during the Roman period. It is the road leading to the western gate of Ariassos on the Termessos side. It was declared a First Degree Archaeological Site in 1991 (Antalya Kültür Envanteri, 2025).

3.2.6. Pond

3.2.6.1 Ekşili Lake

It is an artificial reservoir. It was established in 2017 by the 13th Regional Directorate of the State Hydraulic Works (DSİ) for irrigation activities (Antalya kültür envanteri, 2025).

3.3. Findings Based on Swot Analysis Results

SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis is a strategic evaluation method that enables a systematic and comprehensive examination of the current state of a field or subject in the context of internal dynamics (strengths and weaknesses) and external environmental conditions (opportunities and threats). Also referred to in the literature as SWOT analysis, this approach is an important tool, particularly in planning, tourism, conservation, and local development studies, providing decision-makers with a comparative overview of spatial potentials, constraints, and risks. In the context of ecotourism, SWOT analysis contributes to the development of strategies that balance conservation and use by simultaneously addressing

the aspects in which natural and cultural landscape values create appeal, the structural and managerial limitations that hinder sustainable use and management, the new opportunities emerging at the regional and national levels, and long-term threats. The SWOT analysis conducted for Döşemealtı district within the scope of this study simultaneously reveals the elements that support the district's ecotourism potential and the factors that create vulnerability, providing a guiding framework for the creation of spatial planning and management recommendations.

- There are traces stretching from past eras to the present day in terms of cultural values.
- The Karain, Kocain, and Öküzini caves located in Döşemealtı, along with ancient settlements such as Termessos and Ariassos, form a multi-layered heritage ground for ecotourism and cultural tourism.
- The status of Kırkgöz Lake as a "Natural Site – Qualified Natural Protection Area" and the existence of the Düzlerçamı Wildlife Development Area provide a strong framework for the protection of ecological values.
- Güver Canyon and the integrity of the rural landscape provide a high-quality experience for nature walks, sightseeing, photography, and observation activities.
- The Antalya–Burdur–Ankara (E-24) and Antalya–Denizli (D-650) highways passing through the district increase the destination's accessibility, facilitating potential visitor flow.
- Its proximity to the Antalya metropolis strengthens its competitive power thanks to quick access to health and logistics services, the tourism market, and transportation.
- Döşemealtı carpet weaving and the contemporary practices of Yörük culture enable tangible and intangible heritage to be transformed into experiences.
- The biological diversity created by the forest–scrub–steppe transition zones, together with the continuity of ecological corridors, provides an infrastructure conducive to nature-based tourism.
- The low-density settlement pattern in the district allows for the protection of sensitive areas while enabling the flexible positioning of ecotourism products.
- The continuity of historical routes and rural architectural fabric provides a suitable framework for planning thematic culture-nature routes.
- The existence of rural production traditions and local gastronomy enriches the ecotourism experience with unique local products.
- The diversity of natural micro-landscapes around water sources, caves, and canyons allows for the design of different experience stations within a short distance.
- The limited availability of information boards, directional signs, and digital guidance elements at natural and archaeological sites weakens area awareness and visitor management.
- The lack of public transportation and "last mile" access to rural sites makes it difficult to organize sustainable visitor flows.

- The inadequacy of eco-accommodation options, visitor centers, guidance services, and basic services (toilets, waste disposal points, drinking water) lowers the quality of the experience.
- The limited implementation of regular maintenance and conservation practices in a significant portion of the areas increases the risk of damage and vandalism.
- The lack of a comprehensive ecotourism plan and area management plans makes it difficult to consistently implement the balance between conservation and use in the field.
- Non-standard practices in rural infrastructure related to water, wastewater, and solid waste management negatively affect environmental quality.
- Fragmentation of private property and scattered land use create implementation difficulties in terms of route integrity and access permits.
- Limited regular data production on visitor counts, carrying capacity, and ecosystem indicators makes it difficult to conduct evidence-based decision-making processes.
- The lack of visual coherence in the design of inter-area connection routes weakens the perception of destination identity.
- Antalya's strong tourism infrastructure and brand awareness provide an important springboard for controlled redirection from mass tourism to nature- and culture-focused experiences.
- Thematic routes combining caves, inns, ancient roads, and rural life focal points can be diversified with slow tourism principles and attract visitors year-round.
- Local produce markets, craft workshops, and gastronomic experiences can establish a direct economic link between ecotourism and rural development.
- Within the scope of agro-ecotourism, producer markets, craft workshops, and local gastronomic experiences can create a direct value chain between rural development and tourism revenues.
- Anydros-Eudokias has been buried and excavation has become difficult.
- Drought and heat waves associated with climate change create uncertainties that could negatively affect the water regime, especially in the Kırkgöz basin.
- Vandalism and illegal excavations can cause irreversible losses to the archaeological heritage.
- Gaps in security, guidance, and emergency infrastructure can increase the risk of accidents in cave and canyon use.
- Heavy vehicle traffic and inappropriate parking can negatively affect visual quality and pedestrian-bicycle safety on rural routes.
- Information pollution and unauthorized promotional content can misdirect visitor behavior, increasing pressure on sensitive areas.

4. Results and Recommendations

This study has identified a strong resource set for ecotourism by examining the location and protection statuses of 12 natural sites (8 caves, 1 lake, 2 canyons, 1 national park) and 30 tangible cultural assets in Döşemealtı district. The "Natural Site–Qualified Natural Protection Area" status of Kırkgöz Lake, the Düzlerçamı Wildlife Development Area, ancient settlements such as Termessos–Ariassos, and cave systems, particularly Karain–Kocain–Öküzini, form the backbone of a nature-based and culture-focused destination. However, identified shortcomings in access/the "last mile," information–guidance infrastructure, eco-accommodation, and visitor management standards limit the sustainable use of this potential. The findings indicate that ecotourism can contribute simultaneously to rural development and heritage conservation through capacity-based management, strengthening green–blue connections between areas, and institutionalizing local stakeholder participation.

- At the district level, a comprehensive ecotourism master plan should be prepared that is consistent with higher-level planning decisions and protection statuses and addresses natural and cultural focal points together; priority implementation areas, thematic routes, and spatial priorities should be defined in this plan.
- Comprehensive area management plans should be prepared for Kırkgöz Lake, Düzlerçamı Wildlife Development Area, Güver Canyon, and the cave system; these plans should clearly define visitor flow scenarios based on carrying capacity, seasonal changes, and peak visiting hours.
- Protection buffers should be created in sensitive ecosystem zones; landscape restoration and ecological restoration projects should be implemented, especially for damaged mining and surrounding areas.
- Visitor counts, carrying capacity indicators, and ecosystem monitoring data should be collected at regular intervals; based on this data, density control and area management decisions should be periodically updated.
- Thematic ecotourism routes (cave-archaeopark-slow tourism-based routes) connecting focal points such as the Karain–Kocain–Öküzini caves with Evdir/Kırkgöz Han, Döşeme Yolu, Termessos, and Ariassos should be designed; these routes should be marked in a way that ensures a holistic perception of natural and cultural heritage.
- Pressure on the area should be balanced through practices such as timed entry/reservations, visitor quotas, and mandatory guided tours; low-impact usage types should be encouraged through e-bike and trekking trails.
- Low density, adaptation to natural topography, and use of local materials should be adopted as fundamental principles in the location selection for visitor centers and eco-accommodation units (eco-lodges, village guesthouses, etc.); architectural typologies should be standardized in line with these principles.
- "Last mile" solutions (ring minibus routes, micro-mobility systems) that enhance access to natural and archaeological sites via public transportation should be developed, supporting pedestrian and bicycle-priority transportation schemes.

- QR-coded information panels, GIS-based smart maps, and multilingual digital guidance applications should be used at all focal points; route planning, time-elevation profiles, safety warnings, and educational content should be integrated into these platforms.
- Qualified local employment should be supported by creating certification programs covering guidance, first aid, cave/canyon safety, and foreign language proficiency for local guides, operators, and field personnel.
- Agro-ecotourism activities (farmers' markets, agricultural production site visits, gastronomic experiences) and focal points showcasing local crafts such as handicrafts and carpet weaving should be integrated into planned ecotourism routes as official stops; thus ensuring the fair distribution of tourism revenues among the local community.
- An "Ecotourism Governance Board" should be established, consisting of representatives from the municipality, university, civil society organizations, cooperatives, and the private sector; planning, implementation, and monitoring processes should be carried out within a participatory and transparent framework.
- A project portfolio should be developed for EU, UNDP, TÜBİTAK, and similar national/international funding programs; investment processes in ecotourism infrastructure, monitoring systems, and destination branding should be accelerated.
- Education and awareness programs (environmental education, cultural heritage awareness, responsible visitor behavior, etc.) should be organized for the local community, students, and visitors; schools, NGOs, and local governments should play an active role in this process.
- Destination branding efforts highlighting Döşemealtı's natural and cultural values should be carried out; the district's ecotourism identity should be strengthened through organizations such as thematic festivals and walking celebrations, cave and nature sports events.
- Scientific research examining the socio-economic impacts of ecotourism, visitor profiles, habitat fragility, and climate change scenarios should be supported; the findings should be used as key input for regularly reviewing ecotourism strategies.

Thanks and Information Note

The article complies with national and international research and publication ethics. All authors contributed equally to the article.

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Ecological Planning and Spatial Strategy Strategies As a Sustainable Urbanization Approach in The Döşemealtı District Example

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Abstract

Döşemealtı district is one of the central districts of Antalya and is a settlement area that has rapidly become part of the urbanization process in recent years. A large part of the district consists of forest areas, followed by agricultural areas and residential areas. In addition to this natural fabric, points of historical and cultural value, natural conservation areas, agricultural production areas, the Antalya Organized Industrial Zone, and newly developed areas play a decisive role in the spatial development of the district. These factors pave the way for the increasingly rapid development of residential areas and the acceleration of the spatial transformation process, highlighting the need for planned and sustainable spatial development decisions in the district. Within the scope of the study, the current spatial situation of Döşemealtı district was revealed; in this direction, digitization studies were carried out in the ArcGIS environment based on the 1/100,000 scale environmental plan and Google Earth data, and the district's current land use, spatial structure, and natural data were analyzed. Maps of slope, aspect, and water flow direction were produced for the natural environment; protected areas, regions with tourism potential, agricultural areas, forest cover, and settlement areas were mapped in a digital environment. Based on the data obtained, a SWOT analysis was conducted to systematically identify the district's strengths, weaknesses, opportunities, and threats. The findings of the analysis revealed the key parameters to be considered for sustainable spatial development, emphasizing the need to protect natural resources, integrate cultural heritage with tourism potential, and guide controlled urbanization. Consequently, spatial planning proposals supporting the sustainable development of Döşemealtı district were developed in light of the current situation assessments and SWOT analysis findings. In this context, strategic recommendations have been put forward for ecological continuity, green space systems, protected area management, and the integration of agricultural production areas into the planning process, in line with the basic principles of landscape architecture and with due regard for the balance between nature and culture..

Keywords: Döşemealtı, spatial planning, SWOT analysis, sustainable development.

1. Introduction

Throughout human history, cities have been the focal point of economic, social, and cultural development; today, they continue to provide the foundation for civilization to take shape largely in urban spaces. However, the opportunities offered by cities exert significant pressure on the natural environment; rapid urbanization, industrialization, population growth, and changing consumption habits increase the burden on natural resources day by day. Rapid transformations in land use, loss of biodiversity, climate change, soil and water pollution, and the disruption of rural-urban interactions are multidimensional problems that necessitate a rethinking of the relationship between urbanization and nature (Karataş & Kılıç, 2017; Kaya & Taylan Susan, 2020).

This process requires that urban development be considered not only in terms of economic growth and spatial expansion, but also in terms of ecological carrying capacity, social welfare, quality of life, and spatial justice. Sustainability debates have been shaped by the reality that natural resources are limited and that the needs of future generations must also be taken into account; thus, it has become one of the fundamental reference frameworks for urban planning and design disciplines.

In this context, ecological planning stands out as an approach that evaluates natural and cultural landscape components together, placing ecosystem services and environmental sensitivities at the center of the decision-making process. The concept of sustainable urban development based on ecological planning principles aims to reimagine urban growth not by limiting it, but by reframing it within a framework that is compatible with nature, uses resources efficiently, minimizes ecological risks, and strengthens local potential.

This study aims to develop ecological planning and spatial strategy proposals as a sustainable urbanization approach by examining the theoretical background in question at the scale of Döşemealtı district in Antalya province. In this context, sustainable urban development and the ecological planning approach are first discussed theoretically, followed by an assessment of the situation in Turkey to define the purpose, scope, and study area of the research.

1.1. Sustainable urban development and ecological planning approach

The concept of sustainability was first systematically framed in the World Charter for Nature, adopted by the International Union for Conservation of Nature (IUCN) in 1982; it emphasized that ecosystems, organisms, and land–sea–atmosphere resources must be managed at an "optimum level of sustainability" (Yazar, 2016). This understanding necessitates the use of natural resources in a way that considers not only the needs of the present but also the requirements of future generations.

Sustainable urban development refers to the spatial growth processes of cities being guided by taking into account ecological, economic, and social dimensions. Industrialization and urbanization processes, which gained momentum with the Industrial Revolution, have turned cities into areas with the highest energy and water consumption, greenhouse gas emissions, and waste production; unplanned and sprawling urban growth has led to the crossing of natural thresholds and increased ecological risks (Kaya & Taylan Susan, 2020). Therefore, sustainable urban development requires a holistic approach that aims to control urban sprawl, preserve the integrity of natural areas, use resources efficiently, and improve quality of life.

At this point, landscape ecology and landscape planning disciplines provide important theoretical and methodological tools for sustainable urban development. Landscape ecology approaches the landscape as a mosaic composed of different components; it examines the spatial and functional relationships between elements such as patches, corridors, and matrices within this mosaic (Demir & Demirel, 2018). The European Landscape Convention (2000) defines "landscape planning" as a set of forward-looking, fundamental actions aimed at enhancing, improving, or creating new landscapes; it emphasizes an approach based on the balance between conservation and use (Benliay & Yıldırım, 2013).

Translated with DeepL.com (free version)The ecological planning approach aims to shape land use decisions by considering the interaction between natural and cultural landscape components, based on this theoretical foundation. Different layers such as geology, topography, soil, water resources, climate, flora and fauna, agricultural areas, forest areas, settlement areas, transportation networks, and cultural heritage are evaluated together to identify ecologically sensitive areas, risk areas, and potential development areas. Conservation and use are not treated as opposing processes, but as complementary elements that need to be balanced.

Geographic Information Systems (GIS) and multi-criteria decision analyses make the complex choices faced by decision-makers in ecological planning manageable; they enable the comparison of the environmental, social, and economic impacts of different scenarios (Ayhan & Hepcan, 2009; Erkek & Çakır, 2024). Thus, the goal of sustainable urban development moves beyond being an abstract principle and becomes achievable through concrete spatial strategies and planning decisions.

1.2. Sustainable urban development and ecological planning in Türkiye

Discussions on sustainable urban development and ecological planning in Turkey are gaining increasing importance, particularly due to the rapid urbanization, population pressure, and rapid transformations in land use that have accelerated in recent years. Increasing populations in metropolitan cities, new transportation investments, organized industrial zones, and tourism-focused projects are creating significant pressures on agricultural areas, forests, and sensitive ecosystems on the city peripheries (Kaya & Taylan Susan, 2020). Unplanned and fragmented development decisions encourage urban sprawl, disrupting the integrity of natural areas and increasing infrastructure costs.

In the context of rural areas, it is evident that spatial studies on rural settlements in Türkiye have gained importance at both the theoretical and practical levels. The Metropolitan Municipality Law, which came into effect in 2012, transformed numerous villages into neighborhoods within the boundaries of metropolitan municipalities, blurring the administrative and spatial distinction between rural and urban areas. The limited planning experience of local governments regarding rural settlements and uncertainties in legislation create significant problems for municipalities seeking to overcome socio-spatial decline in rural areas through rural development strategies (Çelik, 2006; Akbaş & Kiper, 2022).

In the past, rural planning was often carried out through disjointed policies for sectors such as agriculture, livestock, and forestry; today, there is a growing trend toward holistic policies focused on sustainability. Rural areas are no longer viewed solely as production areas but are also considered in terms of their ecological, cultural, and recreational functions; approaches aimed at balancing the conservation of natural resources with economic development are gaining prominence (Çelik, 2006). In this context, ecological planning has become an important tool that evaluates rural and urban areas as a whole and shapes land use decisions based on ecosystem services, biodiversity, and the balance between conservation and use.

At the urban scale, traditional planning approaches often result in a low-density, horizontally spread-out urban form that inefficiently uses infrastructure and fragments natural areas. Urban

sprawl leads to increased energy and water consumption, higher transportation times and costs, loss of agricultural and forest areas, and disruption of ecological corridors. Within the framework of sustainable urban planning, compact and vertical development, mixed-use urban fabrics, pedestrian- and bicycle-oriented transportation systems, and green infrastructure networks should be supported instead of horizontal sprawl (Tosun, 2013).

Within this general framework, there is both a strong need and ongoing institutional and regulatory developments in the field of sustainable urban development and ecological planning in Turkey. While large-scale environmental plans, spatial strategy plans, and regional plans set out principles and strategies for the protection of ecological thresholds and natural resources, the implementation of these decisions at the local level is often limited. Therefore, developing ecological planning-based spatial strategies in districts and sub-regions located in the hinterland of metropolitan cities is of critical importance for the concretization of sustainable urban development.

The district of Döşemealtı, located north of the Antalya metropolitan area, provides a striking example in this context. The district, which contains numerous natural and cultural assets such as vast forest areas, fertile agricultural lands, caves, canyons, inns, ancient cities, and the Döşeme Road, is also under intense development pressure due to its Organized Industrial Zone, transportation axes, and new residential areas. Achieving the goal of sustainable urbanization in Döşemealtı requires, on the one hand, the protection of natural and agricultural areas and, on the other hand, the management of industrial, tourism, and residential functions while observing environmental thresholds.

1.3. Purpose, scope, and field of study

Located north of the Antalya metropolitan area, Döşemealtı district is home to extensive forest areas, fertile agricultural lands, cave systems, ancient cities, caravanserais, and historical-cultural focal points such as Döşeme Yolu. It is also a district under intense development pressure due to its Organized Industrial Zone, airport, new residential areas, and main transportation axes. While the district had an economic structure based on agriculture, animal husbandry, and carpet weaving for many years, it has entered a transformation process in which industry and urban functions have gained prominence over time (Döşemealtı Belediyesi, 2025). This transformation necessitates the redefinition of spatial relationships between natural and agricultural areas and residential and industrial areas, taking ecological thresholds into account.

The primary objective of this study is to develop spatial strategies based on ecological planning principles in line with the goal of sustainable urbanization in the Döşemealtı district of Antalya province. Within this scope, the 1/100,000 Environmental Planning Map sheets for the Antalya–Burdur–Isparta Planning Region, prepared by the Ministry of Environment, Urbanization, and Climate Change, were used as the primary data source. These sheets were digitized in a GIS environment, and the distribution of forests, agriculture, settlements, industry, transportation, tourism, protected areas, and other functions at the district level was analyzed. The spatial data obtained was compared with Google Earth satellite images and updated, thus accurately revealing changes in current land use.

Based on the findings of the analysis, a SWOT analysis was conducted for the district of Döşemealtı; the strengths, weaknesses, opportunities, and threats for the district as a whole were systematically identified. These assessments reveal the fundamental parameters that must be considered for sustainable spatial development and emphasize the need to protect natural resources, integrate cultural heritage with tourism potential, and guide controlled urbanization. At the end of the study, spatial strategy proposals based on ecological planning principles were developed under four main thematic axes: green space–settlement–transportation, tourism, agriculture–livestock, and industry–energy. thus presenting a development model for Döşemealtı district that is in harmony with nature, while also offering an applicable framework for other urban hinterland areas with similar characteristics.

2. Materials and Methods

2.1.Material

The settlement, named after Kırkgöz Lake which feeds the Düden Waterfall, was established in 1934 as Kırkgöz–Yeniköy when families from the Kızılcadağ area of Korkuteli settled there. Later, it grew into a village with the settlement of 60 Turkish families from Cyprus in 60 housing units built by the then Governor of Antalya, Haşim İşcan, and the transition of the Yörük nomads living in the region to a settled life. Located approximately 20 km from Antalya on the Antalya–Burdur highway, the settlement was established in the 1970s with the Döşemealtı Subdistrict Directorate and included Duacı, Kirişçiler, Kevşirler, Başköy, Odabaşı, Selimiye, Dereli, Çıplaklı, Kızıllı, Ekşili, Karaveliler, Killik, Camili, Ahırtaş, Bıyıklı, Kömürcüler, Yağca, Çığlık, Nebiler, Yukarı Karaman (now Düzlerçamı), Yeşilbayır, Dağbeli, and Bademağacı. Although the municipalities of Dağbeli and Bademağacı were established in 1973, it retained its status as the center due to its proximity to Antalya. Kırkgöz–Yeniköy established its municipal organization on December 17, 1977, when its population reached 2,711, and was named “Döşemealtı Town.” The name “Döşemealtı” comes from the approximately 4 m wide paved stone road that passed through the Derbent Pass and connected the cities of Pamphylia and Pisidia in ancient times, and continued to function during the Byzantine, Seljuk, and Ottoman periods. The local people named the pass through which the road passed “Döşeme Boğazı” (Paved Pass) and the plain below the road “Döşemealtı” (Under the Paved Road). For many years, the district had an economic structure based on agriculture, relying on the production of cotton, olives, wheat, barley, corn, oats, sesame, onions, citrus fruits, and various vegetables and fruits, as well as small and large livestock farming and Döşemealtı carpet weaving. Today, Döşemealtı has become urbanized and one of the central districts of Antalya. With the establishment of the Organized Industrial Zone, employment has shifted predominantly toward the industrial sector (Döşemealtı Belediyesi Tarihçesi, 2016).



Figure 1. Location of the work area

2.2. Method

This study uses the 1:100,000 scale Environmental Planning Map (sheets O24, O25, N24, N25) for the Antalya–Burdur–Isparta Planning Region, published by the Ministry of Environment, Urbanization, and Climate Change, as its primary data source (Çevre Şehircilik ve İklim Değişikliği Bakanlığı Antalya-Burdur-Isparta Planlama Bölgesi, 2025). The plan sheets were placed on the 1/100,000 sheet index using the "Georeferencing" tool in the ArcMap environment to ensure coordinate accuracy and determine the spatial boundaries of the study area. The data on the plan sheets were digitized in ArcMap, the obtained data were updated by comparing them with Google Earth satellite images, and thus the changes in the current land use were accurately identified. The updated data was subjected to area calculation processes in the ArcGIS environment, and the calculated values revealed the current land use at the district level. Based on the spatial analyses obtained, the current situation was evaluated, and planning decisions for the future were developed in line with the principles of conservation-use balance, sustainable development of settlement areas, and protection of natural areas.

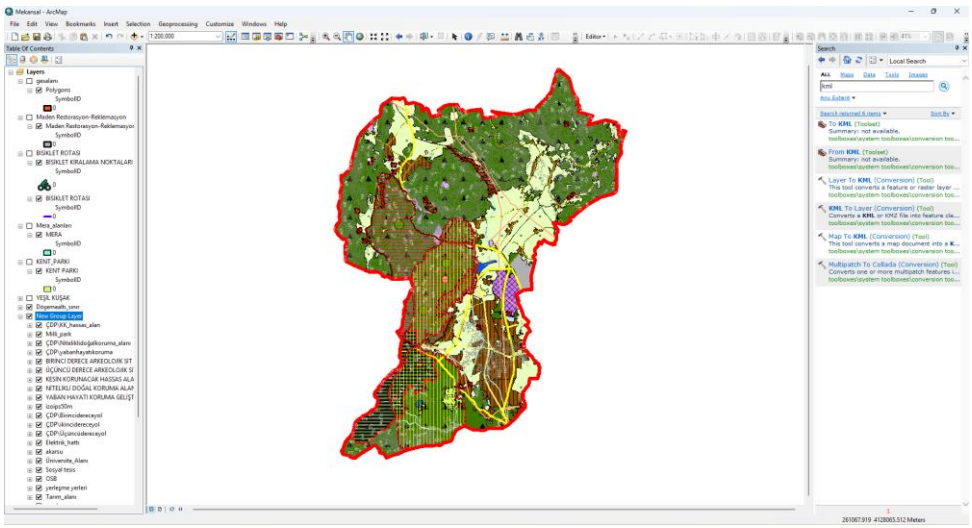


Figure 2. Digitized Döşemealtı District in ArcGIS environment

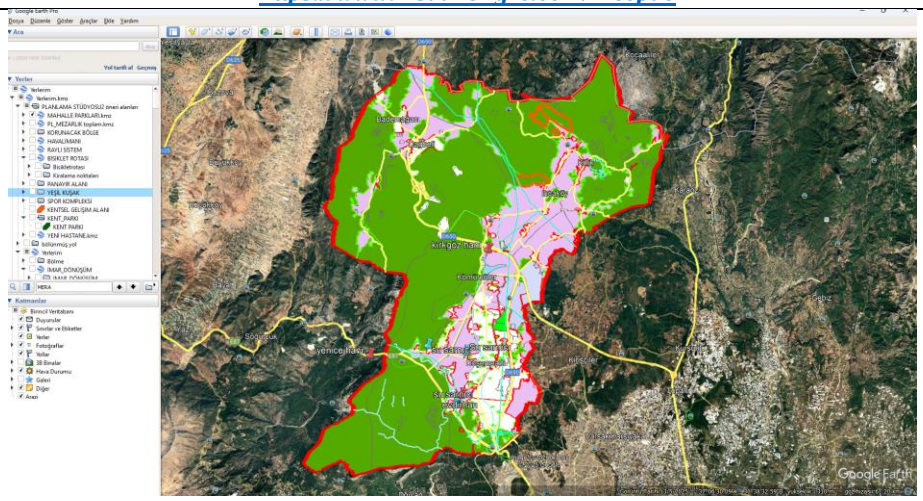


Figure 3. Google Earth satellite image

3. Findings

Figure 4 shows the current land use pattern and protection statuses of Döşemealtı district in a comprehensive manner. Examination of the map reveals that the presence of national parks, wildlife protection areas, archaeological sites, and qualified protection areas within the district boundaries demonstrates that Döşemealtı has an extremely rich potential in terms of both natural and cultural heritage. At the district level, forest areas are scattered in large masses, covering a large part of the study area and forming a strong “natural matrix” in terms of the ecological network and green infrastructure design. The agricultural areas, which occupy a large space between these forest masses and settlement axes, are located as a mosaic transition zone in the vicinity of both rural settlements and the district center, forming the district's main production areas. Settlement areas are concentrated mainly along the main transportation axes and around the Antalya–Burdur highway; this indicates a linear urban development model spreading along the axes and the risk of uncontrolled sprawl. With the expansion of settlement areas over time, some agricultural parcels that previously formed a cohesive fabric have become islands within the settlement fabric, threatening the continuity of agricultural production and land integrity. The fact that built-up functional areas such as Organized Industrial Zones (OIZ) and airports are mostly located on flat topography, intertwined with forest and agricultural areas, indicates that industrial and infrastructure uses may exert pressure on both agricultural lands and ecological corridors in the medium and long term and may reinforce the trend of shifting the production structure from agriculture to industry. Water surfaces, energy production areas, urban green areas, and social service areas are observed on the map as more fragmented and point-like uses, indicating that the spatial distribution of green corridors that ensure ecological continuity and open-green space systems that support urban quality of life is a critical input for planning. The university campus located within the district boundaries forms an important center of attraction with its educational and research functions, adding an additional layer to the district's socio-economic and spatial development dynamics and carrying the potential to directly influence the future transformation of the aforementioned land use pattern.

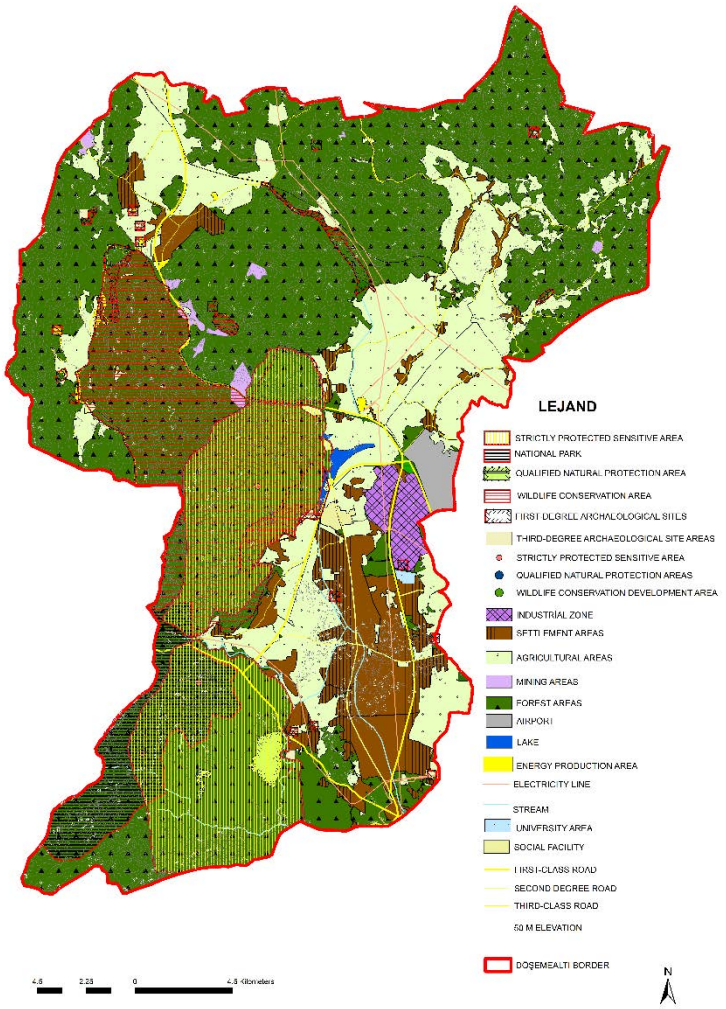


Figure 4. Floor-level existing condition map

The study reveals that the land use pattern in Döşemealtı is shaped primarily around forest areas, agricultural areas, residential areas, and the Organized Industrial Zone (OSB). Forest areas cover a significant portion of the district's total area at 46,628.75 ha, providing a robust ecological infrastructure for the conservation of biological diversity, climate regulation functions, and the balancing of the water regime. Agricultural areas rank second with 16,092.83 ha and are a critical resource for both the district economy and food production on a regional scale. The protection of these areas is of strategic importance when considering the pressures that factors such as the climate crisis, population growth, and water stress may exert on food security in the coming years. The fact that settlement areas cover 7,268.31 ha and the OSB area covers 867.08 ha indicates that urban growth and industrial activities have the potential to exert increasing pressure, particularly on agricultural and forest areas (Table 1). Mining activities within the district boundaries, although covering a relatively limited area, stand out due to their negative effects on habitat destruction and soil degradation, as well as on surface and groundwater resources. High water consumption and potential pollution risks in mining processes can negatively affect irrigation opportunities in agricultural areas and the water cycle of ecosystems; this situation has the potential to weaken both the ecological balance and

agricultural production capacity in the long term. Therefore, in line with the goal of sustainable urbanization in Döşemealtı, it is crucial to comprehensively protect forest and agricultural areas, limit the pressure that residential and industrial zone expansion may exert on these areas, and meticulously monitor the ecological and hydrological impacts of mining activities.

Table 1. Area measurements

AREAS	AREAS THEY COVER
FOREST AREA	46628.75 ha
AGRICULTURAL AREAS	16092.83ha
SETTLEMENT AREA	7268.31 ha
INDUSTRİAL ZONE	867.08 ha
AIRPORT	553.38 ha
MINING AREA	394.24 ha
WATER SURFACES	231.06 ha
ENERGY PRODUCTION AREA	48.3504 ha
URBAN GREEN SPACE	27.4327 ha
SOCIAL SERVICES FIELD	123.62 ha

When examining Figure 5, which shows the ratios of the given area sizes within the total district area, it can be seen that forest areas constitute the largest part of the district area with approximately 64.5%, while agricultural areas rank second with a share of approximately 22.3%. Settlement areas account for approximately 10.1%. Within industrial and infrastructure uses, OSB areas account for approximately 1.2% of the total, while the airport accounts for around 0.8%. The share of mining areas is approximately 0.5%, while the share of water surfaces is 0.3%. The share of other functions, such as the university area, energy production area, urban green area, social service area, and the Mediterranean Research Institute of Aquatic Products, is less than 1% each. Although these are important in terms of urban quality of life and ecological sustainability, they are quantitatively quite limited. This distribution reveals that, on the one hand, Döşemealtı has strong forest and agricultural area potential and, on the other hand, it presents an important window of opportunity for transitioning to a sustainable urbanization model if urban green areas, social facilities, and environmentally compatible investment areas are increased in a planned manner.

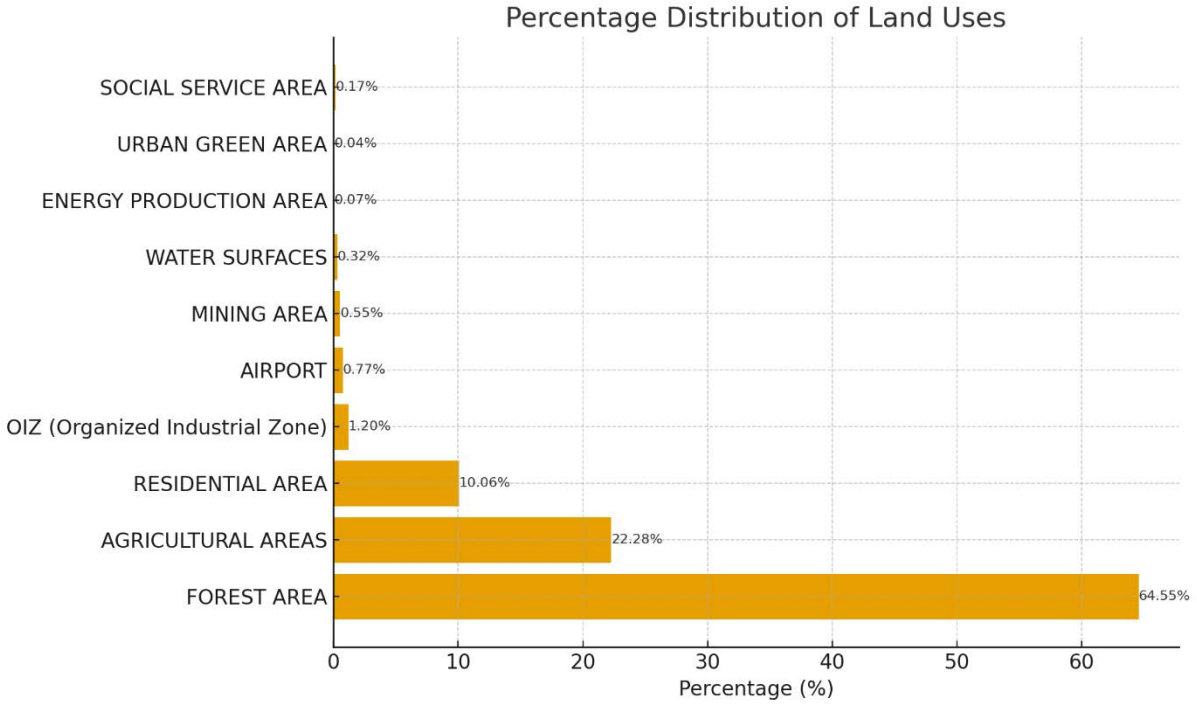


Figure 5. Percentage distribution of areas

SWOT Analysis

Strengths

- The high proportion of forests and natural areas throughout the district; providing strong "natural capital" for ecological networks and green infrastructure design.
- Strong agricultural production potential thanks to fertile agricultural land, irrigation facilities, and suitable climate conditions.
- The concentration of rich cultural and natural heritage elements such as caves (Karain, Kocain, Öküzini), canyons, inns, ancient cities, and the Döşemealtı Road in the same basin.
- The existence of local cultural values such as Yörük culture, Döşemealtı carpets, and rural life practices, and their potential to be transformed into tourism products.
- Proximity to Antalya city center, potential for integration with main highways and rail systems, thus making it accessible and strategically located.
- The existing Organized Industrial Zone creates employment and lays the groundwork for planned development by concentrating industrial activities within a specific area.

Weakness

- The proportion of urban green spaces and social areas is quite low relative to the total area; the amount of active green space per person is insufficient.
- Settlement areas tend to spread out along certain axes; there is a risk of uncontrolled urban sprawl.

- Inadequate visitor management, guidance, and recreation design in some natural and cultural heritage areas.
- Occasional overlap between industrial zones, transportation axes, and settlement areas with agricultural and forest areas; the potential for this to create fragmentation and environmental pressure in ecological corridors.

Opportunities

- Increased interest in climate change, ecological planning, and sustainable urbanization at the national and international levels; availability of related grant and project resources.
- Rising demand for ecotourism, agrotourism, and cultural tourism; Döşemealtı's potential for branding through thematic routes featuring caves, canyons, and ancient cities.
- Strengthening low-carbon transportation and improving district-city integration with the development of a rail system line extending to Antalya city center.
- Favorable climate and land conditions for renewable energy investments, particularly solar energy and biogas.
- Support for rural development through organic production in agriculture and livestock farming, branding of local products, rural cooperatives, and producer markets.

Threat

- Population growth, housing demand, and land speculation putting agricultural areas and forests under settlement pressure.
- The expansion trend of industrial zones and industrial areas; the risk of increased air, water, and soil pollution, as well as noise and traffic congestion during this process.
- Increased environmental risks such as drought, extreme rainfall, water scarcity, and forest fires due to climate change.
- The possibility of irreversible damage to cave systems, canyons, and sensitive ecosystems if transportation capacity is not taken into account in ecotourism and recreational activities.
- Frequent revision of high-level planning decisions due to political/economic pressures; risk of increased plan changes and fragmented implementation processes that disregard ecological thresholds.
- When no compromise can be reached between the economic expectations of local communities and conservation objectives, increased social resistance to conservation decisions and illegal construction.

4. Conclusion and Recommendations

The 1/100,000 scale Environmental Planning data and GIS-based analyses for Döşemealtı district reveal that forest areas constitute a very high proportion of approximately 83% of the dominant land use type in the study area; in contrast, settlement areas and, in particular, urban green spaces and social service areas remain quantitatively quite limited. The location of the Organized Industrial Zone and the airport, intertwined with forest and agricultural areas, mostly

on flat topography, indicates that the pressure of urban development may increase its impact on natural areas and agricultural lands in the future. This distribution shows that, on the one hand, Döşemealtı has strong forest and natural area potential, and on the other hand, open-green areas that support ecological continuity and urban quality of life need to be strengthened in a planned manner.

Based on these findings, a strategic framework has been developed for the district that centers on ecological planning principles and aims for a balanced spatial organization between agriculture, industry, tourism, and settlement functions. Based on these findings, a strategic framework has been developed for the district that centers on ecological planning principles and aims to achieve a balanced spatial organization between agriculture, industry, tourism, and settlement functions. The study evaluates Döşemealtı through a sustainable urbanization model that simultaneously considers the protection of natural areas, the promotion of green transportation, the use of renewable energy, and the preservation of local cultural values. The proposed model has been transformed into spatial strategy recommendations based on four main thematic axes: green space–settlement–transportation, tourism, agriculture–livestock, and industry–energy.

In conclusion, Döşemealtı's natural landscape, agricultural production potential, and cultural heritage offer important “reserve landscape capital” for the sustainable development of the Antalya metropolitan area. Preserving and utilizing this capital necessitates an urbanization approach that is guided by ecological thresholds and carrying capacity, rather than uncontrolled urban sprawl and industry-focused growth. The ecological planning and spatial strategy approach developed within the scope of this study presents an innovative and livable urban model that is compatible with nature at the district level; it also serves as an adaptable example for other hinterland districts of Antalya.

Within this framework, the fundamental spatial strategy recommendations developed based on the study findings are summarized below:

- Urban development boundaries should be clearly defined; new developments should be directed within controlled-density development areas that integrate with the existing settlement fabric and are based on a maximum of four stories.
- The amount of active green space per person across the district should be increased; a green infrastructure/green corridor system should be established to ensure continuity between forest areas, city parks, recreation areas, and stream corridors.
- Open-green areas should be designed according to climate-resilient design principles through rainwater harvesting, permeable pavement use, and microclimate-improving vegetation decisions.
- The rail system line from Antalya city center should be extended to Döşemealtı and supported by bicycle paths and pedestrian axes to strengthen the low-carbon transportation network. This will reduce dependence on private vehicles, creating a positive impact on both air quality and carbon emissions.
- Ecotourism routes connecting the Karain, Kocain, and Öküzini caves with Evdir Han, Döşeme Yolu, and other nearby archaeological sites should be created; these routes

should be supported by urban forests, recreation parks, festival and fairgrounds, and bicycle and pedestrian paths.

- Local cultural values such as Yörük culture and Döşemealtı carpet weaving should be transformed into tourism products through visitor centers, open-air exhibition areas, and traditional handicraft workshops.
- Visitor management plans should be prepared for tourism activities, taking into account carrying capacity, area sensitivity, and seasonality; low-density ecotourism models that do not put pressure on natural and cultural heritage and from which the local population derives direct economic benefit should be supported.
- Strict protection measures should be implemented for prime agricultural land and irrigable areas, and urban and industrial development should not be permitted in these areas. Agricultural production should be diversified with climate-compatible crop patterns that do not exceed the carrying capacity of soil and water resources.
- The designated “livestock development zone” should be supported with modern and environmentally friendly production techniques; circular economy principles should be applied through facilities focused on waste management, biogas production, and fertilizer recycling.
- The income level of local producers should be increased and the retention of the rural population should be encouraged through rural cooperatives, producer markets, and agro-tourism practices based on agriculture-tourism integration.
- Industrial development should be limited within the boundaries of the existing Organized Industrial Zone; new industrial area requests should be evaluated taking into account environmental impacts and ecological thresholds. Plan notes mandating green infrastructure, energy efficiency, and clean production standards should be developed within the OSB.
- Renewable energy sources (primarily solar and biogas) should be prioritized at the district level, with the aim of meeting a significant portion of the energy needs of both industrial establishments and rural settlements from local and clean sources.
- The environmental burden of the OSB should be reduced through wastewater treatment and solid waste recycling practices; the relationships between industry, agriculture, and settlements should be reconfigured to minimize environmental risks.

Finally, the proposed spatial strategies should not remain solely at the level of planning notes and land use decisions; they must be supported by participatory planning, institutional collaboration, and monitoring and evaluation mechanisms. When a governance model based on regular data sharing is established, bringing together local government, OSB management, professional associations, civil society organizations, and universities around the same table, it will be possible to achieve Döşemealtı's vision of sustainable urbanization based on ecological planning principles.

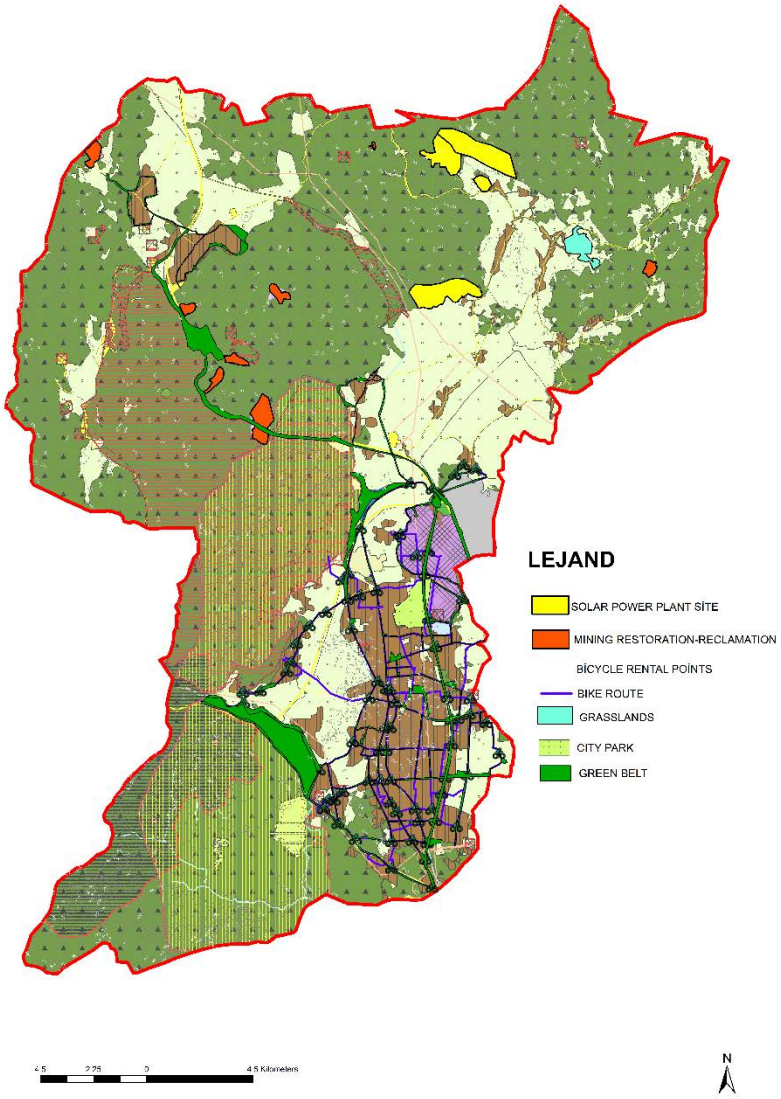


Figure 5. Floor Space Utilization Recommendation Map

Figure 5 shows the main proposed areas developed for Döşemealtı district. Solar energy production areas have been proposed in suitable regions to support energy production; restoration and rehabilitation works are envisaged for existing mining areas to improve them ecologically and visually. Pasture areas have been designated to support animal husbandry and rural development; at the urban scale, new green space uses have been planned to increase the amount of green space per capita and to provide the city's population with access to quality recreational areas. Bicycle paths and bicycle rental points have been proposed to support the transportation network, reduce carbon emissions, and limit the use of motor vehicles. Furthermore, green areas have been designed as ecological thresholds to ensure the continuity of the green fabric within and outside the city and to create a restrictive/regulatory function at the city's periphery.

Thanks and Information Note

The article complies with national and international research and publication ethics. All authors contributed equally to the article.

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Smart Agriculture in Protected Areas: Synergies of Vertical Farming, AgriVoltaic Systems, and Nature-Based Water Management

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Abstract

Protected areas are essential for biodiversity conservation, ecosystem resilience, and the provision of critical ecosystem services. However, these regions face increasing pressures from surrounding agricultural activities, which can lead to habitat fragmentation, soil degradation, and water overuse. This study examines the integration of climate-smart agricultural approaches, vertical farming, agrivoltaic systems (AvS), and nature-based water management. to enhance food security while minimising environmental impact in and around protected areas. Vertical farming and soilless cultivation techniques, including hydroponics, aeroponics, and aquaponics, enable high-density crop production in controlled environments, reducing land-use pressure and chemical inputs. AvS combine solar energy generation with crop cultivation, promoting efficient land use, reducing carbon footprints, and providing additional income for rural communities. Nature-based water management strategies, such as rainwater harvesting, artificial wetlands, and sand dams, optimise irrigation efficiency and support ecosystem resilience. Case studies from Türkiye (Istanbul, Ankara, Konya Plain, GAP regions) and internationally (Singapore, Japan, Germany, France, India, Israel, Kenya) illustrate the practical applications, benefits, and challenges of these approaches. The findings indicate that integrating these strategies creates synergistic effects that balance agricultural productivity, renewable energy generation, and conservation objectives. Nevertheless, challenges such as high initial investment, energy consumption, technical complexity, policy constraints, and social acceptance remain critical considerations. This study provides policy recommendations for pilot projects in buffer zones of protected areas, emphasises the role of cooperatives and rural communities, and identifies research gaps related to long-term ecological effects, cost-benefit analysis, and socio-economic feasibility. By combining innovative agricultural technologies with nature-based solutions, climate-smart agriculture can support sustainable food systems while preserving biodiversity and ecosystem services in sensitive landscapes.

Keywords: AgriVoltaic systems, nature-based solutions, protected areas, climate-smart agriculture, water management, biodiversity conservation

1. Introduction

Protected areas are designated regions established to conserve biodiversity, maintain ecosystem integrity, and protect natural resources. These areas play a crucial role in preserving habitats for endangered species, maintaining genetic diversity, and ensuring ecosystem resilience to environmental change. Beyond biodiversity conservation, protected areas provide a range of ecosystem services, including carbon sequestration, soil stabilisation, water regulation, and climate regulation. These services are essential not only for ecological sustainability but also for supporting local livelihoods and regional development. Globally, protected areas are a cornerstone of conservation strategies and contribute to international frameworks such as the Convention on Biological Diversity and the United Nations Sustainable Development Goals (Urban & Hametner, 2022). Effective management of these areas is crucial for achieving long-term ecological and socio-economic objectives.

Despite their conservation aims, protected areas are often under pressure from surrounding agricultural activities. Balancing food production with biodiversity conservation creates complex land use challenges. Agriculture can introduce multiple stressors, including habitat

fragmentation, soil degradation, pesticide leaching, and excessive water use, all of which threaten the ecological integrity of protected areas. Conflicts may also arise when agricultural expansion encroaches on protected areas or when conservation restrictions limit the productive use of adjacent land (Jayaraman et al., 2021). Addressing these conflicts requires integrated management approaches that reconcile agricultural productivity with ecosystem conservation.

Sustainable agriculture offers a means to mitigate the negative impacts of farming while maintaining productivity. In the context of protected areas, sustainable practices aim to optimise resource use, minimise environmental degradation, and promote ecosystem health (Eggermont et al., 2015). Complementing these practices, nature-based solutions (NbS) use natural processes and ecosystems to address societal challenges such as water management, soil fertility, and climate adaptation. Integrating sustainable agriculture with NbS presents significant opportunities for synergistic outcomes: productive agricultural systems can coexist with conservation objectives and contribute to both food security and biodiversity conservation. Innovative approaches such as vertical farming, agrivoltaic systems (AvS), and water-efficient management demonstrate how agricultural systems can be adapted to support ecological and social resilience in sensitive landscapes (Panotra et al., 2024).

Building on this framework, this study explores three key questions:

1. How can vertical farming and soilless cultivation contribute to sustainable food production in or near protected areas?

2. What potential do AvS have to simultaneously generate renewable energy and maintain agricultural productivity while supporting conservation goals?

3. How can nature-based water management solutions improve irrigation efficiency and ecosystem health in protected agricultural landscapes?

These questions are crucial for developing management strategies that combine modern agricultural innovations with the protection of protected areas. By exploring these approaches, the study aims to identify ways to harmonise food production, renewable energy generation, and ecosystem protection to ultimately support the sustainable management of protected areas.

2. Materials and Methods

2.1. Literature Review Approach

A systematic literature review was conducted to collect up-to-date information on sustainable agricultural practices in Türkiye and globally. Keywords such as sustainable agriculture, climate change adaptation, and food security were used. Peer-reviewed articles, conference proceedings, and reliable reports published after 2015 were included. This period was selected to align with the Paris Agreement and the Sustainable Development Goals. Studies focusing solely on traditional agriculture and lacking scientific evidence were excluded.

2.2. Case Study Selection

Case studies were selected based on whether sustainable agricultural practices demonstrated measurable environmental, economic, and social outcomes. While examples from Türkiye were primarily included, international cases were also considered for comparison. Studies featuring innovative methods, documented results, and scalability were prioritised.

2.3. Data Sources

The study used databases such as Web of Science, Scopus, and Google Scholar, and searched journals such as "Agriculture, Ecosystems & Environment," "Journal of Cleaner Production," and "Sustainability." In addition, FAO reports and, specifically for Türkiye, publications from the Ministry of Agriculture and Forestry and national research institutions were used.

3. Findings and Discussion

3.1. Vertical Farming and Soilless Agriculture

Vertical farming is an innovative agricultural method in which crops are grown in stacked layers or on vertically inclined surfaces, often within controlled indoor environments. This approach employs soilless cultivation techniques such as hydroponics, aeroponics, and aquaponics. In hydroponics, plants are grown in nutrient-rich water solutions; in aeroponics, plant roots receive nutrients via mist (Urban & Hametner, 2022); and in aquaponics, fish farming is combined with plant cultivation, with fish waste providing organic nutrients for the plants.

Vertical farming offers numerous advantages over traditional agriculture, particularly in urban areas where space is limited. By maximising vertical space, these systems can achieve significantly higher crop yields per square metre than traditional farming methods. The controlled environment enables year-round cultivation, regardless of external weather conditions, and allows precise control of temperature, humidity, and light levels. This level of control not only optimises plant growth but also reduces the need for pesticides and herbicides, resulting in cleaner, potentially organic produce (Blom et al., 2022).

In addition, vertical farming systems are extremely water efficient, using up to 95% less water than conventional farming methods. This is achieved through water recirculation systems and the avoidance of water loss in soil. The proximity of vertical farms to urban centres also reduces transport costs and carbon emissions associated with distributing food over long distances. As the world's population continues to urbanise and climate change affects traditional agriculture, vertical farming represents a promising solution for sustainable food production, with the potential to revolutionise urban food systems and improve food security in densely populated areas (Martin et al., 2019).

3.1.1. Impact on Protected Areas

The introduction of vertical farming can have significant effects on protected areas and biodiversity conservation. By relocating agricultural production to urban environments, this innovative approach greatly reduces the need for extensive agricultural land, which often encroaches on natural habitats. Vertical farms make efficient use of vertical space, allowing crops to be grown in multi-storey structures, on rooftops, and in converted buildings within cities (Köthe et al., 2023). This city-centred model of food production helps reduce pressure on rural and wild areas and may halt or reverse the trend of habitat destruction for agricultural purposes.

Conserving natural habitats through vertical farming extends beyond simply preserving land. By reducing the need for traditional agricultural practices in rural areas, vertical farming can help restore ecosystem connectivity and maintain wildlife corridors. This, in turn, promotes biodiversity by enabling species to move freely between protected areas, increasing genetic diversity and population resilience (Hilty et al., 2020). Additionally, the reduced use of pesticides and fertilisers in vertical farming systems can minimise chemical runoff into nearby

ecosystems, further protecting the integrity of surrounding natural habitats and waterways. As cities adopt vertical farming technologies, they can become not only centres of human life but also unexpected allies in the conservation of global biodiversity.

The Sky Greens vertical farm in Singapore exemplifies the potential of innovative agricultural technologies to address food security challenges in land-poor areas. The farm's rotating tower system, which ensures even light distribution for all crops, demonstrates the ingenuity required to overcome the limitations of traditional agriculture. With the capacity to produce up to ten times the yield per unit area compared to conventional farming methods, Sky Greens illustrates the economic viability and efficiency of vertical farming. This low-carbon, hydraulically powered system aligns with Singapore's sustainability goals and serves as a model for other urban areas seeking to improve food production capabilities while minimising environmental impact.

3.1.2. Case studies

İstanbul (Indoor Vertical Farming Application Centre): Türkiye

The Istanbul Indoor Vertical Farming Application Centre, established by the Ministry of Agriculture and Forestry on the 8th floor of the New Cultural Centre Complex in the Kağıthane district, is 30 metres underground and serves as the world's second-deepest vertical farming production unit. This centre uses hydroponic systems and LED lighting technologies to produce high yield crops year-round. By reducing water consumption by 99%, it produces more crops in just 320 square metres than would normally be possible in a 20,000-square-metre area with traditional farming. Furthermore, this centre uses no pesticides in its production (Tarım ve Orman Bakanlığı, 2022).

Sky Greens, Singapore

Zhang et al. (2025) investigated the development of multifunctional agrivoltaic building envelope (ABE) systems in Singapore. These systems combine building-integrated photovoltaic (BIPV) technology with hydroponic vertical farming modules on building facades. The research focuses on optimising space utilisation in high-density urban environments by integrating solar energy production with urban agriculture.

Miyagi Prefecture's Vertical Farming Practices: Japan

Vertical farming was introduced in Miyagi Prefecture, Japan, after the 2011 Great East Japan Earthquake. These practices aim to ensure the continuity of food production following the disaster and to reduce environmental impacts. Vertical farming is emerging as a solution to challenges such as an ageing population and urbanisation in Japan (Liu et al., 2022).

Vertical Farms in Urban Parking Lots: Israel

An Israeli agri-tech startup has developed vertical farms in urban environments by utilising underused spaces such as city parking lots. These vertical farms, developed by the Ra'anana-based company Vertical Field, use hydroponic systems to grow fresh produce, addressing space constraints in densely populated areas. This initiative contributes to urban food security and sustainable agricultural practices (Reich, 2020).

Tatton Agriculture Park's Uptake of Vertical Farming: Kenya

A study conducted by Njoroge (2023) examined the adoption of vertical farming practices at Tatton Agriculture Park in Kenya. The research identified opportunities and perceived barriers

for farmers regarding the implementation of vertical farming techniques. The findings provide insights into the factors influencing the uptake of innovative agricultural practices in the region.

3.2. AgriVoltaic Systems

Agrivoltaic systems offer an innovative approach to land management, addressing the growing demand for both renewable energy and agricultural production. By integrating solar panels with crop cultivation, these systems create a symbiotic relationship between energy and food production. In AvS, solar panels are typically mounted above the crop canopy, allowing sufficient sunlight to reach the crops while generating electricity at the same time. This arrangement can lead to higher land productivity, as the same area is used for two purposes simultaneously (Pascaris et al., 2020).

The benefits of AvS extend beyond efficient land use. The presence of solar panels can create a microclimate that benefits certain crops by providing partial shade, reducing water evaporation, and protecting crops from extreme weather. Additionally, revenue from electricity generation can provide farmers with a stable supplementary income, enhancing the economic viability of farms. As global concerns over food security and clean energy production continue to grow, AvS present a promising solution that can balance these competing land use needs while improving overall system efficiency.

3.2.1. Impacts on Protected Areas

AvS integrate agriculture and energy production on the same land, supporting both food security and the preservation of natural habitats. In these systems, solar panels are positioned above vegetation, enabling electricity generation and agricultural production. This reduces the need for new agricultural land and minimises agricultural pressure on protected areas (Pascaris et al., 2020).

The partial shading provided by the panels reduces water loss, particularly in areas where sensitive plant species grow, and helps protect against soil erosion. This microclimate effect supports the natural water cycle in arid and semi-arid regions, strengthening both agricultural and ecosystem health. Furthermore, AvS systems help reduce the use of chemical fertilisers and pesticides, limiting chemical runoff into surrounding water resources and neighbouring habitats.

Projects in Ayaş and Konya in Türkiye demonstrate the indirect benefits of these systems to protected areas. Hybrid solar- and wind-assisted irrigation systems, particularly in the Konya Plain, have reduced environmental pressure by combining energy and agricultural production (Köse et al., 2019). By limiting the development of new agricultural land in rural areas, AvS indirectly supports the preservation of natural habitats and helps maintain biodiversity.

In addition, AvS offer further advantages for protected areas in relation to climate change adaptation. Movable panels or V-shaped arrangements optimise sunlight, maximise plant photosynthesis, and simultaneously increase energy production capacity. These designs provide models that reduce ecosystem pressure while ensuring sustainable production in areas adjacent to protected areas (Campana et al., 2024; Tiffon-Terrade et al., 2023).

Consequently, AvS not only combine energy and agricultural production but also represent a strategic solution that supports environmental sustainability in regions where protected areas are under pressure. These systems contribute to the preservation of natural habitats while also

providing economic and social benefits, offering additional income for farmers and safer food production for communities.

3.2.2. Case Studies

Konya (Hybrid Solar/Wind System for Irrigation): Türkiye

An experimental study by Köse et al. (2019) examined a hybrid solar/wind irrigation system in the Konya Plain. The results showed that renewable energy-supported irrigation reduces dependence on fossil fuels, increases the sustainability of agricultural production, and that agrivoltaics systems can contribute to water management. This study is considered one of the first steps towards agrivoltaics applications in Türkiye.

Central Anatolia (Sugar Beet and Wheat – System Design): Türkiye

Yalçın et al. (2025) examined the design of agrivoltaics systems for sugar beet and wheat production in Central Anatolia. Different panel configurations were compared, and V-shaped systems, in particular, were shown to offer advantages in both photosynthetic light utilisation and energy production. Additional benefits, such as the potential for rainwater harvesting, were also identified. However, due to the limited scale of the study, caution is warranted in generalising the results.

Ankara (Ayaş Agrivoltaics Research Project): Türkiye

In 2023, Türkiye launched its first agrivoltaics research project in Ayaş, Ankara. The project features a single-axis solar tracking system integrated with agricultural activities. Collaborating institutions include the Ayaş District Directorate of Agriculture and Forestry, the ODTÜ-GÜNAM Centre for Solar Energy Research and Applications, and a local farmer. This initiative aims to explore the potential of combining solar energy production with sustainable agriculture in Türkiye's capital region (Meza, 2023).

National Level (Simulation of Agrivoltaics Integration): Türkiye

Coşgun et al. (2024) analysed the agrivoltaics potential in different regions of Türkiye using PVsyst software. Provinces such as Konya, Kayseri, and Manisa stood out, with promising results in both energy production capacity and agricultural adaptation. While the study provides guidance for policy development and investment planning, the lack of field applications necessitates practical testing of the simulation findings.

Heggelbach Research Facility (Field Crops and Vegetables): Germany

Trommsdorff et al. (2021) examined the design of agrivoltaic systems integrated with barley and vegetable production at the Fraunhofer Institute's Heggelbach research facility in Germany. The study evaluated different panel arrangements and heights; results showed both high efficiency in energy production and competitive agricultural yields. Additionally, shading was reported to have a stress-reducing effect on some vegetables. These findings provide pioneering field data supporting the practical feasibility of agrivoltaics in Europe.

Greenhouse Applications (Comparative Context): Sweden

Campana et al. (2024) conducted a field study in northern latitudes to examine the effects of AvS on both biomass yield and economic feasibility. The study showed that shading did not cause a significant loss in grass yield and that land equivalent ratio values were above 1. These

findings demonstrate the feasibility of AvS in Swedish conditions, both for agricultural production and energy efficiency.

Sun'Agri Dynamic Agrivoltaics (Vineyards and Orchards): France

Dynamic agrivoltaics applications implemented by Sun'Agri offer pioneering examples in France, particularly in the viticulture and fruit-growing sectors. In these systems, solar panels are designed with movable mechanisms that can be adjusted according to plant needs. This allows the panels to maintain the light necessary for photosynthesis in vineyards and orchards while also providing protection against climate risks such as extreme heat, drought, and hail. A case study published by Campbell Scientific (2020) reported that this technology provides both high energy efficiency and improved product quality. Furthermore, it is strategically important for producers, as it creates income diversification and supports adaptation to climate change.

KUSUM Scheme (Solar Pumps and Elevated PV over Crops): India

The Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan (PM-KUSUM) Programme in India is one of the most comprehensive agrivoltaics initiatives targeting rural farmers. The programme supports the installation of solar-powered irrigation pumps and grid-connected solar power plants. Field applications of PV panels mounted on various crops across diverse climatic zones have reduced irrigation costs and increased income diversification for farmers(Rathi & Soni, 2024). According to Union Bank of India (2025) data, the programme has increased energy independence in agricultural production, reduced the carbon footprint of fossil fuel-based irrigation systems, and significantly contributed to rural development.

Sub-Saharan – Solar-Powered Irrigation and Crop Production: Africa

A study by Ebhota and Tabakov (2024) examined the integration of solar-assisted irrigation systems with agricultural production in Sub-Saharan Africa. Various panel configurations and heights were tested, and the study found that the system increased water use efficiency and maintained yields in certain vegetable and grain crops. Energy production also enhanced economic sustainability by providing farmers with additional income. These systems support resource management and sustainable agricultural practices in the region by reinforcing the WEF (Water-Energy-Food) nexus. However, the limited fieldwork and climatic variability necessitate caution in generalising the results.

South America (Semi-Arid Tomato Production): Brazil

A study by Martínez (2022) evaluated agrivoltaic systems implemented for tomato production in a semi-arid region of Brazil. Solar panels were installed at a specific height and orientation, creating a microclimate beneath the panels that reduced evaporation rates and irrigation requirements. The study demonstrated that the system increased crop yields while also ensuring consistent energy production. By providing farmers with additional income and enhancing economic resilience, it serves as a valuable model for agricultural and energy policy in the region. However, the system's efficiency is sensitive to regional climate conditions and panel design, so its large-scale applicability requires further research.

Vertical Agrivoltaics System on Arable Crops: Central France

French energy company Engie announced the results of a vertical agricultural solar demonstration conducted in the Puy-de-Dôme region in 2024. The 100 kW agricultural solar installation, connected to a cow farm, did not affect pasture operation or animal behaviour. This

project demonstrates the feasibility of integrating vertical solar panels with livestock farming without disrupting existing agricultural practices (Deboutte, 2024).

A study by Tiffon-Terrade et al. (2023) examined the implementation of a double-sided, vertically mounted photovoltaic system integrated with field crops in central France. The first experimental year showed promising results, with stable or slightly increased annual crop yields. The study suggests that vertical agricultural solar systems can increase land productivity while maintaining or improving crop quality.

Modular Agrivoltaics in Urban Buildings: Singapore

Sky Greens, established in Singapore, implements vertical farming using a rotating tower system. This system enables high-yield production in limited spaces and contributes to Singapore's food security. Sky Greens is also an example of sustainable agriculture with low carbon emissions and high energy efficiency (Begum, 2019).

3.3. Nature-Based Water Management Techniques

NbS provide innovative methods for water management, ecosystem restoration, and biodiversity conservation in agriculture. These approaches use natural processes to protect water resources, reduce climate change risks, and increase the resilience of agricultural systems (Torun & Çakmak, 2024).

NbS offers various methods to improve water efficiency in agricultural production. *Rainwater harvesting systems* can range from simple rooftop collection methods to more complex community-scale projects, providing a sustainable water source for both agricultural and domestic use. This technique is particularly valuable in water-scarce regions, reducing dependence on groundwater and mitigating the impacts of irregular rainfall patterns (Khudhair et al., 2020).

Artificial wetlands, also known as constructed wetlands, serve a dual purpose in water management. These engineered ecosystems effectively treat wastewater through natural filtration processes, removing pollutants and improving water quality. At the same time, they create valuable habitats for diverse plant and animal species, enhancing local biodiversity (Ferreira et al., 2023).

Sand dams, another nature-based technique, are particularly effective in arid and semi-arid regions. These structures, built across seasonal riverbeds, trap and store water in the accumulated sand, protecting it from evaporation and contamination. This technique provides a reliable water source for local communities and helps recharge groundwater aquifers, contributing to long-term water security in vulnerable areas (Yifru et al., 2021).

3.3.1. Impacts on Protected Areas

NbS in agriculture have multidimensional impacts on protected areas and biodiversity. These approaches enhance ecosystem services while providing sustainable infrastructure for agricultural production. For example, wetland restoration regulates water regimes, improves ecosystem connectivity, and contribute to the preservation of flora and fauna diversity. This process indirectly increases agricultural irrigation capacity and supports flood prevention and groundwater conservation (Arıman & Koyuncu, 2019).

Water Management and Microclimate Regulation: Rainwater harvesting, constructed wetlands, and riparian buffer zones are key NbS approaches for improving water availability and quality.

In semiarid and Mediterranean climates, such as those in southeastern Türkiye, rainwater harvesting systems provide water for agricultural irrigation and indirectly protect the hydrology of protected wetlands by reducing runoff and soil erosion (Khudhair et al., 2020; Ministry of Agriculture and Forestry, 2021). Constructed wetlands serve a dual purpose: they filter agricultural runoff, reducing nutrient loads in rivers, and provide habitat for local flora and fauna. These interventions regulate the local water cycle, stabilise the microclimate, and alleviate temperature and moisture stress, creating positive effects for both agricultural land and surrounding natural ecosystems (Ferreira et al., 2023).

Biodiversity and Habitat Connectivity: NbS supports biodiversity by maintaining or restoring habitat connectivity between agricultural land and protected areas. For example, vegetated buffer strips, agroforestry areas, and restored riparian corridors enhance genetic diversity and population resilience by enabling wildlife movement (Hilty et al., 2020). Reducing pesticide and fertiliser use in NbS-managed areas minimises chemical runoff into protected areas, safeguarding aquatic and terrestrial species. International studies show that agroecological landscapes integrated with NbS support higher species richness than traditional monocultures (Garibaldi et al., 2021; Tscharntke et al., 2021).

Economic and Social Impacts: Installing NbS infrastructure (sand dams, wetlands, or rainwater harvesting systems) can be initially costly; however, long-term benefits include reduced irrigation costs, increased crop resilience, and enhanced ecosystem services (Torun & Çakmak, 2024). In areas adjacent to protected areas, NbS prevents conflicts between agriculture and conservation objectives, reduces agricultural damage to wildlife, and maintains ecosystem services that benefit local communities. Furthermore, NbS practices enable income diversification through activities such as aquaculture-integrated wetlands or agroforestry, as well as additional income sources such as ecotourism or ecosystem service payments.

Climate Adaptation and Resilience: Soil restoration and vegetation enhancement enable NbS to protect agricultural production against extreme weather events such as drought and floods by improving carbon sequestration and soil moisture (Yifru et al., 2021). These effects are particularly important in areas adjacent to protected areas; maintaining hydraulic and soil stability prevents habitat degradation and supports climate adaptation goals. Microclimate stabilisation positively affects crop phenology, pest management, and overall productivity.

NbS is not only a tool for water and agricultural management but also a comprehensive solution for protecting protected areas, increasing biodiversity, regulating the microclimate, and ensuring economic sustainability. This holistic approach creates long-term ecological and economic benefits by strengthening the harmony between agricultural production and natural habitats.

3.3.2. Case Studies

Konya Closed Basin – Rainwater Harvesting: Türkiye

Rainwater harvesting practices in the Konya Closed Basin increase irrigation efficiency by optimising agricultural water use. These methods reduce pressure on water resources and support adaptation to climate change. Rainwater harvesting techniques, in particular, aim to reduce the blue water footprint by retaining water in the soil. This is a significant step towards efficient water use in agriculture (Torun & Çakmak, 2024).

GAP Region (Constructed Wetlands): Türkiye

Constructed wetland applications implemented within the Southeastern Anatolia Project (GAP) stand out as a key strategy for conserving water in agricultural irrigation and contributing to ecosystem restoration in the region. These applications offer effective solutions, particularly for the management and reuse of irrigation water. For example, pilot projects in the Harran Plain designed curtain-type constructed wetland systems to improve the quality of irrigation water, and their effectiveness was evaluated (Tarım ve Orman Bakanlığı, 2021).

Kızılırmak Delta (Wetland Restoration Efforts): Türkiye

Wetland restoration efforts in the Kızılırmak Delta have contributed to biodiversity conservation and significantly supported flood control by regulating the water regime. Rehabilitation activities, particularly in reedbed and lagoon systems, have indirectly supported agricultural irrigation capacity by helping maintain groundwater levels. By increasing the water retention capacity of wetlands, slowing surface runoff, and strengthening the natural drainage cycle, the ecological and hydrological balance in the region has become more sustainable (Arıman & Koyuncu, 2019).

Shafdan (Treated Wastewater for Irrigation): Israel

The Negev Desert is Israel's driest region, with an average annual rainfall of 200–400 mm. However, the region is a success story in the use of treated wastewater for agricultural irrigation. Shafdan, Israel's largest wastewater treatment plant, treats approximately 470,000 cubic metres of raw wastewater daily from the Tel Aviv area, producing about 140 million cubic metres of clean water annually. This treated water irrigates 60% of the agricultural land in the Negev Desert. The Shafdan plant improves water quality by combining biological and soil aquifer treatment, ensuring the water is safe and productive for agricultural use. Additionally, 230 reservoirs constructed by the Israel Forests and Parks Authority store more than 260 million cubic metres of treated water each year, balancing seasonal water imbalances (Israel21c, 2021).

Makueni County (Community-Based Water Management): Kenya

A study by Muriuki (2021) examines the sustainability of community-based water projects in Makueni County, Kenya. The research demonstrates that the participation of local people in decision-making, ownership, and resource management increases long-term success, particularly in groundwater and rainwater projects. Such practices offer an important model for adapting to water scarcity and building local capacity through NbS.

Al Murunah (Community-Based Water Management Project): Kenya

The Al Murunah Project in Kenya is based on NbS to increase water security, particularly in arid and semi-arid regions. Methods such as rainwater harvesting, small-scale dam systems, and underground water storage structures were implemented with the participation of local communities. Al Murunah is considered an exemplary NbS application that strengthens both agricultural production and climate resilience by supporting the natural water cycle of the ecosystem through community-based management. The project also stands out for its long-term sustainability due to the involvement of local people in decision-making processes (IUCN, n.d.).

Pretoria, Maseru, and Harare (NbS Applications in Urban Agriculture): South Africa

A review by Mashanye et al. (2025) examined urban agriculture practices and the adoption of NbS in Pretoria, South Africa, Maseru, Lesotho, and Harare, Zimbabwe. The study highlights

the importance of urban agriculture in these cities for enhancing food security and ensuring environmental sustainability. Using policy documents and secondary data, the study analysed the opportunities and barriers to adopting nature-based urban agriculture solutions. The results reveal how differences in policy frameworks, environmental awareness, and local urban dynamics across cities influence NbS applications.

Southern Regions (Stakeholder Perspectives on NbS for Agriculture): Italy

Netti et al. (2024) conducted a study in the Apulia and Basilicata regions of southern Italy, focusing on the implementation of NbS in agriculture. Through a tailored questionnaire, the study investigated farmers' perceptions of NbS, addressing key issues in the region and evaluating their role in addressing soil and water management challenges. The findings highlight the potential of NbS to enhance water retention and soil fertility, with a strong emphasis on community involvement and local knowledge in the adoption process.

South Asia (Coastal Mangrove Reforestation for Climate Resilience): Bangladesh

In coastal Bangladesh, a mangrove reforestation project was undertaken to enhance climate resilience and water management. The initiative involved planting mangrove trees along the coastline to stabilise soil, reduce erosion, and improve water quality. This Nature-Based Solution not only mitigated the impacts of floods and storm surges but also supported local livelihoods by enhancing fishery resources and protecting agricultural land from saline intrusion (Iqbal et al., 2025).

Satoyama Landscape Restoration (Integration of Agriculture and Water Management): Japan

In Japan, traditional Satoyama systems have been adapted into NbS models by integrating terraced rice fields, natural water channels, and forest ecosystems. These multifunctional landscapes provide effective solutions in rural areas by enhancing water retention, regulating local hydrology, and supporting biodiversity. Furthermore, Satoyama practices contribute to climate resilience and sustainable land management by maintaining ecological connectivity and promoting traditional knowledge in agricultural planning (Fukamachi, 2020).

Garonne River Basin (Nature-Based Flood Control): France

Flood management around the Garonne River in France is supported by restoring natural floodplains. In addition to reducing flood risks, these restoration efforts help preserve agricultural land and enhance carbon sink capacity by regenerating wetlands. In particular, the restoration of wetland ecosystem functions offers benefits such as improving water quality and supporting biodiversity (European Commission, 2020).

Agroforestry for Water Retention: France

Agroforestry systems implemented in southwestern France reduce the need for irrigation by capturing rainwater in fields and orchards and increasing soil erosion resistance. These systems, through the integration of trees and crops, promote water retention and improve soil structure, enabling more efficient water use. Furthermore, agroforestry practices contribute to the sustainability of ecosystem services by supporting biodiversity (Sollen-Norrlin et al. 2020).

Rajasthan and Maharashtra (Groundwater Recharge and Traditional Rain Harvesting): India

In Rajasthan and Maharashtra, the renovation of traditional water harvesting structures such as Johad and Baoli with modern NbS has increased water security in rural agriculture and

improved groundwater levels. These structures play a crucial role in rainwater harvesting and recharging groundwater resources (Yadav, 2023).

Emscher River Restoration (Blue-Green Corridors): Germany

The conversion of the Emscher River in the Rhine-Ruhr region from a canal system to a natural river is a significant nature-based solution for wastewater management, wetland restoration, and ecosystem connectivity. The Emscher Restoration project is one of Europe's largest river restoration initiatives and aims to improve water quality, enhance biodiversity, and address climate change. The project is led by Emschergenossenschaft and was completed in 2022 (European Environment Agency, 2024).

3.4. Synergies and Challenges

3.4.1. Integration of Sustainable Practices

The integration of vertical farming, AvS, and nature-based water management provides a holistic approach to sustainable agriculture and resource management. By combining these innovative practices, significant synergies emerge that address multiple challenges simultaneously. Resource efficiency is maximised through the strategic use of vertical space for crop production, solar energy generation on agricultural land, and natural water management techniques. This integrated approach enables optimal use of limited land resources while enhancing overall productivity and sustainability.

Furthermore, the synergistic benefits extend beyond resource efficiency to broader environmental and climate resilience objectives. The reduced environmental footprint achieved through these combined practices supports biodiversity conservation and ecosystem health. Vertical farming minimises land use and reduces the need for pesticides, while AvS foster diverse plant and animal habitats beneath solar panels. Nature-based water management techniques improve soil health and sustain natural hydrological cycles. Together, these practices strengthen adaptive capacity to climate-related challenges by creating more resilient agricultural systems capable of withstanding extreme weather events, water scarcity, and changing environmental conditions. This integrated approach represents a promising pathway towards sustainable and climate-smart agriculture in the face of growing global challenges.

3.4.2. Challenges

Despite the considerable potential benefits of vertical farming, AvS, and nature-based water management, several challenges remain that may limit their scalability and effectiveness in protected areas:

High Initial Investment Costs

- Vertical farming requires substantial capital for infrastructure, including LED lighting, climate control systems, automation, and multi-tier growing structures.

- AvS involve costs for solar panels, mounting structures, and integration with irrigation systems, which can be a barrier for smallholder farmers.

Energy Consumption and Operational Costs

- Indoor vertical farms rely heavily on artificial lighting and climate control, resulting in high energy consumption. While renewable energy integration can mitigate this, it increases operational complexity and costs.

- AvS also require monitoring and maintenance of both energy and agricultural outputs, creating additional operational demands.

Technical Complexity and Expertise Requirements

- Implementing hydroponic, aeroponic, or aquaponic systems requires specialised knowledge in plant physiology, nutrient management, and system maintenance.

- AvS require careful design to avoid shading that reduces crop yield, as well as integration of solar energy management with farm operations.

Adaptation to Local Climatic and Soil Conditions

- Both vertical farming and agrivoltaics need site-specific adaptations. For example, vertical farming in regions with low electricity availability may be less feasible, while agrivoltaics require crop selection compatible with partial shading.

- Nature-based water management approaches must consider local hydrology and ecosystem dynamics to avoid unintended consequences, such as altering natural water flows or impacting wetland habitats.

Market Acceptance and Socioeconomic Factors

- Products from vertical farms or AvS may face price sensitivity compared to conventional agriculture, potentially limiting consumer adoption.

- Community and farmer acceptance is crucial, particularly when integrating new technologies into traditional farming systems or protected areas where land-use restrictions exist.

Regulatory and Policy Challenges

- Protected areas often have strict land-use regulations, which can constrain the installation of infrastructure-intensive systems like vertical farms or solar panels.

- Navigating policies related to renewable energy subsidies, water rights, and biodiversity conservation requires coordinated governance.

Maintenance and Long-Term Sustainability

- Continuous monitoring, maintenance, and system updates are necessary to sustain productivity and efficiency. For example, LED replacement, nutrient solution management, and cleaning of hydroponic systems are recurring tasks.

- Agrivoltaic panels also require regular cleaning, electrical inspections, and adaptation to crop rotation cycles to maintain both energy and agricultural output.

In conclusion, while these innovative agricultural strategies offer significant opportunities for sustainable land use and biodiversity conservation in protected areas, addressing economic, technical, regulatory, and social barriers is critical for their long-term adoption and impact. Future research should focus on integrated cost-benefit analyses, policy frameworks, and community engagement strategies to facilitate broader implementation.

4. Conclusion and Recommendations

This study shows that integrating vertical farming, AvS, and nature-based water management provides a viable pathway to reconcile food security with nature conservation in Türkiye. Vertical farming and soilless agriculture reduce land pressure in protected areas while

maintaining high productivity through controlled, multi-level cultivation systems. AvS improve land-use efficiency by combining energy production with crop cultivation, reducing carbon footprints and generating additional income for rural communities. Nature-based water management techniques, such as rainwater harvesting, artificial wetlands, and closed-loop irrigation, optimise water use, mitigate drought risks, and support ecosystem resilience. Together, these approaches offer complementary benefits, balancing agricultural productivity with environmental protection and biodiversity conservation.

Policy Implications

To maximise the potential of these innovations, Turkish agricultural policies should explicitly integrate nature-based solutions. Pilot projects in buffer zones of protected areas are recommended to test practical applications and monitor ecological impacts. Active engagement of cooperatives and rural communities is essential to ensure local acceptance, facilitate knowledge transfer, and promote equitable distribution of benefits. Policies should also address economic incentives, training programmes, and infrastructure support to encourage the adoption of sustainable practices while preserving natural habitats.

Future Research Directions

Despite their promise, several research gaps remain. Further studies are needed to evaluate the long-term ecological effects, energy costs, and social acceptance of these technologies within the Turkish context. Future research should explore site-specific adaptations, optimal combinations of vertical farming and AvS, and effective integration of water management strategies in protected areas and their surroundings. By addressing these gaps, policymakers and practitioners can develop evidence-based strategies to support sustainable agricultural development aligned with conservation goals.

Thanks and Information Note

The article complies with national and international research and publication ethics.

Ethics Committee approval was not required for the study.

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Spatio-Temporal Changes in the Land Use and Vegetation Health of Two Protected Areas in North-Central Nigeria

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Abstract

Remote sensing (RS) has been widely employed for conservation and monitoring of protected areas. This study evaluated the land use and land cover (LULC), and vegetation changes of two protected areas in North-Central Nigeria: Jos wildlife Park (JWLP) and Pandam Wildlife Park (PWLP) from 1990 to 2024. This study utilized different Landsat satellite data to classify and assess the changes within the study period. LULC categories used vary with respect to the peculiarity of the identified land cover in each forest including forested area, riparian forest, built up and open land. The image classification involved supervised classification while different vegetation indices were calculated using the respective bands of the satellite data. The results revealed a slight increase in 1998 followed by a consistent decrease in the forested area of the JWLP from 1998-2024 representing a 38.8% (4329900 m^2) of the total area. However, the PWLP experienced a consistent decrease (47.68%) in riparian vegetation followed by a dramatic increase (266.23%) in the forested area from 1991 to 2024 constituting 29.95% of the total area. There were variations in the vegetation indices of the two protected areas. Most importantly, all the vegetations indices of the PWLP increased consistently from 1990 to 2024 which is an indication of the healthiness of the forest. By implication, JWLP appeared to have undergone some degree of encroachments which has led to the reduction in the forested areas. Periodic monitoring coupled with the enforcement of protection of these protected areas should be prioritized to forestall the further loss.

Keywords: Land use, NDVI, protected areas, remote sensing, vegetation

1. Introduction

In Nigeria, remote sensing has been successfully used to assess vegetation changes of protected and unprotected areas across various ecological zones (Adamu, 2019; Akomolafe & Anumeh, 2025; Akomolafe and Rahmad, 2020), thereby providing valuable insights for conservation planning and policymaking. National parks and protected forest reserves make up the bulk of the world's protected areas overall. About 2000 national parks and protected areas are distributed across the Sub-Saharan Africa's four regions (Northern, Central, Western, and Eastern), totalling up to over 3,200,000 km^2 of all of Africa's territory (Osabohien *et al.*, 2019).

Despite the importance of these protected areas as vital ecosystems, especially in Nigeria, they are experiencing rapid and unsustainable changes because of anthropogenic and natural factors. Over the years, threats such as climate change, deforestation, illegal grazing, and agricultural encroachment have negatively impacted their vegetation health, thereby

disrupting the ecosystem balance and impact important biological populations (Akomolafe & Anumeh, 2025).

Previous studies have indicated an alarming decline in forest cover within some of these protected areas in Nigeria. For instance, forest cover change was observed at several gazetted forests of Nasarawa State (Chunwate, 2024); a significant loss of forest cover at Ngel Nyaki forest reserve from 1990 to 2023 (Akomolafe & Anumeh, 2025). This rapid rate of deforestation threatens the habitat of numerous plant and animal species and compromises the forest's ecological functions. Despite the numerous studies done, there is still paucity of current, comprehensive data on the state of some of these forests and ongoing land use changes, which hampers effective forest management and conservation planning.

Most importantly, there has not been an updated record of the assessment of the changes in the land use and vegetation of Jos wildlife park (JWLP) and Pandam wildlife park (PWLP) in north-central Nigeria. Hence this study aimed at bridging this gap through a detailed spatio-temporal evaluation of the changes in land use and vegetation health of these two protected areas in north-central Nigeria in the last 30 years using remote sensing techniques.

2. Materials and Methods

Study Area

Jos wildlife park (JWLP) is located in Jos, Plateau State, Nigeria (Figure 1). The park covers an area of 8 hectares and it's a home for variety of plants and wildlife species, including lions, elephants, giraffes and monkeys. The park offers educational programs and conservation efforts to help protect and preserve the wildlife within its boundaries. Pandam forest is located in Plateau State, Nigeria, approximately between latitudes 8°30' and 8°45' N and longitudes 8°30' and 8°45' E (Figure 2). The forest covers an area of approximately 2,240 hectares and is part of the Pandam Wildlife Park (PWLP). The region where the two parks are located is characterized by a tropical savanna climate (Köppen climate classification Aw) with distinct wet and dry seasons. The vegetation is primarily Guinea savanna woodland with a mix of grasslands and forest patches.

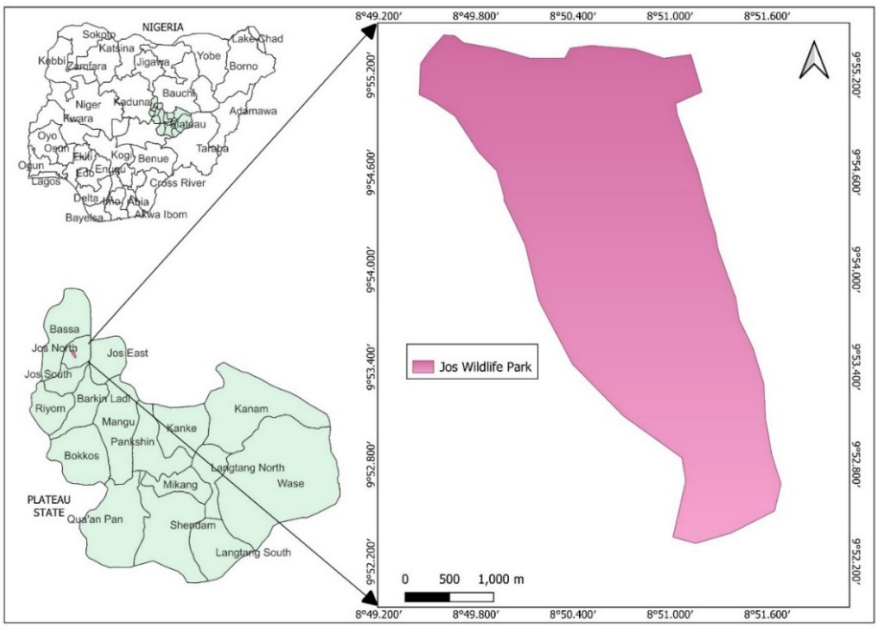


Figure 1. The study area map of Jos wildlife park

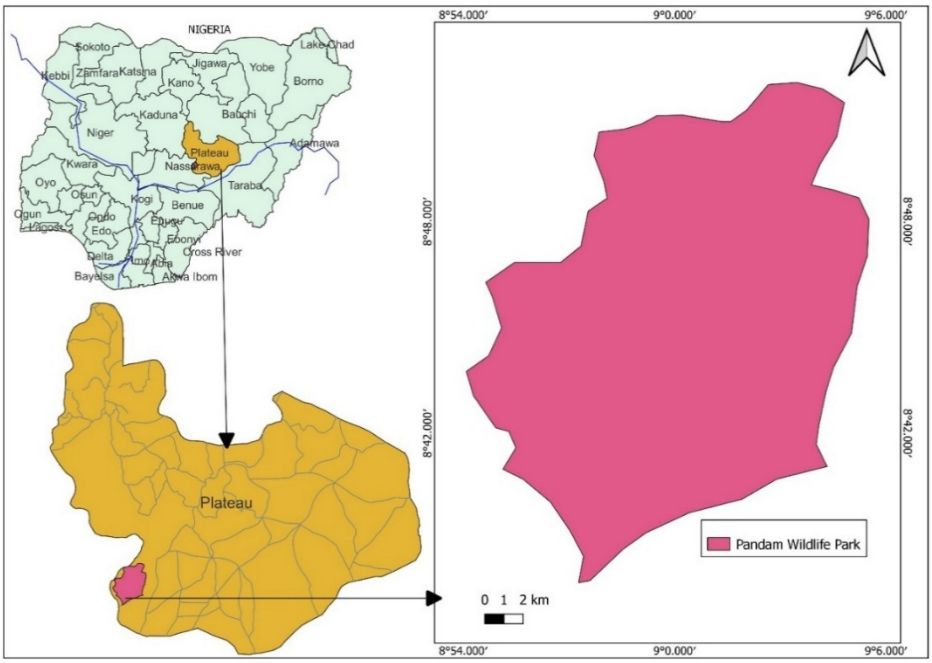


Figure 2. The study area map of Pandam wildlife park

Satellite Data Collection

This study utilized satellite data to analyze land use and vegetational changes in the two parks from 1990 to 2024. Primary data consisted of ground truth information collected through field visits to the parks. A digital camera was used to capture photographs of different land use and land cover types to aid in image classification and accuracy assessment. The multi-temporal satellite imageries were downloaded from the USGS website (www.earthexplorer.usgs.gov) covering the study periods (Table 1).

Table 1. Characteristics of the Landsat satellite images used.

Satellite Features	Jos Wildlife Park				Pandam Wildlife Park		
	1990	1998	2014	2024	1991	2014	2024
Sensors	Landsat 4 TM+	Landsat 5 TM	Landsat 8 OLI_TIRS	Landsat 8 OLI_TIRS	Landsat 4 TM+	Landsat 8 OLI_TIRS	Landsat 8 OLI_TIRS
Path/row	188/053	188/053	188/053	188/053	188/054	188/054	188/054
Spatial Resolution	30 m	30 m	30 m	30 m	30 m	30 m	30 m
Date of acquisition	22/12/1990	18/11/1998	15/02/2014	27/02/2024	07/01/1991	14/01/2014	27/02/2024
Number of bands	7	7	11	11	7	11	11

Data Processing and Analysis

Georeferencing techniques

Image processing techniques were applied to improve the clarity of the image, making it easier to identify and categorize different land use types (Jande *et al*., 2019; Akomolafe & Rahmad, 2020). The boundary of the JWLP was used to isolate the area of interest within the larger image mosaic using QGIS 3.32.1. The image enhancement was done to ensure easier detection and classification of the land-use types (Jande *et al.*, 2019).

Land Use Classification

Land cover categories at the JWLP include forested area, built up and open land (Table 2). The Forested area class represents areas where the tree canopy density between 40% and above. Open land refers to areas with very low or no vegetation. This category includes rocky outcrops, barren lands, and abandoned agricultural fields. Built-up Areas encompass urban and rural regions, including farmhouses and other structures. Land cover categories at the PWLP include water body, forested area, riparian vegetation, built up and open land (Table 2). The riparian vegetation represents plant communities that grow along the banks of rivers, streams, lakes, or other water bodies. Water body is a region with natural or artificial ponds and lakes. These areas are characterized by the presence of water, either permanently or seasonally.

Table 2. Description of LULC Classes of the study area

LULC class	Description
Forested area	Forest with tree canopy density between 40% and above
Riparian vegetation	Plant communities that grow along the banks of rivers, streams, lakes, or other water bodies.
Open Land	Area with very low or no vegetation, rocky outcrops, barren land, abandoned land
Built Up	Urban Areas, Rural Areas, Farmhouses
Water body	Natural & Artificial ponds/lakes

The satellite image classification involved both unsupervised random selection of sample training points and supervised classifications of the LULC types as seen in Table 2. The determination of the rate and extent of change in the LULC of JWLP within the studied periods was carried out using the following equations (Akomolafe & Rahmad, 2020):

Changed area (C a) = T a (2^{nd} year) – T a (1^{st} year)……..… (i)

Changed extent (C e) = C a / Ta (1^{st} year) …….. (ii)

Percentage of change = C e x 100……..... (iii)

Where (Ta) = total area

Accuracy Assessment

Accuracy assessment is a critical step in remote sensing analysis to evaluate the reliability and precision of classified land cover maps or vegetation indices. The results obtained from remote sensing data were compared with ground truth information collected from field surveys or higher-resolution imagery. The overall accuracy and Kappa coefficient metrics were used to describe the accuracy of the LULC classification. The kappa coefficient is a statistical measure of agreement between classified and reference data, correcting for the agreement that would be expected by chance alone. It considers both omission and commission error and provides a measure of classification accuracy that accounts for class imbalance.

Kappa Coefficient = (Overall Accuracy - Expected Accuracy) / (1 - Expected Accuracy).

Vegetation Change Analysis

The vegetation change analysis involved time-series analysis of vegetation indices, such as the Normalized Difference Vegetation Index (NDVI), Normalized Difference Water Index (NDWI), Enhanced Vegetation Index (EVI), Soil-Adjusted Vegetation Index (SLAVI) and Green Chlorophyll Index (GCI). Changes in vegetation greenness over different time periods were analyzed to identify trends and anomalies. The vegetation indices were calculated using the following formulas:

1. Normalized difference vegetation index (NDVI) = (NIR - Red) / (NIR + Red)

For Landsat 8/9: NDVI = (Band5 – Band4) / (Band5 + Band4)

For Landsat 4/5: NDVI = (Band5 – Band4) / (Band5 + Band4)

2. Enhanced vegetation index (EVI) = 2.5 x ((Band Near Infrared – Band Red)/(Band Near Infrared + 6 x Band Red + 7.5 x Band Blue + 1))

For Landsat 8: EVI = 2.5 x ((Band5 - Band4) / (Band5 + 6 x Band4 + 7.5 x Band2 + 1))

For Landsat 4/5: EVI = 2.5 x ((Band4 - Band3) / (Band4 + 6 x Band3 + 7.5 x Band 1 + 1))

3. Normalized difference water index (NDWI) = (Band Green – Band Near Infrared)/(Band Green + Band Near Infrared)

For Landsat 4/5: NDWI = (Band2 - Band4) / (Band2 + Band4)

For Landsat 8/9: NDWI = (Band3 - Band5) / (Band3 + Band5)

4. Specific Leaf Area Vegetation Index (SLAVI) = (Band Near Infrared)/(Band Red+ Band SWIR-1)

For Landsat 8: SLAVI = ((Band 5))/((Band 4+ Band 6))

For Landsat 4&5: SLAVI = ((Band 4))/((Band 3+ Band 5))

5. Green Chlorophyll Index (GCI) = Band 5/Band 3 - 1 for Landsat 8

For Landsat 8/9: GCI = Band 5/Band 3 - 1

For Landsat 4&5: GCI = Band 4/Band2 – 1

3. Findings and Discussion

Land Use and Land Cover (LULC) Classification

The land use and land cover (LULC) change analysis revealed varying degrees of change among the categories of land use for the JWLP between 1990 and 2024 (Table 3 and Figure 3). In 1990, the JWLP had 6327000 m^2 of forested area, constituting 56.6% of the total area. This increased in 1998 to 66.0% and has consistently decreased from 2014 to 2024 whereby it represents 38.8% (4329900 m^2) of the total area. This also means 31.6% of the forested area has decreased significantly from 1991 to 2024 (Table 4). This indicates a severe loss of forest cover within the park. However, the area classified as built up in 1990 was 4173300 m^2, accounting for 37.4% of the total area. From 1990 to 1998, this built up area decreased to 3500100 m^2 and drastically decreased from 1998 to 2024 constituting 56.4% (6298200 m^2) of the total area. This represents a percentage increase of 50.9%.

This indicates a considerable expansion of built up area within the reserve. Overall, there has been a substantial loss of forested area, accompanied by a considerable increase in built up areas in JWLP. This is similar to the findings of Akomolafe & Anumeh (2025) who reported loss of forest cover on Ngel Nyaki forest reserve in Taraba State. The loss of forest land in any land-use classifications has been attributed to several anthropogenic activities such as logging and clearing of land for farming (Akomolafe & Rahmad, 2020).

Table 3. LULC area of Jos wildlife park

LULC CLASS	1990		1998		2014		2024	
	Area (m^2)	%	Area (m^2)	%	Area (m^2)	%	Area (m^2)	%
Forested area	6327000	56.6	7375500	66.0	6431400	57.6	4329900	38.8
Built up	4173300	37.4	3500100	31.3	4475700	40.1	6298200	56.4
Open land	670500	6.0	295200	2.6	263700	2.4	542700	4.9
Total	11170800	100	11170800	100	11170800	100	11170800	100

Table 4. Change in the LULC area of Jos wildlife park

LULC CLASS	1990-1998	1998-2014	2014-2024	1990-2024
	Change in area (%)	Change in area (%)	Change in area (%)	Change in area (%)
Forested area	16.6	-12.8	-32.7	-31.6
Built up	-16.1	27.9	40.7	50.9
Open land	-55.9	-10.7	105.8	-19.1
Total	-55.4	4.4	113.8	0.2

As for the LULC of the PWLP, the results revealed that in 1991, the PWLP had 239796000 m^2 of riparian vegetation, constituting 71.42% of the total area. This has consistently decreased from 2014 to 2024 whereby it represents 37.37% (125451900 m^2) of the total area. This also means 47.68% of the riparian vegetation has decreased significantly from 1991 to 2024 (Table 5 and Figure 4). This indicates a severe loss of riparian forest cover within the reserve. However, the area classified as forested in 1991 was 27455400 m^2, accounting for 8.18% of the total area. From 1991 to 2024, this forested area increased dramatically to 100550700 m^2, constituting 29.95% of the total area. This represents a percentage increase of

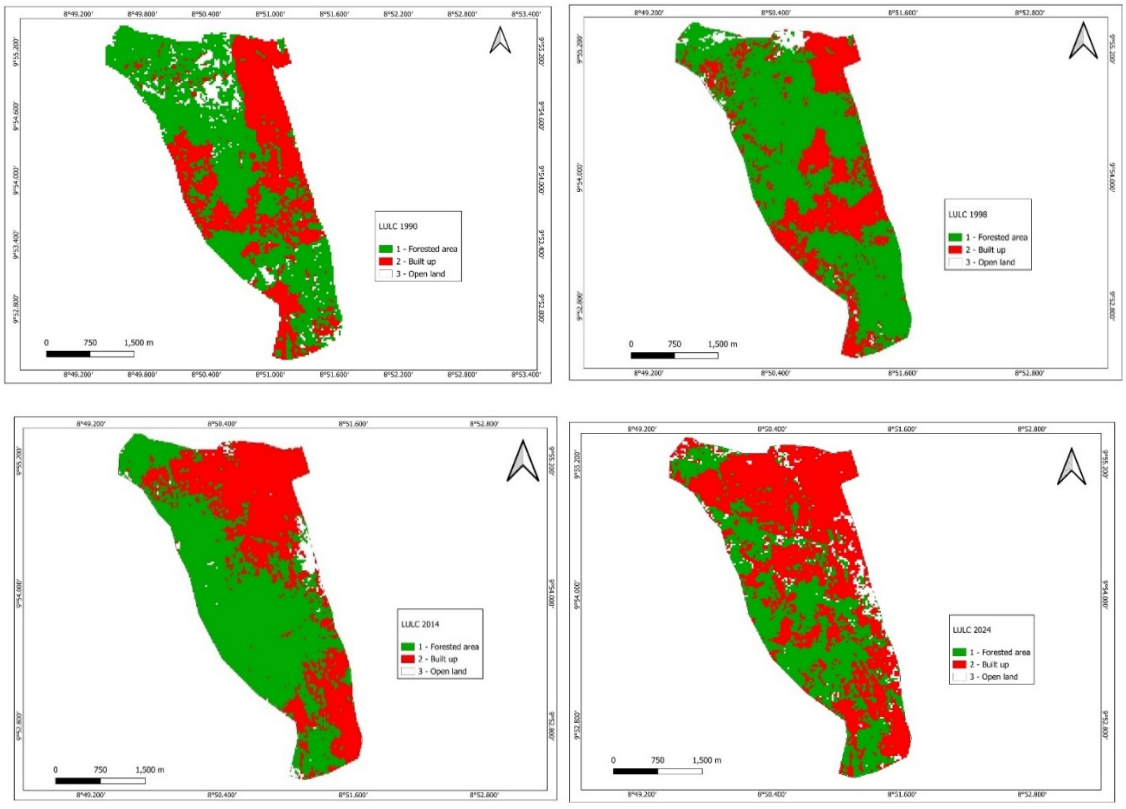
266.23% which indicates a considerable expansion of forested area within the reserve (Table 6).

Table 5. LULC area of Pandam Wildlife Park

LULC CLASS	1991		2014		2024	
	Area (m^2)	%	Area (m^2)	%	Area (m^2)	%
Water body	1346400	0.40	1403100	0.42	1581300	0.47
Riparian vegetation	239796000	71.42	130998600	39.02	125451900	37.37
Forested area	27455400	8.18	79112700	23.56	100550700	29.95
Open land	63017100	18.77	29121300	8.67	17982900	5.36
Built up	4119300	1.23	95098500	28.33	90167400	26.86
Total	335734200	100	335734200		335734200	

Table 6. Change in the LULC area of Pandam Wildlife Park

LULC CLASS	1991-2014	2014-2024	1991-2024
	Change in area (%)	Change in area (%)	Change in area (%)
Water body	4.21	12.70	17.45
Riparian vegetation	-45.37	-4.23	-47.68
Forested area	188.15	27.09	266.23
Open land	-53.79	-38.25	-71.46
Built up	2208.60	-5.19	2088.90
Total	2301.8	-7.88	2253.44



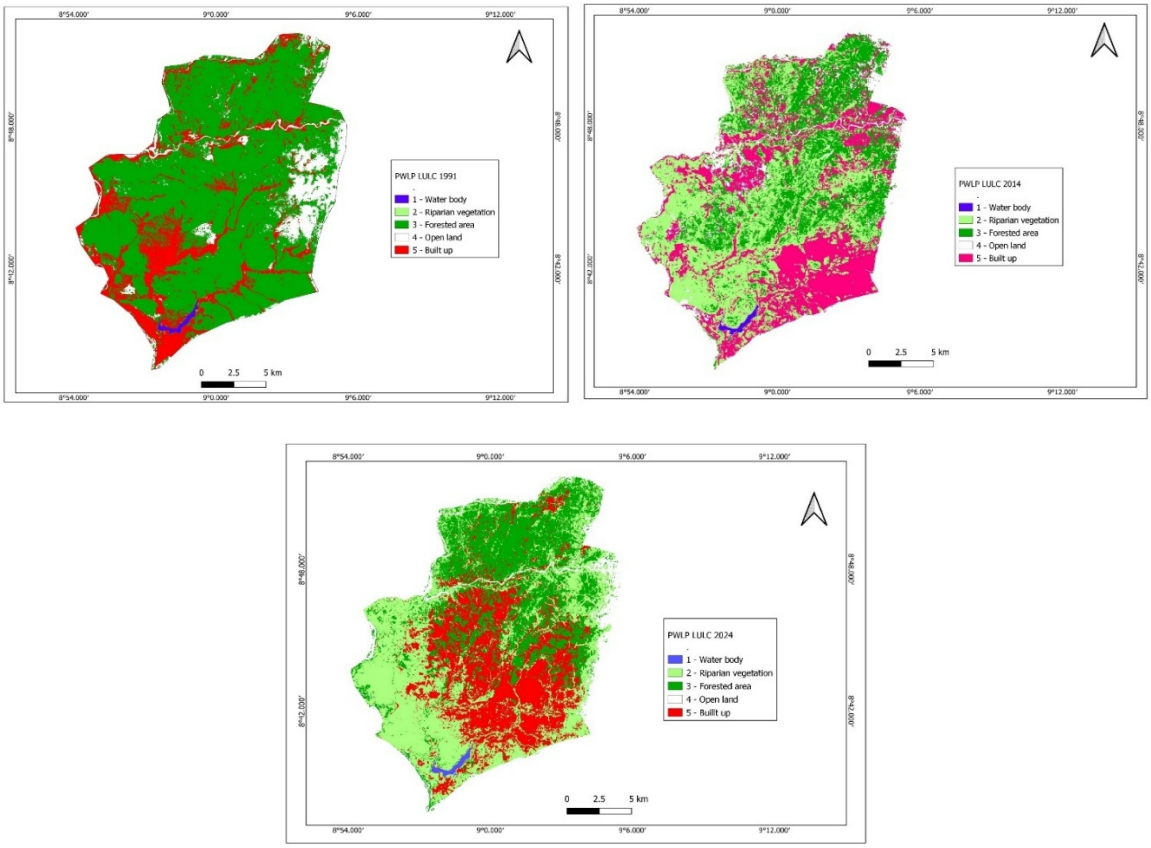


Figure 3. LULC of Jos Wildlife Park from 1990-2014

Accuracy of LULC classification

The accuracy assessments for both JWLP and PWLP include producer's accuracy, user's accuracy, kappa coefficient, and overall accuracy. All the producer's accuracies for all the LULC classes at JWLP and PWLP are above 70%, indicating the percentage of correctly classified pixels of the classes out of all reference pixels (Tables 7 and 8). The user's accuracies are exceptionally high between 80% and 99% while the kappa coefficients for all the classes are closer to 1, indicating almost perfect agreement between the classified results and reference data. The overall accuracy for all the classes is 84.3%. In the other periods, similar trends were observed. Other researchers have also used similar land-use classification methods in Northern Nigeria, and they reported higher degrees of classification accuracy (Adamu, 2019; Jande et al., 2019).

Table 7. Accuracy assessment showing the Kappa coefficient, producer, user, and overall accuracy for JWLP LULC classifications.

LULC class	Producer's accuracy	User's accuracy	Kappa coefficient	Overall accuracy (%)
		1990		
Forested area	72.12	99.00	0.89	84.3
Built up	73.13	84.21	0.92	
Open land	74.52	89.34	0.82	
		1998		
Forested area	73.12	99.00	0.95	89.41
Built up	74.43	85.91	0.82	
Open land	80.22	77.84	0.98	
		2014		
Forested area	78.12	94.12	0.99	88.52
Built up	71.21	79.80	0.89	
Open land	80.11	82.31	0.91	
		2024		
Forested area	75.12	90.12	0.89	85.20
Built up	79.21	75.80	0.95	
Open land	86.11	88.31	0.97	

Table 8. Accuracy assessment showing the Kappa coefficient, producer, user, and overall accuracy for PWLP LULC classifications

LULC class	Producer's accuracy	User's accuracy	Kappa coefficient	Overall accuracy (%)
		1991		
Water body	73.44	98.09	0.96	85.42
Riparian vegetation	79.89	87.60	0.82	
Forested area	74.12	100.00	1.00	
Open land	75.13	89.21	0.87	
Built up	79.82	91.32	0.79	
		2014		
Water body	73.80	99.76	0.99	79.41
Riparian vegetation	92.66	87.10	0.68	
Forested area	76.12	100.00	1.00	
Open land	77.43	88.91	0.87	
Built up	82.32	79.80	0.92	
		2024		
Water body	73.80	99.76	0.89	88.41
Riparian vegetation	92.66	87.10	0.68	
Forested area	78.12	94.12	0.99	
Open land	71.21	79.80	0.89	
Built up	80.11	82.31	0.91	

Vegetation Indices Change

Table 9 presents the mean values of the vegetation indices assessed for the JWLP in the years 1990 - 2024. In 1990, the mean NDVI for JWLP was 0.16 and from 1998 - 2024, the mean NDVI value had increased to 0.22. The EVI also increased slightly from 0.05 in 1990 to 0.10 in 2024. The mean SLAVI value increased from 0.50 in 1990 to 0.72 in 2024. From 1990 to 2024, the mean NDWI values consistently decreased from -0.17 to -0.21. The mean GCI value slightly increased from 0.59 in 1990 to 0.62 in 2024.

As for the PWLP, the mean NDVI value for PWLP was 0.05 in 1991 and from 2014 - 2024, the mean NDVI value had increased to 0.17 (Table 10). The EVI also increased slightly from 0.02 in 1991 to 0.09 in 2024. The SLAVI value increased from 0.48 in 1991 to 0.72 in 2024. From 1991to 2024, the mean NDWI values consistently decreased from -0.04 to -0.14. The mean GCI value increased from 0.19 in 1991 to 0.46 in 2024. These results show increased greenness and photosynthetic activity in the two protected areas.

Table 9. Mean of vegetation indices of JWLP within the study periods

Vegetation index	1990	1998	2014	2024
NDVI	0.16	0.19	0.17	0.22
EVI	0.05	0.06	0.07	0.10
SLAVI	0.50	0.49	0.64	0.72
NDWI	-0.17	-0.24	-0.16	-0.21
GCI	0.59	0.71	0.41	0.62

Table 10. Mean of vegetation indices of PWLP within the study periods

Vegetation index	1991	2014	2024
NDVI	0.05	0.16	0.17
EVI	0.02	0.07	0.09
SLAVI	0.48	0.69	0.72
NDWI	-0.04	-0.11	-0.14
GCI	0.19	0.36	0.46

4. Conclusion and Recommendations

These findings suggest key land-use shifts within both the JWLP and PWLP from 1990 to 2024. Early urban encroachment and infrastructure development dominated, likely driven by weak enforcement, dominated the study area. Forest regeneration likely explains the observed increase in the forest cover of PWLP, despite the loss of the riparian vegetations. However, all the vegetation indices showed a positive trend in plant health of both protected areas.

Thanks and Information Note

The article complies with national and international research and publication ethics. Ethics Committee approval was not required for the study. We appreciate the management of the Federal University of Lafia, Nigeria for creating enabling environment for this study. 1st author did the analyses, supervision and editing of the manuscript. The 2nd and 3rd authors did the literature review and wrote the original draft of the manuscript.

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Checklist of Spiders (*Arachnida: Araneae*) of Serbia

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Abstract

This paper presents a comprehensive review of the current data on the fauna of spiders (Araneae) of the Republic of Serbia. The aim of the paper was to compile an updated and systematically organized list of spider species present in Serbia, based available literature items with original records. A literature sources are given for each species. A total of 790 species were recorded, classified into 41 families, which indicates the significant richness and diversity of this group of arthropods within the national framework. The most represented families are: Linyphiidae (199 species), Gnaphosidae (78), Salticidae (71), Lycosidae (68), Araneidae (54), Theridiidae (54) and Thomisidae (45). The genera with the largest number of species are: Pardosa (28), Clubiona (20), Zelotes (17), Xysticus (16), Alopecosa (14) and Centromerus (14).This database represents a valuable resource for further zoogeographical, taxonomic and conservation research, and lays the foundation for future additions and revisions.

Keywords: Araneae, fauna of Serbia, biodiversity, taxonomy, species checklist, spiders

1. Introduction

The spider fauna in Serbia is still insufficiently studied. Among the Balkan countries, Serbia ranks quite high in terms of the study of its spider fauna, but compared to most other European countries, this level is relatively low (Deltshev et al., 2003). The arachnological studies of Serbia started in the late 19th century. The first data on spiders can be found in the works of Spasojević (1891), Chyzer & Kulczyński (1894, 1897) and Bresjančeva (1907). The most significant work on the spider fauna of Serbia was published by Stojićević (1929). This publication provides an overview of the species and literature published to that time, where reported 432 species from 34 families. Drensky (1936) summarized the spider fauna of the Balkan Peninsula, where he listed 447 species from 34 families for Serbia. Then, Nikolić & Polenec (1981) summarize data for spiders of the former Yugoslavia and reported 525 species from 35 families for Serbia. In the work of Deltshev et al. (2003), which was based on the literature on spiders in Serbia, 618 species from 36 families were reported. Many recent authors in their papers add contribution to the arachnological research in Serbia.

The aim of this study is to give a taxonomic and faunistic review of the spider fauna of Serbia based on previous research.

2. Materials and Methods

The present checklist is based on available literature items with original records of spiders. The following literature was used in this work: Spasojević, 1891; Chyzer & Kulczyński, 1894, 1897; Bresjančeva, 1907; Stojićević, 1929; Fage, 1931; Kratochvíl, 1934; Drensky, 1936; Kolosváry, 1938, 1940; Kratochvíl & Miller, 1938; Šilhavý, 1944; Marinković et al., 1954; Deeleman-Reinhold, 1974, 1986; Sisojević & Miller, 1978, 1979, 1985; Nikolić & Polenec, 1981; Grimm, 1985; Thaler & Höfer, 1988; Deltshev et al., 1996, 1997, 1998, 2014; Knoflach, 1996; Deltshev & Ćurčić, 1997, 2002, 2011; Ćurčić et al., 1999a, 1999b, 1999c, 2000a, 2000b, 2003, 2004, 2007; Tomić, 2006; Komnenov & Pavićević, 2008, 2009; Tomić & Grbić, 2008; Grbić & Savić, 2010; Stanković, 2010, 2012, 2019, 2023; Deltshev, 2011; Dudić et al., 2011, 2013, 2023; Grbić et al., 2011, 2015, 2019, 2021; Pavićević et al., 2011;

Vrenozi & Jäger, 2013; Petrović, 2014; Gajić & Grbić, 2016; Naumova et al., 2016; Geci & Naumova, 2021a, 2021b; Grapci-Kotori et al., 2022; Grbić & Hänggi, 2022; Grbić & Stanković, 2022; Geci et al., 2023, 2024, 2025a, 2025b, 2025d; Grbić & Marinković, 2023; Ibrahimi et al., 2024; Islami et al., 2024; Komnenov, 2025b.

Additionally, species from the „Spiders of Europe“ website (Nentwig et al., 2025), which do not have a corresponding reference confirming their presence in Serbia (with**), are included in the list with the temporary reference - Nentwig et al., 2025. The classification and nomenclature follow the World Spider Catalog (2025), and all taxa are listed alphabetically.

3. Findings and Discussion

According to records published in the available literature, 790 species from 41 families of spiders have been registered in Serbia so far (Table 1).

Table 1. Checklist of spiders of Serbia with references.

Family AGELENIDAE
Agelena labyrinthica (Clerck, 1757): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1979; Nikolić & Polenec, 1981; Ćurčić et al., 2004; Grbić & Savić, 2010; Dudić et al., 2011; Grbić, et al., 2011, 2021; Petrović, 2014; Gajić & Grbić, 2016; Grbić & Stanković, 2022; Geci et al., 2023; Stanković, 2023.
Allagelena gracilens (C.L. Koch, 1841): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1978, 1979; Nikolić & Polenec, 1981; Ćurčić et al., 2004; Tomić, 2006; Tomić & Grbić, 2008; Grbić et al., 2011, 2019, 2021; Geci et al., 2025a.
Coelotes atropos (Walckenaer, 1830): Bresjančeva, 1907; Drensky, 1936; Ćurčić, 1969; Deltshev et al., 1996; Stanković, 2023.
Coelotes titaniacus (Brignoli, 1977): Ćurčić et al., 2003.
Eratigena agrestis (Walckenaer, 1802): Dudić et al., 2011, 2013; Geci & Naumova, 2021b; Grbić & Hänggi, 2022.
Eratigena atrica (C. L. Koch, 1843): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
Eratigena fuesslini (Pavesi, 1873): Bolzern et al., 2013b.
Eratigena picta (Simon, 1870): Nikolić & Polenec, 1981.
**Eratigena mirusha* (Geci, Naumova & Ibrahimi, 2025): Geci et al., 2025b.
***Histopona conveniens* (Kulczyński, 1914): temporarily - Nentwig et al., 2025.
***Histopona dubia* (Absolon & Kratochvíl, 1933): temporarily - Nentwig et al., 2025.
Histopona laeta (Kulczyński, 1897): Ćurčić et al., 1999c, 2000b, 2004; Pavićević et al., 2011; Grapci-Kotori et al., 2022.
Histopona luxurians (Kulczyński, 1897): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Ćurčić et al., 2000a, 2003; Tomić, 2006; Pavićević et al., 2011; Geci et al., 2023.
Histopona torpida (C. L. Koch, 1837): Chyzer & Kulczyński, 1897; Stojićević, 1929; Nikolić & Polenec, 1981; Ćurčić et al., 2000a, 2003; Tomić, 2006; Tomić & Grbić, 2008; Grbić et al., 2011, 2015; Gajić & Grbić, 2016; Geci & Naumova, 2021b; Grbić & Stanković, 2022; Grbić & Hänggi, 2022; Geci et al., 2023.
Inermocoelotes anoplus (Kulczyński, 1897): Bresjančeva, 1907; Drensky, 1936; Nikolić & Polenec, 1981.
Inermocoelotes falciger (Kulczyński, 1897): Stojićević, 1929; Drensky, 1936; Kolosváry, 1938, 1940b; Nikolić & Polenec, 1981; Ćurčić et al., 2004; Tomić, 2006; Komnenov & Pavićević, 2009; Grbić & Savić, 2010; Geci & Naumova, 2021b; Grbić & Stanković, 2022.
Inermocoelotes inermis (L. Koch, 1855): Stojićević, 1929; Drensky, 1936; Kolosváry, 1938, 1940b; Ćurčić, 1969; Nikolić & Polenec, 1981; Deltshev et al., 1996; Ćurčić et al., 2000a, 2003, 2004; Tomić & Grbić, 2008; Grbić & Savić, 2010; Dudić et al., 2011; Grbić et al., 2011, 2015; Vrenozi & Jäger, 2013; Grbić & Stanković, 2022; Grbić & Hänggi, 2022.
Inermocoelotes jurinitschi (Drensky, 1915): Ćurčić et al., 2003.
**Inermocoelotes karlinskii* (Kulczyński, 1906): Grapci-Kotori et al., 2022; Geci et al., 2023.
**Inermocoelotes kulczynskii* (Drensky, 1915): Geci & Naumova, 2021b.
**Inermocoelotes melovskii* (Komnenov, 2017): Grapci-Kotori et al., 2022.
**Lycosoides coarctata* (Dufour, 1831): Vrenozi & Jäger, 2013.
**Tegenaria bosnica* (Kratochvíl & Miller, 1940): Geci & Naumova, 2021b.
Tegenaria campestris (C. L. Koch, 1843): Stojićević, 1929; Drensky, 1936; Ćurčić, 1969; Sisojević & Miller, 1978, 1979; Nikolić & Polenec, 1981; Deltshev et al., 1996; Ćurčić et al., 2004; Tomić & Grbić, 2008; Dudić et al., 2011; Grbić et al., 2015; Gajić & Grbić, 2016; Geci & Naumova, 2021b; Grbić & Stanković, 2022; Grbić & Hänggi, 2022.
Tegenaria domestica (Clerck, 1757): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Ćurčić, 1969; Nikolić & Polenec, 1981; Deltshev et al., 1996; Ćurčić et al., 2003; Komnenov & Pavićević, 2009; Dudić et al., 2011; Petrović, 2014; Geci & Naumova, 2021b; Stanković, 2023.

Tegenaria ferruginea (Panzer, 1804): Stojićević, 1929; Drensky, 1936; Ćurčić, 1969; Nikolić & Polenec, 1981; Deltshev et al., 1996, 1998; Ćurčić et al., 2000b; Geci et al., 2023.
Tegenaria hasperi (Chyzer, 1897): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Dudić et al., 2013; Grbić et al., 2021; Geci et al., 2025a.
Tegenaria pagana (C. L. Koch, 1840): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
Tegenaria parietina (Fourcroy, 1785): Nikolić & Polenec, 1981.
Tegenaria silvestris (L. Koch, 1872): Stojićević, 1929; Drensky, 1936; Ćurčić 1969; Nikolić & Polenec, 1981; Deltshev et al., 1996; Ćurčić et al., 1999a, 2000b; Grbić & Savić, 2010; Gajić & Grbić, 2016; Geci et al., 2023.
Textrix denticulata (Olivier, 1789): Nikolić & Polenec, 1981.
Urocoras longispina (Kulczyński, 1897): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Ćurčić et al., 2000b, 2003; Tomić, 2006; Tomić & Grbić, 2008; Komnenov & Pavićević, 2009; Grbić & Savić, 2010; Grbić et al., 2011, 2015, 2019; Gajić & Grbić, 2016; Grbić & Stanković, 2022; Grbić & Hänggi, 2022; Stanković, 2023.
Family AMAUROBIIDAE
Amaurobius erberi (Keyserling, 1863): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Komnenov & Pavićević, 2009; Geci et al., 2023.
Amaurobius fenestralis (Ström, 1768): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Ćurčić et al., 2000b; Grapci-Kotori et al., 2022; Stanković, 2023.
Amaurobius ferox (Walckenaer, 1830): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Ćurčić, 1969; Nikolić & Polenec, 1981; Deltshev et al., 1996; Komnenov & Pavićević, 2009; Grbić & Savić, 2010; Stanković, 2023.
Amaurobius pallidus (L. Koch, 1868): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Ćurčić et al., 2003; Tomić, 2006.
**Amaurobius phaeacus* (Thaler & Knoflach, 1998): Geci & Naumova, 2021b.
Family ANAPIDAE
***Comaroma simoni* (Bertkau, 1889): temporarily - Nentwig et al., 2025.
***Zangherella relicta* (Kratochvíl, 1935): temporarily - Nentwig et al., 2025.
Family ANYPHAENIDAE
Anyphaena accentuata (Walckenaer, 1802): Chyzer & Kulczyński, 1897; Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1978, 1979, 1985; Nikolić & Polenec, 1981; Tomić & Grbić, 2008; Dudić et al., 2011; Grbić et al., 2011, 2019, 2021; Geci & Naumova, 2021b; Grbić & Hänggi, 2022; Geci et al., 2023.
Family ARANEIDAE
Aculepeira carbonaria (L. Koch, 1869): Nikolić & Polenec, 1981.
Aculepeira ceropegia (Walckenaer, 1802): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Vrenozi & Jäger, 2013; Grapci-Kotori et al., 2022; Grbić & Stanković, 2022; Geci et al., 2023.
Agalenatea redii (Scopoli, 1763): Stojićević, 1929; Drensky, 1936; Kolosváry, 1938, 1940b; Nikolić & Polenec, 1981; Komnenov & Pavićević, 2009; Grbić & Savić, 2010; Petrović, 2014; Grbić et al., 2011, 2015, 2019, 2021; Geci & Naumova, 2021b; Geci et al., 2023; Stanković, 2023.
Araneus alsine (Walckenaer, 1802): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Grbić et al., 2011; Islami et al., 2024.
Araneus angulatus (Clerck, 1757): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1979; Nikolić & Polenec, 1981; Ćurčić et al., 2000b, 2004; Tomić & Grbić, 2008; Grbić et al., 2011, 2019, 2021; Vrenozi & Jäger, 2013; Petrović, 2014; Grapci-Kotori et al., 2022; Geci et al., 2023; Stanković, 2023.
Araneus circe (Audouin, 1826): Bresjančeva, 1907; Drensky, 1936; Nikolić & Polenec, 1981; Grbić, et al., 2011; Vrenozi & Jäger, 2013.
Araneus diadematus (Clerck, 1757): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Ćurčić, 1969; Sisojević & Miller, 1978, 1979, 1985; Nikolić & Polenec, 1981; Deltshev et al., 1996; Tomić, 2006; Tomić & Grbić, 2008; Dudić et al., 2011; Grbić et al., 2011, 2019, 2021; Petrović, 2014; Gajić & Grbić, 2016; Grapci-Kotori et al., 2022; Geci et al., 2023; Stanković, 2023.
Araneus grossus (C. L. Koch, 1844): Kolosváry, 1938; Sisojević & Miller, 1979; Nikolić & Polenec, 1981; Ibrahimi et al., 2024.
Araneus marmoreus (Clerck, 1757): Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1979, 1985; Grbić et al., 2011, 2019; Geci et al., 2023.
Araneus nordmanni (Thorell, 1870): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
Araneus quadratus (Clerck, 1757): Bresjančeva, 1907; Drensky, 1936; Nikolić & Polenec, 1981; Ćurčić et al., 2004; Grbić & Savić, 2010; Dudić et al., 2011; Grbić et al., 2011, 2021; Gajić & Grbić, 2016; Geci & Naumova, 2021b; Grapci-Kotori et al., 2022.
Araneus saevus (L. Koch, 1872): Bresjančeva, 1907; Drensky, 1936; Dudić et al., 2011.
Araneus sturmi (Hahn, 1831): Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1979, 1985; Nikolić & Polenec, 1981.
Araneus triguttatus (Fabricius, 1793): Kolosváry, 1938; Sisojević & Miller, 1979, 1985; Nikolić & Polenec, 1981.
Araniella alpica (L. Koch, 1869): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
Araniella cucurbitina (Clerck, 1757): Bresjančeva, 1907; Drensky, 1936; Sisojević & Miller, 1978, 1979, 1985; Nikolić & Polenec, 1981; Tomić & Grbić, 2008; Grbić et al., 2011; Vrenozi & Jäger, 2013; Geci et al., 2023; Stanković, 2023.

Araniella displicata (Hentz, 1847): Bresjančeva, 1907; Drensky, 1936; Sisojević & Miller, 1978; Nikolić & Polenec, 1981; Tomić & Grbić, 2008.
Araniella inconspicua (Simon, 1874): Bresjančeva, 1907; Drensky, 1936; Sisojević & Miller, 1978; Nikolić & Polenec, 1981; Tomić & Grbić, 2008; Dudić et al., 2011.
Araniella opisthographa (Kulczyński, 1905): Vrenozi & Jäger, 2013; Grbić et al., 2021; Grapci-Kotori et al., 2022.
Argiope bruennichi (Scopoli, 1772): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Kolosváry, 1938; Marinković et al., 1954; Nikolić & Polenec, 1981; Ćurčić et al., 2004; Tomić, 2006; Tomić & Grbić, 2008; Grbić et al., 2011, 2015, 2019, 2021; Petrović, 2014; Geci et al., 2023; Stanković, 2023.
Argiope lobata (Pallas, 1772): Chyzer & Kulczyński, 1897; Nikolić & Polenec, 1981; Tomić & Grbić, 2008; Grbić et al., 2011, 2019, 2021; Ibrahimi et al., 2024.
Cercidia prominens (Westring, 1851): Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1979; Nikolić & Polenec, 1981; Ćurčić et al., 2003; Tomić, 2006; Tomić & Grbić, 2008; Grbić & Häggi, 2022.
Cyclosa conica (Pallas, 1772): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1978, 1979, 1985; Tomić & Grbić, 2008; Dudić et al., 2011; Grbić et al., 2011, 2015, 2019; Petrović, 2014; Geci & Naumova, 2021b; Grapci-Kotori et al., 2022; Grbić & Stanković, 2022; Geci et al., 2023; Stanković, 2023.
Cyclosa oculata (Walckenaer, 1802): Grbić et al., 2011, 2021; Stanković, 2023; Ibrahimi et al., 2024.
Gibbaranea bituberculata (Walckenaer, 1802): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1978, 1979; Nikolić & Polenec, 1981; Tomić & Grbić, 2008; Komnenov & Pavićević, 2009; Dudić et al., 2011; Grbić et al., 2011, 2019, 2021; Geci & Naumova, 2021b; Grapci-Kotori et al., 2022; Geci et al., 2023; Stanković, 2023.
Gibbaranea gibbosa (Walckenaer, 1802): Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1979; Nikolić & Polenec, 1981; Geci et al., 2023.
Gibbaranea omoeda (Thorell, 1870): Nikolić & Polenec, 1981.
Gibbaranea ullrichi (Hahn, 1835): Nikolić & Polenec, 1981.
***Glyptogona sextuberculata* (Keyserling, 1863): temporarily - Nentwig et al., 2025.
Hypsosinga albovittata (Westring, 1851): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Geci et al., 2023.
Hypsosinga heri (Hahn, 1831): Bresjančeva, 1907; Drensky, 1936; Nikolić & Polenec, 1981; Grbić et al., 2011, 2021; Grbić & Stanković, 2022.
Hypsosinga pygmaea (Sundevall, 1831): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Grbić & Savić, 2010; Grbić et al., 2011, 2021; Dudić et al. 2013; Gajić & Grbić, 2016; Stanković, 2023.
Hypsosinga sanguinea (C. L. Koch, 1844): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Tomić & Grbić, 2008; Grbić et al., 2011; Petrović, 2014.
Larinioides cornutus (Clerck, 1757): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Dudić et al., 2011; Grbić et al., 2021; Stanković, 2023.
Larinioides ixobolus (Thorell, 1873): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Grbić et al., 2011; Grbić & Stanković, 2022; Stanković, 2023.
Larinioides patagiatus (Clerck, 1757): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1978, 1979; Nikolić & Polenec, 1981; Tomić & Grbić, 2008; Gajić & Grbić, 2016; Geci & Naumova, 2021b; Grapci-Kotori et al., 2022; Geci et al., 2023.
Larinioides sclopetarius (Clerck, 1757): Nikolić & Polenec, 1981.
Larinioides suspicax (O. Pickard-Cambridge, 1876): Grbić & Savić, 2010; Grbić, et al., 2011; Geci & Naumova, 2021b; Stanković, 2023.
Leviellus kochi (Thorell, 1870): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
Leviellus stroemi (Thorell, 1870): Chyzer & Kulczyński, 1897; Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1978; Nikolić & Polenec, 1981; Tomić & Grbić, 2008.
Leviellus thorelli (Ausserer, 1871): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Grbić et al., 2011; Geci & Naumova, 2021b.
Mangora acalypha (Walckenaer, 1802): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1978, 1979; Nikolić & Polenec, 1981; Tomić, 2006; Tomić & Grbić, 2008; Dudić et al., 2011; Grbić et al., 2011, 2015, 2021; Petrovic, 2014; Gajić & Grbić, 2016; Geci & Naumova, 2021b; Geci et al., 2023; Stanković, 2023.
Neoscona adianta (Walckenaer, 1802): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Grbić et al., 2021; Geci et al., 2023.
**Neoscona byzanthina* (Pavesi, 1876): Geci & Naumova, 2021.
Neoscona subfusca (C. L. Koch 1837): Stanković, 2023.
Nuctenea silvicultrix (C. L. Koch, 1835): Nikolić & Polenec, 1981.
Nuctenea umbratica (Clerck, 1757): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1978, 1979; Nikolić & Polenec, 1981; Ćurčić et al., 2004; Tomić & Grbić, 2008; Dudić et al., 2011; Grbić et al., 2011; Geci & Naumova, 2021b; Grbić & Stanković, 2022; Stanković, 2023.
Parazygiella montana (C. L. Koch, 1834): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
Singa hamata (Clerck, 1757): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Kolosváry, 1938, 1940a; Nikolić & Polenec, 1981; Dudić, et al. 2013; Gajić & Grbić, 2016; Grbić et al., 2021.
Singa lucina (Audouin, 1826): Grbić et al., 2021.

Singa nitidula (C. L. Koch, 1844): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Kolosváry, 1938; Sisojević & Miller, 1979; Nikolić & Polenec, 1981; Grbić et al., 2011, 2021; Dudić, et al. 2013; Grbić & Stanković, 2022; Stanković, 2023.
Zilla diodia (Walckenaer, 1802): Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1979, 1985; Nikolić & Polenec, 1981; Dudić et al., 2011; Grbić et al., 2011, 2019, 2021; Geci & Naumova, 2021b; Geci et al., 2023.
Zygiella atrica (C. L. Koch, 1845): Bresjančeva, 1907; Drensky, 1936.
Zygiella keyserlingi (Ausserer, 1871): Kolosváry, 1938, 1940b; Nikolić & Polenec, 1981.
Zygiella x–notata (Clerck, 1757): Nikolić & Polenec, 1981; Dudić et al., 2011; Stanković, 2023.
Family ATYPIDAE
Atypus affinis (Eichwald, 1830): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
Atypus muralis (Bertkau, 1890): Grbić et al., 2011, 2019.
Atypus piceus (Sulzer, 1776): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Tomić, 2006; Tomić & Grbić, 2008; Grbić & Hänggi, 2022; Stanković, 2023.
Family CHEIRACANTHIIDAE
Cheiracanthium effossum (Herman, 1879): Sisojević & Miller, 1985.
Cheiracanthium elegans (Thorell, 1875): Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1978, 1979; Nikolić & Polenec, 1981; Tomić & Grbić, 2008; Grbić et al., 2011, 2019.
Cheiracanthium erraticum (Walckenaer, 1802): Chyzer & Kulczyński, 1897.
Cheiracanthium mildei (L. Koch, 1864): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Komnenov & Pavićević, 2009; Stanković, 2023; Geci et al., 2025a.
Cheiracanthium oncognathum (Thorell, 1871): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Geci et al., 2023.
Cheiracanthium pelasgicum (C. L. Koch, 1837): Nikolić & Polenec, 1981.
**Cheiracanthium pennyi* (O. Pickard-Cambridge, 1873): Geci et al., 2023.
Cheiracanthium punctorium (Villers, 1789): Sisojević & Miller, 1979; Nikolić & Polenec, 1981; Tomić & Grbić, 2008; Petrović, 2014; Grbić et al., 2021.
Cheiracanthium virescens (Sundevall, 1833): Chyzer & Kulczyński, 1897; Sisojević & Miller, 1979, 1985; Nikolić & Polenec, 1981; Tomić, 2006.
Family CICURINIDAE
Bromella falcigera (Balogh, 1935): Ćurčić et al., 1999a; Grbić et al., 2021.
Cicurina cicur (Fabricius, 1793): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Ćurčić 1969; Nikolić & Polenec, 1981; Deltshev et al., 1996; Ćurčić et al., 2000; Grbić & Savić, 2010; Dudić et al., 2011; Naumova et al., 2016; Grbić & Häggi, 2022.
Family CLUBIONIDAE
Clubiona brevipes (Blackwall, 1841): Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1979; Nikolić & Polenec, 1981; Gajić & Grbić, 2016; Grbić et al., 2021.
Clubiona caerulescens (L. Koch, 1867): Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1978, 1979, 1985; Nikolić & Polenec, 1981; Ćurčić et al., 2000a; 2000b; Tomić & Grbić, 2008; Geci et al., 2025a.
Clubiona comta (C. L. Koch, 1839): Sisojević & Miller, 1978, 1979, 1985; Nikolić & Polenec, 1981; Ćurčić et al., 2003; Tomić & Grbić, 2008; Grbić et al., 2011, 2015, 2019, 2021; Gajić & Grbić, 2016; Grapci-Kotori et al., 2022; Grbić & Hänggi, 2022.
Clubiona corticalis (Walckenaer, 1802): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Geci et al., 2023.
Clubiona frutetorum (L. Koch, 1867): Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1979; Nikolić & Polenec, 1981.
Clubiona germanica (Thorell, 1871): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
**Clubiona juvenis* (Simon, 1878): Geci et al., 2023.
Clubiona lutescens (Westring, 1851): Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1978; Nikolić & Polenec, 1981; Tomić & Grbić, 2008; Dudić et al., 2011; Grbić et al., 2011; Gajić & Grbić, 2016.
Clubiona marmorota (L. Koch, 1866): Sisojević & Miller, 1978, 1979, 1985; Nikolić & Polenec, 1981; Tomić & Grbić, 2008.
Clubiona neglecta (O. Pickard–Cambridge, 1862): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Dudić et al., 2011; Geci et al., 2025a.
Clubiona pallidula (Clerck, 1757): Bresjančeva, 1907; Drensky, 1936; Sisojević & Miller, 1979, 1985; Grbić et al., 2011, 2021; Gajić & Grbić, 2016.
Clubiona phragmitis (C. L. Koch, 1843): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Gajić & Grbić, 2016.
Clubiona pseudoneglecta (Wunderlich, 1994): Grbić & Savić, 2010; Grbić et al., 2021; Grapci-Kotori et al., 2022.
Clubiona rosserae (Locket, 1953): Grbić et al., 2021.
Clubiona saxatilis (L. Koch, 1867): Ćurčić et al., 2003.
**Clubiona similis* L. (Koch, 1867): Geci et al., 2023.
**Clubiona stagnatilis* (Kulczyński, 1897): Vrenozi & Jäger, 2013.
Clubiona subsultans (Thorell, 1875): Nikolić & Polenec, 1981; Geci et al., 2023.

Clubiona terrestris (Westring, 1851): Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1978, 1979; Nikolić & Polenec, 1981; Ćurčić et al., 2000b, 2003; Tomić, 2006; Tomić & Grbić, 2008; Dudić et al., 2011; Grbić et al., 2011, 2019, 2021; Gajić & Grbić, 2016; Geci & Naumova, 2021b; Grbić & Häggi, 2022; Stanković, 2023.
Clubiona trivialis (C. L. Koch, 1843): Chyzer & Kulczyński, 1897.
Porrhoclubiona genevensis (L. Koch, 1866): Sisojević & Miller, 1979; Nikolić & Polenec, 1981; Geci & Naumova, 2021b.
Family CYBAEIDAE
Cryphoeca silvicola (C. L. Koch, 1834): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Ćurčić et al., 2000a; Geci et al., 2023.
Cybaeus angustiarum (L. Koch, 1868): Stojićević, 1929; Drensky, 1936; Ćurčić, 1969; Nikolić & Polenec, 1981; Deltshev et al., 1996.
Cybaeus balkanus (Deltshev, 1997): Ćurčić et al., 2000b, 2003; Grapci-Kotori et al., 2022; Grbić & Stanković, 2022.
Cybaeus tetricus (C. L. Koch, 1839): Stojićević, 1929.
Family DICTYNIDAE
Archaeodictyna ammophila (Menge, 1871): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
Argenna patula (Simon, 1874): Grbić et al., 2021.
Argenna subnigra (O. Pickard–Cambridge, 1861): Stojićević, 1929; Nikolić & Polenec, 1981; Grbić et al., 2015, 2021.
Argyroneta aquatica (Clerck, 1757): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Grbić et al., 2011.
Brigittea civica (Lucas, 1848): Grbić & Savić, 2010.
Brigittea latens (Fabricius, 1775): Chyzer & Kulczyński, 1897; Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Tomić & Grbić, 2008; Geci & Naumova, 2021b; Stanković, 2023.
Brigittea vicina (Simon, 1873): Sisojević & Miller, 1979; Nikolić & Polenec, 1981.
Dictyna arundinacea (Linnaeus, 1758): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1979; Nikolić & Polenec, 1981; Ćurčić et al., 2003; Dudić et al., 2011; Grbić et al., 2011, 2021.
Dictyna major (Menge, 1869): Nikolić & Polenec, 1981.
Dictyna uncinata (Thorell, 1856): Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1979; Nikolić & Polenec, 1981; Grbić, et al., 2011; Gajić & Grbić, 2016.
Emblyna brevidens (Kulczyński, 1897): Nikolić & Polenec, 1981.
Lathys hetrophthalma (Kulczyński, 1891): Grbić et al., 2015, 2021.
Lathys humilis (Blackwall, 1855): Sisojević & Miller, 1978, 1979; Nikolić & Polenec, 1981; Tomić & Grbić, 2008; Dudić et al., 2011; Grbić et al., 2021.
Lathys stigmatisata (Menge, 1869): Grbić et al., 2021.
Nigma flavescens (Walckenaer, 1830): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1978, 1979; Nikolić & Polenec, 1981; Tomić & Grbić, 2008; Dudić et al., 2011; Geci & Naumova, 2021b.
Nigma walckenaeri (Roewer, 1951): Bresjančeva, 1907; Drensky, 1936; Nikolić & Polenec, 1981; Sisojević & Miller, 1985.
Family DOLOMEDIDAE
Dolomedes fimbriatus (Clerck, 1757): Stojićević, 1929; Nikolić & Polenec, 1981; Grbić & Savić, 2010; Grbić, et al., 2011; Gajić & Grbić, 2016.
Dolomedes plantarius (Clerck, 1757): Bresjančeva, 1907; Stojićević, 1929; Nikolić & Polenec, 1981; Grbić et al., 2011, 2021; Gajić & Grbić, 2016; Grbić & Stanković, 2022.
Family DYSDERIDAE
Dasumia canestrinii (L. Koch, 1876): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Tomić, 2006; Grbić & Savić, 2010.
***Dasumia chyzeri* (Kulczyński, 1906): temporarily - Nentwig et al., 2025.
Dasumia kusceri (Kratochvíl, 1935): Nikolić & Polenec, 1981.
Dysdera adriatica (Kulczyński, 1897): Nikolić & Polenec, 1981; Deeleman–Reinhold & Deeleman, 1988; Ćurčić et al., 1999c, 2003.
Dysdera crocata (C. L. Koch, 1838): Bresjančeva, 1907; Drensky, 1936; Nikolić & Polenec, 1981; Dudić et al., 2011; Geci & Naumova, 2021b; Stanković, 2023.
***Dysdera dubrovninnii* (Deeleman-Reinhold, 1988): temporarily - Nentwig et al., 2025.
***Dysdera granulata* (Kulczyński, 1897): temporarily - Nentwig et al., 2025.
Dysdera hungarica (Kulczyński, 1897): Stojićević, 1929; Drensky, 1936; Ćurčić et al., 2000a, 2000b; Grbić et al., 2021; Stanković, 2023.
***Dysdera kollari* (Doblika, 1853): temporarily - Nentwig et al., 2025.
Dysdera longirostris (Doblika, 1853): Chyzer & Kulczyński, 1897; Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1978; Nikolić & Polenec, 1981; Deeleman–Reinhold & Deeleman, 1988; Ćurčić et al., 2000a, 2000b, 2004; Tomić & Grbić, 2008; Komnenov & Pavićević, 2009; Grbić et al., 2011, 2019; Vrenozi & Jäger, 2013; Gajić & Grbić, 2016; Grbić & Hänggi, 2022; Grbić & Stanković, 2022.
Dysdera microdonta (Gasparo, 2014): Grbić et al., 2015; Grbić & Hänggi, 2022.
Dysdera moravica (Řezáč, 2014): Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1979; Nikolić & Polenec, 1981; Ćurčić et al., 2000, 2003; Grbić & Savić, 2010; Gajić & Grbić, 2016.

**Dysdera spinicrus* (Simon, 1882): temporarily - Nentwig et al., 2025.
Dysdera westringi (O. Pickard–Cambridge, 1872): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
Dysderocrates egregius (Kulczyński, 1897): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
Dysderocrates silverstris (Deeleman–Reinhold, 1988): Ćurčić et al., 2004; Grapci-Kotori et al., 2022.
Dysderocrates storkani (Kratochvíl, 1935): Kratochvíl, 1935; Deeleman–Reinhold & Deeleman, 1988; Ćurčić et al., 1999, 2003; Grapci-Kotori et al., 2022; Geci et al., 2023.
Harpactea complicata (Deltshev, 2011): Deltshev & Ćurčić, 2011.
Harpactea hombergi (Scopoli, 1763): Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1978; Nikolić & Polenec, 1981; Ćurčić et al., 2000b; Tomić & Grbić, 2008; Dudić et al., 2011; Geci & Naumova, 2021b.
Harpactea lepida (C. L. Koch, 1838): Ćurčić et al., 2000a, 2004; Geci et al., 2023.
**Harpactea nausicaae* (Brignoli, 1976): Geci & Naumova, 2021b.
Harpactea rubicunda (C. L. Koch, 1838): Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1979; Nikolić & Polenec, 1981; Ćurčić et al., 2003; Grbić & Savić, 2010; Grbić et al., 2011, 2015, 2019, 2021; Grbić & Hänggi, 2022.
Harpactea saeva (Herman, 1879): Stojićević, 1929; Nikolić & Polenec, 1981; Ćurčić et al., 1999b, 2000b; Tomić, 2006; Tomić & Grbić, 2008; Grbić et al., 2015; Geci & Naumova, 2021b; Grbić & Hänggi, 2022; Geci et al., 2023; Stanković, 2023.
Harpactea simovi (Deltshev & Lazarov, 2018): Komnenov, 2025b
Harpactea tenuiemboli (Deltshev, 2011): Deltshev, 2011.
Kaemis carnicus (Gasparo, 1995): Ćurčić et al., 1999c, 2000a, 2003.
**Parastalita stygia* (Joseph, 1882): temporarily - Nentwig et al., 2025.
**Stalagtia hercegovinensis* (Nosek, 1905): temporarily - Nentwig et al., 2025.
Family ERESIDAE
Eresus kollari (Rossi, 1846): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Ćurčić et al., 2004 (recorded as *Eresus cinnaberius* Olivier, 1789); Geci et al., 2023.
Eresus moravicus (Rezač, 2007): Grbić & Savić, 2010; Geci et al., 2025a.
Family GNAPHOSIDAE
Aphantaulax cincta (L. Koch, 1866): Chyzer & Kulczyński, 1897; Nikolić & Polenec, 1981; Sisojević & Miller, 1978; Tomić & Grbić, 2008.
Aphantaulax trifasciata (O. Pickard-Cambridge, 1872): Nikolić & Polenec, 1981; Chyzer & Kulczyński, 1897; Tomić & Grbić, 2008; Grbić et al., 2021.
Berlandina cinerea (Menge, 1872): Grbić et al., 2021.
**Berlandina plumalis* (O. Pickard–Cambridge, 1872): Vrenozi & Jäger, 2013.
**Callilepis cretica* (Roewer, 1928): Geci & Naumova, 2021b.
Callilepis nocturna (Linnaeus, 1758): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Grimm, 1985; Ćurčić et al., 2003.
Callilepis schuszteri (Herman, 1879): Grbić & Hänggi, 2022.
Civizelotes caucasius (L. Koch, 1866): Nikolić & Polenec, 1981; Geci et al., 2023.
Civizelotes gracilis (Canestrini, 1868): Grbić & Savić, 2010; Dudić et al., 2013; Grbić et al., 2015.
Civizelotes pygmaeus (Miller, 1943): Dudić et al., 2013;
Drassodes cupreus (Blackwall, 1834): Geci & Naumova, 2021b; Grbić & Hänggi, 2022.
Drassodes lapidosus (Walckenaer, 1802): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1978, 1979; Nikolić & Polenec, 1981; Deltshev et al., 1996; Ćurčić et al., 2004; Tomić & Grbić, 2008; Grbić, et al., 2011, 2015, 2019, 2021; Dudić et al., 2013; Geci & Naumova, 2021b; Grapci-Kotori et al., 2022; Grbić & Stanković, 2022; Geci et al., 2023.
Drassodes montenegrinus (Kulczyński, 1897): Bresjančeva, 1907; Drensky, 1936; Nikolić & Polenec, 1981.
Drassodes pubescens (Thorell, 1856): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Dudić et al., 2011; Grbić et al., 2021.
**Drassodes striatus* (L. Koch, 1866): temporarily - Nentwig et al., 2025.
Drassodes villosus (Thorell, 1856): Drensky, 1936; Geci et al., 2023.
Drassodex hypocrita (Simon, 1878): Bresjančeva, 1907; Drensky, 1936; Nikolić & Polenec, 1981.
Drassyllus lutetianus (L. Koch, 1866): Stojićević, 1929; Drensky, 1936; Dudić et al., 2013; Gajić & Grbić, 2016; Grbić et al., 2021.
Drassyllus praeficus (L. Koch, 1866): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Grbić & Savić, 2010; Dudić et al., 2013; Grbić et al., 2015, 2021; Grbić & Hänggi, 2022; Grbić & Stanković, 2022; Stanković, 2023.
Drassyllus pumilus (C. L. Koch, 1839): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
Drassyllus pusillus (C. L. Koch, 1833): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Dudić et al., 2013; Gajić & Grbić, 2016; Grbić et al., 2021.
Drassyllus villicus (Thorell, 1875): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Grbić et al., 2015, 2021; Gajić & Grbić, 2016; Geci & Naumova, 2021b; Grbić & Hänggi, 2022.
Echemus angustifrons (Westring, 1861): Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1978; Nikolić & Polenec,

1981; Tomić & Grbić, 2008.
Gnaphosa bicolor (Hahn, 1833): Bresjančeva, 1907; Drensky, 1936.
Gnaphosa dolosa (Herman, 1879): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
Gnaphosa lucifuga (Walckenaer, 1802): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Deltshev et al., 1996; Dudić et al., 2013; Grbić et al., 2015; Grbić & Stanković, 2022; Stanković, 2023.
Gnaphosa lugubris (C. L. Koch, 1839): Chyzer & Kulczyński, 1897; Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
Gnaphosa modestior (Kulczyński, 1897): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
Gnaphosa mongolica (Simon, 1895): Grbić et al., 2021.
Gnaphosa montana (L. Koch, 1866): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
Gnaphosa muscorum (L. Koch, 1866): Grbić et al., 2011, 2019, 2021.
Gnaphosa occidentalis (Simon, 1878): Nikolić & Polenec, 1981.
Gnaphosa opaca (Herman, 1879): Grbić & Savić, 2010.
Haplodrassus bohemicus (Miller & Buchar, 1977): Grbić et al., 2021.
Haplodrassus cognatus (Westring, 1861): Bresjančeva, 1907; Drensky, 1936; Nikolić & Polenec, 1981.
Haplodrassus dalmatensis (L. Koch, 1866): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Dudić et al., 2013.
Haplodrassus kulczynskii (Lohmander, 1942): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
Haplodrassus minor (O. Pickard–Cambridge, 1879): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Dudić et al., 2013; Grbić et al., 2021.
Haplodrassus moderatus (Kulczyński, 1897): Grbić et al., 2021.
Haplodrassus signifer (C. L. Koch, 1839): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Dudić et al., 2013; Grbić et al., 2015, 2021; Grbić & Hänggi, 2022; Grbić & Stanković, 2022; Geci et al., 2023.
Haplodrassus silverstris (Blackwall, 1833): Chyzer & Kulczyński, 1897; Sisojević & Miller, 1978, 1979; Nikolić & Polenec, 1981; Tomić, 2006; Tomić & Grbić, 2008; Grbić et al., 2015, 2021; Gajić & Grbić, 2016; Grbić & Stanković, 2022.
Haplodrassus umbratilis (L. Koch, 1866): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
Kishidaia conspicua (L. Koch, 1866): Sisojević & Miller, 1978; Nikolić & Polenec, 1981; Grbić & Stanković, 2022.
Micaria albovittata (Lucas, 1846): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
**Micaria coarctata* (Lucas, 1846): Geci et al., 2025a.
Micaria dives (Lucas, 1846): Grbić et al., 2015, 2021.
Micaria formicaria (Sundevall, 1831): Chyzer & Kulczyński, 1897; Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Tomić & Grbić, 2008; Grbić et al., 2015, 2021; Grbić & Hänggi, 2022.
Micaria fulgens (Walckenaer, 1802): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Ćurčić et al., 2003; Grbić et al., 2021.
Micaria guttulata (C. L. Koch, 1839): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
Micaria pulicaria (Sundevall, 1831): Stojićević, 1929; Kolosváry, 1938, 1940b; Nikolić & Polenec, 1981; Gajić & Grbić, 2016; Grbić et al., 2021.
Micaria silesiaca (L. Koch, 1875): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
Micaria sociabilis (Kulczyński, 1897): Nikolić & Polenec, 1981.
Micaria subopaca (Westring, 1861): Sisojević & Miller, 1979; Nikolić & Polenec, 1981.
Nomisia aussereri (L. Koch, 1872): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Grimm, 1985; Grbić et al., 2011, 2019.
Nomisia exornata (C. L. Koch, 1839): Chyzer & Kulczyński, 1897; Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Tomić & Grbić, 2008; Geci et al., 2025a.
**Nomisia levyi* (Chatzaki, 2010): Geci et al., 2025a.
Phaeocedus braccatus (L. Koch, 1866): Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1978; Nikolić & Polenec, 1981; Tomić & Grbić, 2008; Grbić et al., 2011, 2019.
Poecilochroa variana (C. L. Koch, 1839): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Grbić et al., 2021; Grbić & Hänggi, 2022.
***Pterotricha lentiginosa* (C. L. Koch, 1837): temporarily - Nentwig et al., 2025.
Scotophaeus blackwalli (Thorell, 1871): Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1978; Nikolić & Polenec, 1981; Tomić & Grbić, 2008.
Scotophaeus scutulatus (L. Koch, 1866): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1978; Nikolić & Polenec, 1981; Ćurčić et al., 2004; Grbić, et al., 2011; Tomić & Grbić, 2008; Stanković, 2023.
Sosticus loricatus (L. Koch, 1866): Stojićević, 1929; Nikolić & Polenec, 1981.
Trachyzelotes pedestris (C. L. Koch, 1837): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Grbić & Savić, 2010; Dudić et al., 2013; Grbić et al., 2015, 2021; Gajić & Grbić, 2016; Grbić & Hänggi, 2022; Grbić & Stanković, 2022.
Zelotes apricorum (L. Koch, 1876): Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1979; Nikolić & Polenec, 1981; Ćurčić et al., 2003; Tomić, 2006; Grbić et al., 2011, 2019, 2021; Gajić & Grbić, 2016; Geci & Naumova, 2021b; Grbić &

Stanković, 2022.
Zelotes aurantiacus (Miller, 1967): Grbić et al., 2011, 2019.
Zelotes clivicola (L. Koch, 1870): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
Zelotes electus (C. L. Koch, 1839): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Grbić et al., 2021.
Zelotes erebeus (Thorell, 1871): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Grbić & Savić, 2010; Dudić et al., 2011; Grbić et al., 2011, 2019, 2021; Grbić & Hänggi, 2022.
Zelotes exiguus (Müller & Schenkel, 1895): Grimm, 1985.
Zelotes hermani (Chyzer, 1897): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Grbić et al., 2015; Grbić & Stanković, 2022.
Zelotes latreillei (Simon, 1878): Bresjančeva, 1907; Drensky, 1936; Grbić et al., 2015, 2021; Gajić & Grbić, 2016; Grbić & Hänggi, 2022; Grbić & Stanković, 2022.
Zelotes longipes (L. Koch, 1866): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Grbić et al., 2011, 2019, 2021; Geci & Naumova, 2021b.
Zelotes mundus (Kulczynski, 1897): Dudić et al., 2013.
Zelotes oblongus (C. L. Koch, 1833): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Grbić & Savić, 2010; Grapci-Kotori et al., 2022.
**Zelotes olympi* (Kulczyński, 1903): Grapci-Kotori et al., 2022.
Zelotes petrensis (C. L. Koch, 1839): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Stanković, 2023.
Zelotes segrex (Simon, 1878): Grbić et al., 2011, 2019, 2021.
Zelotes similis (Kulczyński, 1887): Grimm, 1985; Grapci-Kotori et al., 2022; Geci et al., 2023.
Zelotes subterraneus (C. L. Koch, 1833): Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1978; Nikolić & Polenec, 1981; Tomić & Grbić, 2008; Grbić, et al., 2011, 2019.
Zelotes tenuis (L. Koch, 1866): Dudić et al., 2013.
Familly HAHNIIDAE
Hahnia nava (Blackwall, 1841): Ćurčić et al., 1999a; Grbić et al., 2021; Grbić & Stanković, 2022.
Hahnia ononidum (Simon, 1875): Sisojević & Miller, 1979; Nikolić & Polenec, 1981; Tomić, 2006.
Hahnia pusilla (C. L. Koch, 1841): Stojićević, 1929; Drensky, 1936; Grbić & Savić, 2010; Geci & Naumova, 2021b.
Iberina montana (Blackwall, 1841): Nikolić & Polenec, 1981; Grbić & Hänggi, 2022.
Family LEPTONETIDAE
***Barusia hofferi* (Kratochvíl, 1935): temporarily - Nentwig et al., 2025.
Protoleptoneta bulgarica (Deltshev, 1972): Deltshev et al., 1997, 1998; Ćurčić et al., 2000b.
Sulcia occulta (Kratochvíl, 1938): Deltshev et al., 2014.
Family LINYPHIIDAE
Abacoproeces saltuum (L. Koch, 1872): Sisojević & Miller, 1978; Nikolić & Polenec, 1981; Ćurčić et al., 1999c; Tomić & Grbić, 2008; Grbić et al., 2011, 2015, 2019.
Acartauchenius scurrilis (O. Pickard–Cambridge, 1872): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Dudić et al., 2013; Grbić et al., 2021.
Agnyphantes expunctus (O. Pickard-Cambridge, 1875): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Dudić et al., 2011.
Agyneta affinis (Kulczyński, 1898): Ćurčić et al., 2000a; Geci et al., 2023.
Agyneta fuscipalpus (C. L. Koch, 1836): Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1978; Nikolić & Polenec, 1981; Tomić & Grbić, 2008; Dudić et al., 2011; Grbić et al., 2011, 2015, 2019; Vrenozi & Jäger, 2013; Grbić & Hänggi, 2022.
Agyneta innotabilis (O. Pickard–Cambridge, 1863): Stojićević, 1929; Drensky, 1936.
Agyneta mollis (O. Pickard–Cambridge, 1871): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Grbić et al., 2021.
Agyneta rurestris (C. L. Koch, 1836): Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1979, 1985; Nikolić & Polenec, 1981; Ćurčić et al., 2000a, 2003; Grbić et al., 2011, 2015, 2019, 2021; Dudić et al., 2013; Grbić & Hänggi, 2022.
Agyneta simplicitarsis (Simon, 1884): Grbić et al., 2015, 2021; Grbić & Hänggi, 2022.
Anguliphantes angulipalpis (Westring, 1851): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
Anguliphantes monticola (Kulczyński, 1881): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
Antrohyphantes sophianus (Drensky, 1931): Nikolić & Polenec, 1981.
Araeoncus crassiceps (Westring, 1861): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
Araeoncus humilis (Blackwall, 1841): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Grbić, et al., 2011, 2019, 2021; Dudić et al., 2013; Grbić & Hänggi, 2022.
Asthenargus bracianus (Miller, 1938): Grbić & Hänggi, 2022.
Bathyphantes approximatus (O. Pickard–Cambridge, 1871): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Dudić et al., 2011.
Bathyphantes gracilis (Blackwall, 1841): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Grbić & Savić, 2010; Dudić et al., 2011, 2013; Grbić, et al., 2011, 2015, 2021.

Bathyphantes nigrinus (Westring, 1851): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Dudić et al., 2011.
Bathyphantes parvulus (Westring, 1851): Dudić et al., 2011.
Bolyphantes alticeps (Sundevall, 1833): Ćurčić et al., 2003; Grapci-Kotori et al., 2022.
Bolyphantes kolosvaryi (Caporiacco, 1936): Ćurčić et al., 2003.
Bolyphantes luteolus (Blackwall, 1833): Petrović, 2014.
Canariphantes nanus (Kulczyński, 1898): Grbić et al., 2021.
Centromerita bicolor (Blackwall, 1833): Drensky, 1936; Nikolić & Polenec, 1981.
Centromerus acutidentatus (Deltshev, 2002): Ćurčić et al., 1999a; Deltshev & Ćurčić, 2002.
Centromerus arcanus (O. Pickard-Cambridge, 1873): Ćurčić et al., 1999b, 2000b; Tomić, 2006.
Centromerus brevipalpus (Menge, 1866): Stojićević, 1929; Drensky, 1936; Ćurčić et al., 2004.
Centromerus cavernarum (L. Koch, 1872): Ćurčić et al., 1999b, 2000a, 2000b, 2003, 2004; Tomić, 2006; Pavićević et al., 2011; Naumova et al., 2016; Grbić & Häggi, 2022.
Centromerus dacicus (Dumitrescu & Georgescu, 1980): Deltshev & Ćurčić, 1997, 2002.
Centromerus incilium (L. Koch, 1881): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Grbić & Häggi, 2022.
Centromerus lakatnikensis (Drensky, 1931): Ćurčić et al., 1999a, 2000b.
Centromerus obenbergeri (Kulczyński, 1897): Ćurčić et al., 2004.
Centromerus obscurus (Bösenberg, 1902): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
Centromerus pabulator (O. Pickard–Cambridge, 1875): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
Centromerus serbicus (Deltshev, 2002): Fage, 1931; Kratochvíl, 1934; Drensky, 1936; Kratochvíl & Miller, 1938; Nikolić & Polenec, 1981; Thaler & Höfer, 1988; Deltshev et al., 1996, 1997, 2014; Deltshev & Ćurčić, 1997, 2002; Ćurčić et al., 1999a; Naumova et al., 2016.
Centromerus serratus (O. Pickard–Cambridge, 1875): Sisojević & Miller, 1979; Nikolić & Polenec, 1981.
Centromerus silvicola (Kulczyński, 1887): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Ćurčić et al., 2000a, 2003.
Centromerus sylvaticus (Blackwall, 1841): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Ćurčić et al., 1999a, 2000a, 2000b; Tomić, 2006; Grbić & Savić, 2010; Grbić et al., 2011, 2019, 2021; Grapci-Kotori et al., 2022; Grbić & Häggi, 2022; Grbić & Stanković, 2022.
Ceratinella brevipes (Westring, 1851): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Grbić et al., 2021; Grapci-Kotori et al., 2022
Ceratinella brevis (Wider, 1834): Chyzer & Kulczyński, 1894; Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Ćurčić et al., 2000b, 2003; Grbić et al., 2011, 2019, 2021.
Ceratinella major (Kulczyński, 1894): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
Ceratinella scabrosa (O. Pickard - Cambridge, 1871): Grbić et al., 2015; Grbić & Häggi, 2022; Grbić & Stanković, 2022.
Cinetata gradata (Simon, 1881): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
Cnephalocotes obscurus (Blackwall, 1834): Chyzer & Kulczyński, 1894; Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
Cresmatoneta mutinensis (Canestrini, 1868): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Grbić et al., 2011.
Crosbyarachne silvestris (Georgescu, 1973): Ćurčić et al., 1999a, 2015; Grbić & Häggi, 2022.
Dactylopisthes digiticeps (Simon, 1881): Gajić & Grbić, 2016; Grbić et al., 2021.
Dicymbium nigrum (Blackwall, 1834): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Grbić & Savić, 2010; Grbić et al., 2021; Grbić & Häggi, 2022.
Dicymbium tibiale (Blackwall, 1836): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Gajić & Grbić, 2016.
Diplocephalus connatus (Bertkau, 1889): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
Diplocephalus crassilobus (Simon, 1884): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
Diplocephalus cristatus (Blackwall, 1833): Stojićević, 1929; Fage, 1931; Kratochvíl, 1934; Drensky, 1936; Nikolić & Polenec, 1981; Deltshev et al., 1998; Ćurčić et al., 1999b, 2000a, 2000b, 2003; Tomić, 2006; Grbić & Savić, 2010; Pavićević et al., 2011.
Diplocephalus latifrons (O. Pickard–Cambridge, 1863): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Ćurčić et al., 2000a, 2000b, 2003.
Diplocephalus picinus (Blackwall, 1841): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Ćurčić et al., 2000a, 2000b, 2003; Grbić et al., 2021.
Diplostyla concolor (Wider, 1834): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Ćurčić et al., 1999a, 2000a, 2000b, 2003; Tomić, 2006; Grbić & Savić, 2010; Dudić et al., 2013; Grbić et al., 2015, 2021; Gajić & Grbić, 2016; Grbić & Häggi, 2022; Grbić & Stanković, 2022.
Dismodicus bifrons (Blackwall, 1841): Sisojević & Miller, 1979; Nikolić & Polenec, 1981; Dudić et al., 2011.
Dismodicus elevatus (L. Koch, 1838): Chyzer & Kulczyński, 1897; Delshev et at., 2003; Tomić & Grbić, 2008.
Donacochara speciosa (Thorell, 1875): Grbić & Savić, 2010.
Drapetisca socialis (Sundevall, 1833): Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1978; Nikolić & Polenec, 1981; Ćurčić et al., 2003; Tomić & Grbić, 2008; Grbić, et al., 2011, 2019.
Entelecara acuminata (Wider, 1834): Chyzer & Kulczyński, 1894; Sisojević & Miller, 1978, 1979, 1985; Nikolić &

Polenec, 1981; Ćurčić et al., 2003; Tomić & Grbić, 2008.
Entelecara congenera (O. Pickard–Cambridge, 1879): Sisojević & Miller, 1985.
Entelecara erythropus (Westring, 1851): Sisojević & Miller, 1985.
Entelecara flavipes (Blackwall, 1834): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981;
Erigone atra (Blackwall, 1833): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
Erigone dentipalpis (Wider, 1834): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Ćurčić et al., 2003; Grbić & Savić, 2010; Grbić et al., 2011, 2021; Dudić et al., 2013; Gajić & Grbić, 2016; Grbić & Hänggi, 2022.
Erigonoplus foveatus (Dahl, 1912): Grbić et al., 2015; Grbić & Häggi, 2022.
Erigonoplus globipes (L. Koch, 1872): Dudić et al., 2013; Grbić et al., 2015.
Fageiella ensiger (Deeleman – Reinhold, 1974): Deeleman – Reinhold, 1974; Ćurčić et al., 2000b; Deltshev, 2008b; Geci & Naumova, 2021b.
Fageiella patellata (Kulczyński, 1913): Pavićević et al., 2011.
Floronia bucculenta (Clerck, 1757): Tomić, 2006; Grbić et al., 2021.
Formiphantes lephthyphantiformis (Strand, 1907): Ćurčić et al., 2003.
Frontinellina frutetorum (C. L. Koch, 1834): Stojićević, 1929; Drensky, 1936; van Helsdingen, 1970; Sisojević & Miller, 1978, 1979; Nikolić & Polenec, 1981; Tomić & Grbić, 2008; Grbić, et al., 2011; Petrović, 2014; Stanković, 2023.
Glyphesis taoplesius (Wunderlich, 1969): Grbić et al., 2021.
Gnathonarium dentatum (Wider, 1834): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Grbić et al., 2011, 2021.
Gonatium orientale (Fage, 1931): Ćurčić et al., 2000a, 2003.
Gonatium paradoxum (L. Koch, 1869): Ćurčić et al., 1999c, 2000a, 2000b, 2003; Grbić & Hänggi, 2022.
Gonatium rubellum (Blackwall, 1841): Ćurčić et al., 1999c, 2000b.
Gongylidieum murcidum (Simon, 1884): Grbić et al., 2021.
Gongylidieum rufipes (Linnaeus, 1758): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
Helophora insignis (Blackwall, 1841): Ćurčić et al., 2000a.
Hylyphantes nigritus (Simon, 1881): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
Hypomma bituberculatum (Wider, 1834): Nikolić & Polenec, 1981.
Hypomma cornutum (Blackwall, 1833): Sisojević & Miller, 1979; Nikolić & Polenec, 1981.
Improphantes nitidus (Thorell, 1875): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
Incestophantes annulatus (Kulczyński, 1882): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
Incestophantes crucifer (Menge, 1866): Chyzer & Kulczyński, 1894; Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Grbić & Savić, 2010; Grbić et al., 2011, 2019; Grbić & Hänggi, 2022.
Ipa keyserlingi (Ausserer, 1867): Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1979.
Jacksonella sp.: Ćurčić et al., 2000b.
Kaestneria dorsalis (Wider, 1834): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
Labulla thoracica (Wider, 1834): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
Lepthyphantes centromeroides (Kulczyński, 1914): Fage, 1931; Kratochvíl, 1934; Drensky, 1936; Nikolić & Polenec, 1981; Ćurčić et al., 2000a; Ćurčić et al., 2003; Naumova et al., 2016.
Lepthyphantes leprosus (Ohlert, 1865): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Deltshev et al., 1996, 1997; Ćurčić et al., 1999a, 2000b, 2003; Komnenov & Pavićević, 2009; Grbić et al., 2011, 2019; Pavićević et al., 2011; Naumova et al., 2016; Stanković, 2023.
Lepthyphantes notabilis (Kulczyński, 1887): Drensky, 1936.
Linyphia hortensis (Sundevall, 1830): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1978, 1979, 1985; Nikolić & Polenec, 1981; Ćurčić et al., 2004; Tomić & Grbić, 2008; Grbić et al., 2015; Grapci-Kotori et al., 2022; Stanković, 2023.
Linyphia triangularis (Clerk, 1757): Chyzer & Kulczyński, 1894; Bresjančeva, 1907; Drensky, 1936; van Helsdingen, 1969; Sisojević & Miller, 1978, 1979; Nikolić & Polenec, 1981; Ćurčić et al., 2000a, 2004; Tomić, 2006; Tomić & Grbić, 2008; Dudić et al., 2011; Grbić et al., 2011, 2019, 2021; Petrović, 2014; Gajić & Grbić, 2016; Geci & Naumova, 2021b; Grbić & Stanković, 2022; Stanković, 2023.
Macrargus rufus (Wider, 1834): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Ćurčić et al., 2000a, 2003.
Mansuphantes mansuetus (Thorell, 1875): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Ćurčić et al., 1999a, 2000b; Grbić & Hänggi, 2022.
Maso sundevalli (Westring, 1851): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Ćurčić, et al., 2000a, 2003; Grbić et al., 2015.
Mecopisthes peusi (Wunderlich, 1992): Grbić et al., 2011, 2019.
Mecynargus longus (Kulczyński, 1882): Ćurčić et al., 2000a.
Megalepthyphantes collinus (L. Koch, 1872): Nikolić & Polenec, 1981; Grbić et al., 2011; Grbić et al., 2019.
Mermessus trilobatus (Emerton, 1882): Grbić et al., 2021.
Metopobactrus ascitus (Kulczyński, 1894): Sisojević & Miller, 1979; Nikolić & Polenec, 1981; Grbić et al., 2015, 2021.
Metopobactrus prominulus (O. Pickard–Cambridge, 1872): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.

Micrargus apertus (O. Pickard–Cambridge, 1871): Ćurčić et al., 2000b.
Micrargus herbigradus (Blackwall, 1854): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Ćurčić et al., 2000a, 2000b, 2003.
Micrargus subaequalis (Westring, 1851): Grbić et al., 2015.
Microctenonyx subitaneus (O. Pickard–Cambridge, 1875): Delshev et al., 1996, 1997; Ćurčić et al., 1999a.
Microlinyphia impigra (O. Pickard–Cambridge, 1871): Nikolić & Polenec, 1981.
Microlinyphia pusilla (Sundevall, 1830): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Sisojević & Miller, 1985; Grbić & Savić, 2010; Grbić et al., 2011; Gajić & Grbić, 2016; Grapci-Kotori et al., 2022; Geci et al., 2023.
Microneta viaria (Blackwall, 1841): Sisojević & Miller, 1979; Ćurčić et al., 1999b, 2000a, 2000b, 2003, 2004; Tomić, 2006; Grbić & Savić, 2010.
Minicia marginella (Wider, 1834): Grbić & Savić, 2010; Grbić et al., 2015.
Minyriolus sp.: Delshev et al., 1998.
Moebelia penicillata (Westring, 1851): Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1979; Nikolić & Polenec, 1981.
Mughiphantes mughi (Fickert, 1875): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
**Mughiphantes sp.*: Grapci-Kotori et al., 2022.
Nematogmus sanguinolentus (Walckenaer, 1841): Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1979; Nikolić & Polenec, 1981; Grbić, et al., 2011.
Neriene clathrata (Sundevall, 1830): Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1979; Nikolić & Polenec, 1981; Tomić, 2006; Grbić et al., 2011, 2015, 2021; Gajić & Grbić, 2016; Grbić & Stanković, 2022.
Neriene emphana (Walckenaer, 1841): van Helsdingen, 1969.
Neriene montana (Clerck, 1757): Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1979; Nikolić & Polenec, 1981; Geci & Naumova, 2021b; Stanković, 2023.
Neriene peltata (Wider, 1834): Chyzer & Kulczyński, 1894; Stojićević, 1929; van Helsdingen, 1969; Sisojević & Miller, 1978, 1979, 1985; Nikolić & Polenec, 1981; Tomić & Grbić, 2008; Dudić et al., 2011; Petrović, 2014; Stanković, 2023.
Neriene radiata (Walckenaer, 1842): Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1979; Nikolić & Polenec, 1981; Tomić, 2006; Grbić & Savić, 2010; Dudić et al., 2011; Grbić et al., 2011, 2019; Grbić & Stanković, 2022; Stanković, 2023.
Notioscopus sarcinatus (O. Pickard–Cambridge, 1872): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
Obscuriphantes obscurus (Blackwall, 1841): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Dudić et al., 2011; Geci et al., 2023.
Oedothorax agrestis (Blackwall, 1853): Chyzer & Kulczyński, 1897; Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1979; Nikolić & Polenec, 1981; Grbić & Savić, 2010; Pavićević et al., 2011.
Oedothorax apicatus (Blackwall, 1850): Chyzer & Kulczyński, 1894; Stojićević, 1929; Drensky, 1936; Ćurčić et al., 2004; Dudić et al., 2013; Gajić & Grbić, 2016; Grbić et al., 2021.
Oedothorax fuscus (Blackwall, 1834): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
Oedothorax gibbosus (Blackwall, 1841): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
Oedothorax retusus (Westring, 1851): Chyzer & Kulczyński, 1894; Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
Ostearius melanopygius (O. Pickard-Cambridge, 1880): Grbić et al., 2021; Grbić & Hänggi, 2022; Geci et al., 2024.
Palliduphantes alutacius (Simon, 1884): Ćurčić et al., 1999b; Tomić, 2006; Grbić et al., 2011, 2019; Grbić & Hänggi, 2022.
Palliduphantes istrianus (Kulczyński, 1914): Ćurčić et al., 1999c, 2000a; Grbić et al., 2011, 2019.
Palliduphantes pallidus (O. Pickard-Cambridge, 1871): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Ćurčić et al., 2003; Grbić & Hänggi, 2022; Grbić & Stanković, 2022.
Palliduphantes pillichi (Kulczyński, 1915): Grbić et al., 2015, 2021; Grbić & Hänggi, 2022.
Palliduphantes spelaeorum (Kulczyński, 1914): Fage, 1931; Kratochvíl, 1934; Drensky, 1936; Nikolić & Polenec, 1981; Deltshev et al., 1998, 2014.
Palliduphantes trnovensis (Drensky, 1931): Deeleman – Reinhold, 1986d; Deltshev et al., 1996, 1997; Ćurčić et al., 1999a, 2003; Naumova et al., 2016.
Panamomops affinis (Miller & Kratochvil, 1939): Grbić et al., 2015.
Panamomops mengei (Simon, 1926): Grbić et al., 2021.
Parapelecopsis nemoralis (Blackwall, 1841): Stojićević, 1929; Drensky, 1936.
Pelecopsis elongata (Wider, 1834): Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1978, 1979; Nikolić & Polenec, 1981; Tomić & Grbić, 2008.
Pelecopsis loksai (Szinetár & Samu, 2003): Grbić et al., 2011, 2015, 2019; Grbić & Hänggi, 2022.
Pelecopsis parallela (Wider, 1834): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Grbić, et al., 2011, 2015, 2021; Dudić et al., 2013.
Pelecopsis radicicola (L. Koch, 1872): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Grbić et al., 2015; Gajić & Grbić, 2016; Grbić & Hänggi, 2022.
Pityohyphantes phrygianus (C. L. Koch, 1836): Nikolić & Polenec, 1981; Geci et al., 2023.
Pocadicnemis juncea (Locket & Millidge, 1953): Ćurčić et al., 2000b; Grbić et al., 2021.

Pocadicnemis pumila (Blackwall, 1841): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
Poeciloneta variegata (Blackwall, 1841): Dudić et al., 2011.
Porrhomma campbelli (F. O. Pickard-Cambridge, 1894): Ćurčić et al., 2000b; Naumova et al., 2016.
Porrhomma convexum (Westring, 1851): Fage, 1931; Kratochvíl, 1934; Drensky, 1936; Nikolić & Polenec, 1981; Deltshev et al., 1996, 1997, 2014; Ćurčić et al., 1999a, 2000b, 2003, 2004; Pavićević et al., 2011; Naumova et al., 2016.
Porrhomma microphthalmum (O. Pickard–Cambridge, 1871): Sisojević & Miller, 1978; Nikolić & Polenec, 1981; Tomić & Grbić, 2008; Grbić et al., 2021; Grbić & Hänggi, 2022.
Porrhomma microps (Roewer, 1931): Deltshev et al., 1997; Grbić et al., 2021; Grbić & Hänggi, 2022.
Porrhomma oblitum (O. Pickard – Cambridge, 1871): Grbić et al., 2021.
**Porrhomma profundum* (M. Dahl, 1939): temporarily - Nentwig et al., 2025.
Porrhomma pygmaeum (Blackwall, 1834): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Grbić et al., 2021; Grbić & Hänggi, 2022.
Porrhomma rosenhaueri (L. Koch, 1872): Stojićević, 1929; Kratochvíl, 1934; Drensky, 1936; Nikolić & Polenec, 1981; Dudić et al., 2011.
Prinerigone vagans (Audouin, 1826): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Grbić, et al., 2011; Gajić & Grbić, 2016.
Saaristoa firma (O. Pickard-Cambridge, 1906): Ćurčić et al., 2003.
Saloca diceros (O. Pickard-Cambridge, 1871): Grbić & Savić, 2010.
Sauron rayi (Simon, 1881): Grbić et al., 2015.
Scotargus pilosus (Simon, 1913): Ćurčić et al., 1999c, 2000a, 2003.
Sintula spiniger (Balogh, 1935): Grbić, et al., 2011.
Staveleya pusilla (Menge, 1869): Grbić et al., 2021.
Stemonyphantes lineatus (Linnaeus, 1758): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Ćurčić et al., 2003; Grbić et al., 2015; Grbić & Hänggi, 2022.
Styloctetor compar (Westring, 1861): Stojićević, 1929; Nikolić & Polenec, 1981; Grbić et al., 2021.
Styloctetor romanus (O. Pickard–Cambridge, 1873): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
Syedra apetlonensis (Wunderlich, 1992): Grbić et al., 2021.
Syedra gracilis (Menge, 1869): Grbić et al., 2015.
Tallusia experta (O. Pickard–Cambridge, 1871): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
Tallusia vindobonensis (Kulczyński, 1898): Grbić et al., 2021.
Tapinocyba insecta (L. Koch, 1869): Stojićević, 1929; Drensky, 1936.
Tapinocyba pallens (O. Pickard–Cambridge, 1872): Stojićević, 1929; Drensky, 1936.
**Tapinopa longidens* (Wider, 1834): Geci et al., 2023.
Tenuiphantes alacris (Blackwall, 1853): Stojićević, 1929.
Tenuiphantes cristatus (Menge, 1866): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
Tenuiphantes flavipes (Blackwall, 1854): Chyzer & Kulczyński, 1894, 1897; Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Deltshev et al., 1998; Ćurčić et al., 2000a, 2003, 2004; Tomić, 2006; Tomić & Grbić, 2008; Komnenov & Pavićević, 2009; Grbić & Savić, 2010; Dudić et al., 2011; Grbić et al., 2011, 2015, 2019, 2021; Grbić & Hänggi, 2022; Grbić & Stanković, 2022.
Tenuiphantes floriana (van Helsdingen, 1977): Ćurčić et al., 1999b, 2003, 2004; Tomić, 2006; Komnenov & Pavićević, 2009; Grbić & Savić, 2010; Grbić et al., 2015; Grbić & Hänggi, 2022.
Tenuiphantes mengei (Kulczyński, 1887): Stojićević, 1929; Drensky, 1936; Ćurčić et al., 1999a.
Tenuiphantes tenebricola (Wider, 1834): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Ćurčić et al., 2000a, 2003, 2004; Dudić et al., 2011; Grbić et al., 2015; Geci & Naumova, 2021b; Grapci-Kotori et al., 2022.
Tenuiphantes tenuis (Blackwall, 1852): Chyzer & Kulczyński, 1894, 1897; Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1978; Nikolić & Polenec, 1981; Ćurčić et al., 2000a, 2000b; Tomić & Grbić, 2008; Dudić et al., 2011, 2013; Naumova et al., 2016; Grbić et al., 2021.
Tenuiphantes zimmermanni (Bertkau, 1890): Stojićević, 1929; Dudić et al., 2011.
Thyreosthenius parasiticus (Westring, 1851): Stojićević, 1929; Drensky, 1936; Ćurčić et al., 2000b; Grbić et al., 2011, 2019.
Tiso vagans (Blackwall, 1834): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
Trematocephalus cristatus (Wider, 1834): Nikolić & Polenec, 1981.
Thrichoncoides piscator (Simon, 1884): Sisojević & Miller, 1978; Nikolić & Polenec, 1981; Tomić & Grbić, 2008; Grbić et al., 2011, 2019; Dudić et al., 2013.
Trichoncus affinis (Kulczyński, 1894): Chyzer & Kulczyński, 1894, 1897; Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1979; Nikolić & Polenec, 1981; Tomić & Grbić, 2008; Grbić et al., 2015.
Trichoncus hackmani (Millidge, 1955): Ćurčić et al., 2003; Dudić et al., 2013; Grbić et al., 2015, 2021; Grbić & Hänggi, 2022.
Trichoncus saxicola (O. Pickard–Cambridge, 1861): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
Trichopterna cito (O. Pickard–Cambridge, 1873): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Dudić et al.,

2013; Grbić et al., 2021.
****Troglohyphantes lesserti*** (Kratochvíl, 1935): temporarily - Nentwig et al., 2025.
****Troglohyphantes troglodytes*** (Kulczyński, 1914): temporarily - Nentwig et al., 2025.
Troxochrus scabriculus (Westring, 1851): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
Typhochrestus digitatus (O. Pickard-Cambridge, 1873): Nikolić & Polenec, 1981.
Walckenaeria acuminata (Blackwall, 1833): Ćurčić et al., 2000b.
Walckenaeria alticeps (Denis, 1952): Gajić & Grbić, 2016; Grbić et al., 2021.
Walckenaeria antica (Wider, 1834): Stojićević, 1929; Grbić et al., 2015, 2021; Grbić & Hänggi, 2022.
Walckenaeria atrotibialis (O. Pickard–Cambridge, 1878): Grbić et al., 2021.
Walckenaeria capito (Westring, 1861): Grbić et al., 2021.
Walckenaeria corniculans (O. Pickard–Cambridge, 1875): Ćurčić et al., 1999b; Tomić, 2006; Grbić & Hänggi, 2022.
Walckenaeria cucullata (C. L. Koch, 1836): Ćurčić et al., 2003.
Walckenaeria furcillata (Menge, 1869): Ćurčić et al., 2003; Gajić & Grbić, 2016.
Walckenaeria mitrata (Menge, 1868): Ćurčić et al., 2000a; Gajić & Grbić, 2016; Grbić & Hänggi, 2022.
**Walckenaeria monoceros* (Wider, 1834): Geci et al., 2025a.
Walckenaeria nudipalpis (Westring, 1851): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Grbić et al., 2021.
Walckenaeria simplex (Chyzer, 1894): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Grbić & Savić, 2010; Grbić et al., 2015; Grbić & Hänggi, 2022.
Walckenaeria vigilax (Blackwall, 1853): Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1979; Nikolić & Polenec, 1981.
Family LIOCRANIDAE
Agroeca brunnea (Blackwall, 1833): Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1978, 1979; Nikolić & Polenec, 1981; Tomić & Grbić, 2008; Dudić et al., 2011.
Agroeca cuprea (Menge, 1873): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Grbić & Savić, 2010; Grbić et al., 2011, 2015, 2019, 2021; Gajić & Grbić, 2016; Grbić & Hänggi, 2022; Grbić & Stanković, 2022.
Apostenus fuscus (Westring, 1851): Ćurčić et al., 1999b, 2004; Tomić, 2006; Geci & Naumova, 2021b; Grbić & Hänggi, 2022.
Drapeta rutilans (Thorell, 1875): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Kolosváry, 1938, 1940b; Sisojević & Miller, 1978; Nikolić & Polenec, 1981; Deltshev et al., 1996; Ćurčić et al., 2003; Tomić & Grbić, 2008; Grbić et al., 2015; Geci & Naumova, 2021b; Grbić & Hänggi, 2022.
Liocranoeca striata (Kulczyński, 1882): Gajić & Grbić, 2016; Grbić et al., 2021; Grbić & Stanković, 2022.
Liocranum rupicola (Walckenaer, 1830): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1978; Nikolić & Polenec, 1981; Ćurčić et al., 1999a, 2003; Tomić & Grbić, 2008; Petrović, 2014; Grbić et al., 2015; Grbić & Hänggi, 2022; Stanković, 2023.
Sestakovaia annulipes (Kulczyński, 1897): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
Family LYCOSIDAE
Alopecosa aculeata (Clerck, 1757): Nikolić & Polenec, 1981; Vrenozi & Jäger, 2013; Grbić et al., 2015, 2021; Grbić & Hänggi, 2022; Stanković, 2023.
Alopecosa albofasciata (Brullé, 1832): Bresjančeva, 1907; Drensky, 1936.
Alopecosa cuneata (Clerck, 1757): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Petrović, 2014; Grbić et al., 2015, 2021; Geci & Naumova, 2021b; Grapci-Kotori et al., 2022; Grbić & Hänggi, 2022; Stanković, 2023.
Alopecosa cursor (Hahn, 1831): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Geci et al., 2025a.
Alopecosa fabrilis (Clerck, 1757): Bresjančeva, 1907; Nikolić & Polenec, 1981; Grbić et al., 2011, 2019; Petrović, 2014.
Alopecosa farinosa (Herman, 1879): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Grbić & Savić, 2010; Grbić et al., 2011, 2019; Grbić & Hänggi, 2022; Stanković, 2023.
Alopecosa inquilina (Clerck, 1757): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
Alopecosa mariae (Dahl, 1908): Nikolić & Polenec, 1981; Grbić & Savić, 2010; Grbić et al., 2015, 2021; Grbić & Hänggi, 2022; Grbić & Stanković, 2022.
Alopecosa pinetorum (Thorell, 1856): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Gajić & Grbić, 2016.
Alopecosa pulverulenta (Clerck, 1757): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1979; Nikolić & Polenec, 1981; Dudić et al., 2013; Grbić et al., 2015, 2021; Grbić & Hänggi, 2022; Grbić & Stanković, 2022; Stanković, 2023.
Alopecosa solitaria (Herman, 1879): Stojićević, 1929; Drensky, 1936; Marinković, 1959; Nikolić & Polenec, 1981.
Alopecosa striatipes (C. L. Koch, 1839): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Stanković, 2023.
Alopecosa sulzeri (Pavesi, 1873): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Dudić et al., 2013; Grbić et al., 2021.
Alopecosa trabalis (Clerck, 1757): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Grbić & Savić, 2010; Grbić et al., 2015.

Arctosa cinerea (Fabricius, 1777): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Tomić & Grbić, 2008.
Arctosa figurata (Simon, 1876): Stojićević, 1929; Drensky, 1936; Marinković, 1959; Nikolić & Polenec, 1981; Grbić et al., 2021.
Arctosa leopardus (Sundevall, 1833): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Grbić & Savić, 2010; Grbić, et al., 2011, 2021; Grbić & Hänggi, 2022; Grbić & Stanković, 2022.
Arctosa lutetiana (Simon, 1876): Stojićević, 1929; Grbić et al., 2011, 2019, 2021.
Arctosa maculata (Hahn, 1822): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Ćurčić et al., 2000b, 2004; Grbić & Savić, 2010; Stanković, 2023.
Arctosa perita (Latreille, 1799): Bresjančeva, 1907; Drensky, 1936; Nikolić & Polenec, 1981.
Arctosa stigmosa (Thorell, 1875): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
Arctosa variana (C. L. Koch, 1847): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
Aulonia albimana (Walckenaer, 1805): Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1979; Nikolić & Polenec, 1981; Tomić, 2006; Grbić et al., 2011, 2015, 2019, 2021; Grbić & Savić, 2010; Grbić & Hänggi, 2022; Grbić & Stanković, 2022.
Geolycosa vultuosa (C. L. Koch, 1838): Spasojević, 1891; Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Komnenov & Pavićević, 2009; Grbić & Stanković, 2022.
Hogna radiata (Latreille, 1817): Stojićević, 1929; Drensky, 1936; Kolosváry, 1938, 1940b; Nikolić & Polenec, 1981; Grbić & Savić, 2010; Grbić et al., 2011, 2019, 2021; Geci & Naumova, 2021b; Grbić & Hänggi, 2022; Grbić & Stanković, 2022; Geci et al., 2023; Stanković, 2023.
Lycosa singoriensis (Laxmann, 1770): Bresjančeva, 1907; Stojićević, 1929; Nikolić & Polenec, 1981.
Lycosa tarantula (Linnaeus, 1758): Bresjančeva, 1907.
Pardosa agrestis (Westring, 1861): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Grbić & Savić, 2010; Grbić, et al., 2011, 2021; Dudić et al., 2013; Gajić & Grbić, 2016; Grbić & Stanković, 2022; Stanković, 2023.
Pardosa agricola (Thorell, 1856): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Grbić, et al., 2011; Stanković, 2023.
Pardosa alacris (C. L. Koch, 1833): Wunderlich, 1984; Ćurčić et al., 2000b; Grbić & Savić, 2010; Grbić et al., 2011, 2015, 2019, 2021; Vrenozi & Jäger, 2013; Gajić & Grbić, 2016; Grbić & Hänggi, 2022; Grbić & Stanković, 2022; Stanković, 2023.
Pardosa albatula (Roewer, 1951): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
Pardosa amentata (Clerck, 1757): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Ćurčić et al., 2000a, 2003; Grbić & Savić, 2010; Grbić, et al., 2011; Vrenozi & Jäger, 2013; Petrović, 2014; Gajić & Grbić, 2016; Grbić & Stanković, 2022; Stanković, 2023.
Pardosa bifasciata (C. L. Koch, 1834): Bresjančeva, 1907; Drensky, 1936; Nikolić & Polenec, 1981; Petrović, 2014.
Pardosa blanda (C. L. Koch, 1833): Nikolić & Polenec, 1981.
Pardosa cincta (Kulczyński, 1887): Ćurčić et al., 2007.
Pardosa ferruginea (L. Koch, 1870): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
**Pardosa fulvipes* (Collett, 1876): Kratochvíl, 1935.
Pardosa hortensis (Thorell, 1872): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Ćurčić et al., 2003; Komnenov & Pavićević, 2009; Grbić & Savić, 2010; Grbić, et al., 2011, 2015; Gajić & Grbić, 2016; Grbić & Hänggi, 2022; Grbić & Stanković, 2022; Stanković, 2023.
Pardosa lugubris (Walckenaer, 1802): Stojićević, 1929; Sisojević & Miller, 1978, 1979, 1985; Nikolić & Polenec, 1981; Wunderlich, 1984; Ćurčić et al., 2003, 2004; Tomić, 2006; Tomić & Grbić, 2008; Dudić et al., 2011, 2013; Grbić, et al., 2011; Petrović, 2014; Gajić & Grbić, 2016; Geci & Naumova, 2021b; Geci et al., 2023; Stanković, 2023.
Pardosa maisa (Hippa & Mannila, 1982): Grbić et al., 2021.
Pardosa mixta (Kulczyński, 1887): Kratochvíl, 1935; Nikolić & Polenec, 1981; Gajić & Grbić, 2016; Grbić et al., 2021.
Pardosa monticola (Clerck, 1757): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Ćurčić et al., 2004; Grbić & Savić, 2010; Grbić, et al., 2011; Dudić et al., 2013; Gajić & Grbić, 2016; Grapci-Kotori et al., 2022.
Pardosa morosa (L. Koch, 1870): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Kolosváry, 1938, 1940b; Nikolić & Polenec, 1981.
Pardosa nebulosa (Thorell, 1872): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
Pardosa paludicola (Clerck, 1757): Stojićević, 1929; Nikolić & Polenec, 1981; Grbić et al., 2021; Stanković, 2023.
Pardosa palustris (Linnaeus, 1758): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Grbić et al., 2021; Stanković, 2023.
Pardosa prativaga (L. Koch, 1870): Nikolić & Polenec, 1981; Grbić & Savić, 2010; Grbić, et al., 2011, 2021; Dudić et al., 2013; Vrenozi & Jäger, 2013; Gajić & Grbić, 2016; Grbić & Stanković, 2022.
Pardosa profuga (Herman, 1879): Nikolić & Polenec, 1981.
Pardosa proxima (C. L. Koch, 1847): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Dudić et al., 2011, 2013; Grbić, et al., 2011, 2021; Gajić & Grbić, 2016; Grbić & Stanković, 2022.
Pardosa pullata (Clerck, 1757): Stojićević, 1929.
Pardosa riparia (C. L. Koch, 1833): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Geci et al., 2023.
Pardosa saltuaria (L. Koch, 1870): Bresjančeva, 1907; Kratochvíl, 1935; Drensky, 1936; Nikolić & Polenec, 1981.

Pardosa sordidata (Thorell, 1875): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
Pardosa vittata (Keyserling, 1863): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Gajić & Grbić, 2016;
Pardosa wagleri (Hahn, 1822): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
Pirata piraticus (Clerck, 1757): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Tomić & Grbić, 2008; Grbić, et al., 2011, 2021; Dudić et al., 2013; Gajić & Grbić, 2016; Grbić & Hänggi, 2022.
Pirata piscatorius (Clerck, 1757): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
Pirata tenuitarsis (Simon, 1876): Ćurčić et al., 2007; Grbić et al., 2021.
Piratula hygrophila (Thorell, 1872): Bresjančeva, 1907; Drensky, 1936; Nikolić & Polenec, 1981; Grbić, et al., 2011, 2021; Gajić & Grbić, 2016.
Piratula knorri (Scopoli, 1763): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Ćurčić et al., 2003; Grbić & Savić, 2010; Geci et al., 2023.
Piratula latitans (Blackwall, 1841): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Grbić & Savić, 2010; Grbić, et al., 2011, 2021; Dudić et al., 2013; Gajić & Grbić, 2016; Grbić & Stanković, 2022.
Trochosa hispanica (Simon, 1870): Ćurčić et al., 2004; Gajić & Grbić, 2016; Grbić et al., 2021; Ćurčić et al., 2004; Grbić & Stanković, 2022; Stanković, 2023; Geci et al., 2025a.
Trochosa robusta (Simon, 1876): Bresjančeva, 1907; Kratochvíl, 1935; Nikolić & Polenec, 1981; Dudić et al., 2013; Geci & Naumova, 2021b; Grapci-Kotori et al., 2022; Grbić & Stanković, 2022; Stanković, 2023.
Trochosa ruricola (De Geer, 1778): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Ćurčić et al., 2000b; Dudić et al., 2013; Grbić et al., 2015, 2021; Gajić & Grbić, 2016; Geci & Naumova, 2021b; Grbić & Hänggi, 2022; Geci et al., 2023.
Trochosa spinipalpis (F. O. Pickard-Cambridge, 1895): Ćurčić et al., 2004; Grbić et al., 2021; Grbić & Stanković, 2022.
Trochosa terricola (Thorell, 1856): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1979; Nikolić & Polenec, 1981; Ćurčić et al., 2003; Tomić, 2006; Tomić & Grbić, 2008; Grbić et al., 2011, 2015, 2019, 2021; Grbić & Hänggi, 2022; Stanković, 2023.
Xerolycosa miniata (C. L. Koch, 1834): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Grbić & Savić, 2010; Grbić et al., 2015, 2021; Gajić & Grbić, 2016; Grbić & Hänggi, 2022.
Xerolycosa nemoralis (Westring, 1861): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Dudić et al., 2013; Geci & Naumova, 2021b.
Family MIMETIDAE
Ero aphana (Walckenaer, 1802): Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1979; Nikolić & Polenec, 1981; Tomić & Grbić, 2008; Grbić et al., 2011, 2021.
Ero flammeola (Simon, 1881): Naumova et al., 2016.
Ero furcata (Villers, 1789): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Ćurčić et al., 2000a; Tomić, 2006; Dudić et al., 2011; Grbić et al., 2015, 2021; Gajić & Grbić, 2016; Grbić & Hänggi, 2022.
Ero tuberculata (De Geer, 1778): Sisojević & Miller, 1979; Nikolić & Polenec, 1981; Grbić & Savić, 2010.
**Mimetus laevigatus* (Keyserling, 1863): Geci et al., 2025a.
Family MITURGIDAE
Zora armilata (Simon, 1878): Grbić et al., 2021.
**Zora manicata* (Simon, 1878): Geci & Naumova, 2021b.
Zora nemoralis (Blackwall, 1861): Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1978; Nikolić & Polenec, 1981; Deltshev et al., 1998; Tomić & Grbić, 2008; Grbić et al., 2021; Geci et al., 2025a.
Zora parallela (Simon, 1878): Grbić et al., 2021.
Zora pardalis (Simon, 1878): Stojićević, 1929; Drensky, 1936; Grbić et al., 2021.
**Zora silvestris* (Kulczyński, 1897): Geci & Naumova, 2021b.
Zora spinimana (Sundevall, 1833): Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1979; Grbić et al., 2011, 2019, 2021; Gajić & Grbić, 2016; Grbić & Hänggi, 2022; Stanković, 2023.
Family NEMESIIDAE
**Brachythele kosovarica* (Geci & Sherwood, 2025): Geci et al., 2025d.
**Nemesia dukagjinica* (Geci & Sherwood, 2025): Geci et al., 2025d.
Nemesia pannonica (Herman, 1879): Nikolić & Polenec, 1981; Tomić & Grbić, 2008; Grbić et al., 2015; Grbić & Hänggi, 2022.
Family NESTICIDAE
Nesticus cellulanus (Clark, 1757): Stojićević, 1929; Fage, 1931; Kratochvíl, 1934; Drensky, 1936; Ćurčić, 1969; Nikolić & Polenec, 1981; Deltshev et al., 1996, 1997; Ćurčić et al., 1999a, 2000b, 2003; Pavićević et al., 2011; Petrović, 2014; Naumova et al., 2016; Geci & Naumova, 2021b.
Family OECOBIIDAE
Oecobius maculatus (Simon, 1870): Tomić & Grbić, 2008.
**Uroctea durandi* (Latreille, 1809): Geci et al., 2023.
Family OXYOPIDAE
Oxyopes heterophthalmus (Latreille, 1804): Grbić et al., 2011, 2019, 2021.

Oxyopes lineatus (Latreille, 1806): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1979; Nikolić & Polenec, 1981; Grbić & Savić, 2010; Dudić et al., 2011; Grbić et al., 2011, 2019; Geci et al., 2023; Stanković, 2023.
Oxyopes ramosus (Martini & Goeze, 1778): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1979; Nikolić & Polenec, 1981.
Family PHILODROMIDAE
Philodromus albidus (Kulczynski, 1911): Dudić et al., 2011; Grbić et al., 2011.
Philodromus aureolus (Clerck, 1757): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1978, 1979, 1985; Nikolić & Polenec, 1981; Tomić & Grbić, 2008.
Philodromus buxi (Simon, 1884): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
Philodromus cespitum (Walckenaer, 1802): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Dudić et al., 2011; Grbić et al., 2011, 2021; Grbić & Stanković, 2022; Stanković, 2023.
Philodromus collinus (C. L. Koch, 1835): Nikolić & Polenec, 1981; Geci et al., 2023.
Philodromus dispar (Walckenaer, 1826): Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1978, 1979, 1985; Nikolić & Polenec, 1981; Tomić & Grbić, 2008; Dudić et al., 2011; Grapci-Kotori et al., 2022; Stanković, 2023.
Philodromus emarginatus (Schrank, 1803): Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1978; Nikolić & Polenec, 1981; Tomić & Grbić, 2008.
****Philodromus fuscolimbatus* (Lucas, 1846): temporarily - Nentwig et al., 2025.
Philodromus fuscomarginatus (De Geer, 1778): Nikolić & Polenec, 1981.
Philodromus laricium (Simon, 1875): Sisojević & Miller, 1979; Nikolić & Polenec, 1981.
Philodromus longipalpis (Simon, 1870): Grbić & Häggi, 2022.
Philodromus margaritatus (Clerck, 1757): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1979; Nikolić & Polenec, 1981; Grbić et al., 2015.
Philodromus marmoratus (Kulczynski 1891): Grbić & Savić, 2010.
Philodromus poecilus (Thorell, 1872): Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1979; Nikolić & Polenec, 1981; Grbić, et al., 2011; Grbić & Stanković, 2022.
Philodromus praedatus (O. Pickard–Cambridge, 1971): Ćurčić et al., 2004.
Philodromus rufus (Walckenaer, 1826): Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1978, 1979, 1985; Nikolić & Polenec, 1981; Tomić & Grbić, 2008; Grbić et al., 2011, 2019, 2021; Stanković, 2023.
Pulchellodromus ruficapillus (Simon, 1885): Grbić et al., 2021.
Rhysodromus histrio (Latreille, 1819): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Geci & Naumova, 2021b.
Thanatus arenarius (L. Koch, 1872): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Grbić & Savić, 2010; Dudić et al., 2013; Grbić et al., 2015, 2021; Grbić & Hänggi, 2022; Stanković, 2023.
Thanatus atratus (Simon, 1875): Grbić & Hänggi, 2022.
Thanatus formicinus (Clerck, 1757): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Sisojević & Miller, 1985; Grbić et al., 2021; Geci et al., 2023; Stanković, 2023.
Thanatus pictus (L. Koch, 1881): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Grbić et al., 2011, 2019, 2021.
Thanatus sabulosus (Menge, 1875): Chyzer & Kulczyński, 1897; Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Tomić & Grbić, 2008; Grbić & Stanković, 2022.
Thanatus striatus (L. Koch, 1845): Grbić et al., 2021.
Thanatus vulgaris (Simon, 1870): Sisojević & Miller, 1979; Nikolić & Polenec, 1981; Geci et al., 2023.
Tibellus macellus (Simon, 1875): Grbić et al., 2011, 2015, 2019, 2021; Grbić & Hänggi, 2022; Stanković, 2023.
Tibellus maritimus (Menge, 1875): Gajić & Grbić, 2016.
Tibellus oblongus (Walckenaer, 1802): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Kolosváry, 1938; Nikolić & Polenec, 1981; Tomić & Grbić, 2008; Grbić et al., 2011, 2021; Dudić et al., 2013; Petrović, 2014; Grapci-Kotori et al., 2022; Geci et al., 2023; Stanković, 2023.
Family PHOLCIDAE
Holocnemus pluchei (Scopoli, 1763): Gajić & Grbić, 2016; Geci & Naumova, 2021b; Stanković, 2023.
Hoplopholcus forskali (Thorell, 1871): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Deltshev et al., 1997; Ćurčić et al., 1999a, 2004; Stanković, 2023; Geci et al., 2025a.
Pholcus opilionoides (Schrank, 1781): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Ćurčić, 1969; Nikolić & Polenec, 1981; Deltshev et al., 1996; Ćurčić et al., 2004; Geci & Naumova, 2021b; Geci et al., 2023.
Pholcus phalangioides (Fuesslin, 1775): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Komnenov & Pavićević, 2009; Geci & Naumova, 2021b; Geci et al., 2024.
Psilochorus simoni (Berland, 1911): Komnenov & Pavićević, 2009.
Spermophora senoculata (Dugès, 1836): Bresjančeva, 1907; Geci et al., 2024.
Family PHRUROLITHIDAE
Phrurolithus festivus (C. L. Koch, 1835): Chyzer & Kulczyński, 1897; Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1979; Nikolić & Polenec, 1981; Grbić & Savić, 2010; Dudić et al., 2011; Grbić et al., 2011, 2015, 2019, 2021; Dudić et al., 2013; Gajić & Grbić, 2016; Grbić & Hänggi, 2022; Grbić & Stanković, 2022; Stanković, 2023.

Phrurolithus minimus (C.L. Koch, 1839): Gajić & Grbić, 2016; Grbić et al., 2021; Grbić & Hänggi, 2022.
Phrurolithus szilyi (Herman, 1879): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Grbić et al., 2015; Geci & Naumova, 2021b.
Family PISAURIDAE
Pisaura mirabilis (Clerck, 1757): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Kolosváry, 1938, 1940b; Ćurčić et al., 1969; Sisojević & Miller, 1979; Nikolić & Polenec, 1981; Deltshev et al., 1996; Tomić, 2006; Tomić & Grbić, 2008; Dudić et al., 2011, 2013; Grbić et al., 2011, 2015, 2019, 2021; Petrović, 2014; Gajić & Grbić, 2016; Geci & Naumova, 2021b; Grapci-Kotori et al., 2022; Grbić & Hänggi, 2022; Geci et al., 2023; Stanković, 2023.
Family SALTICIDAE
Aelurillus simplex (Herman, 1879): Nikolić & Polenec, 1981.
Aelurillus v–insignitus (Clerck, 1757): Grbić et al., 2021; Stanković, 2023.
Asianellus festivus (C. L. Koch, 1834): Stanković, 2019.
Attulus caricis (Westring, 1861): Nikolić & Polenec, 1981.
Attulus distinguendus (Simon, 1868): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
Attulus dzieduszyckii (L. Koch, 1870): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
Attulus floricola (C. L. Koch, 1837): Nikolić & Polenec, 1981; Grbić & Savić, 2010; Gajić & Grbić, 2016; Geci & Naumova, 2021b; Grbić et al., 2021.
Attulus penicillatus (Simon, 1875): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
Attulus pubescens (Fabricius, 1775): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Vrenozi & Jäger, 2013.
Attulus rupicola (C. L. Koch, 1837): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
Attulus zimmermanni (Simon, 1877): Nikolić & Polenec, 1981.
Ballus chalybeius (Walckenaer, 1802): Stojićević, 1929; Drensky, 1936; Kolosváry, 1938; Sisojević & Miller, 1978, 1979, 1985; Nikolić & Polenec, 1981; Ćurčić et al., 2003; Tomić & Grbić, 2008; Dudić et al., 2011; Stanković, 2012, 2023; Gajić & Grbić, 2016; Geci et al., 2025a.
Carrhotus xanthogramma (Latreille, 1819): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1979, 1985; Nikolić & Polenec, 1981; Ćurčić et al., 2004; Grbić & Savić, 2010; Grbić et al., 2011, 2021; Stanković, 2012; Geci & Naumova, 2021b.
Dendryphantes hastatus (Clerck, 1757): Bresjančeva, 1907; Drensky, 1936; Nikolić & Polenec, 1981.
Dendryphantes rudis (Sundevall, 1833): Stojićević, 1929; Drensky, 1936.
Euophrys frontalis (Walckenaer, 1802): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Grbić et al., 2015, 2021; Grapci-Kotori et al., 2022; Grbić & Häggi, 2022; Grbić & Stanković, 2022; Stanković, 2023.
***Euophrys rufibarbis* (Simon, 1868): temporarily - Nentwig et al., 2025.
Evarcha arcuata (Clerck, 1757): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1979, 1985; Nikolić & Polenec, 1981; Tomić & Grbić, 2008; Komnenov & Pavićević, 2009; Dudić et al., 2011; Grbić et al., 2011, 2015, 2019, 2021; Stanković, 2012, 2023; Petrović, 2014; Grbić & Hänggi, 2022; Grbić & Stanković, 2022; Geci et al., 2023.
Evarcha falcata (Clerck, 1757): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1979, 1985; Nikolić & Polenec, 1981; Grbić & Savić, 2010; Grbić et al., 2011, 2019, 2021; Stanković, 2012; Petrović, 2014; Gajić & Grbić, 2016; Geci et al., 2023.
Evarcha jucunda (Lucas, 1846): Nikolić & Polenec, 1981.
Evarcha laetabunda (C. L. Koch, 1846): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Gajić & Grbić, 2016.
Heliophanus aeneus (Hahn, 1832): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
Heliophanus auratus (C. L. Koch, 1835): Nikolić & Polenec, 1981; Dudić et al., 2011; Stanković, 2012; Vrenozi & Jäger, 2013; Grbić et al., 2021.
Heliophanus cupreus (Walckenaer, 1802): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1978, 1979, 1985; Nikolić & Polenec, 1981; Ćurčić et al., 2003; Tomić & Grbić, 2008; Grbić et al., 2011, 2019, 2021; Stanković, 2012; Vrenozi & Jäger, 2013; Grbić & Hänggi, 2022; Grbić & Stanković, 2022; Geci et al., 2023.
**Heliophanus dampfi* (Schenkel, 1923): Geci & Naumova, 2021b.
Heliophanus dubius (C. L. Koch, 1835): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Stanković, 2023.
Heliophanus flavipes (Hahn, 1832): Chyzer & Kulczyński, 1897; Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Grbić & Savić, 2010; Grbić et al., 2011, 2019, 2021; Stanković, 2012, 2023; Vrenozi & Jäger, 2013; Gajić & Grbić, 2016; Geci et al., 2023.
Heliophanus kochii (Simon, 1868): Stanković, 2012; Grbić & Stanković, 2022.
Heliophanus lineiventris (Simon, 1868): Grbić et al., 2011, 2019; Geci et al., 2023.
Heliophanus patagiatus (Thorell, 1875): Nikolić & Polenec, 1981.
Heliophanus tribulosus (Simon, 1868): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
Icius hamatus (C. L. Koch, 1846): Stanković, 2010; Geci et al., 2025a.
Icius subinermis (Simon, 1937): Stanković, 2012.
Leptorchestes berolinensis (C. L. Koch, 1846): Grbić & Savić, 2010; Grbić et al., 2011, 2015, 2019; Stanković, 2012.
Macaroeris nidicolens (Walckenaer, 1802): Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1978, 1979; Nikolić & Polenec, 1981; Ćurčić et al., 2004; Tomić & Grbić, 2008; Stanković, 2012; Grbić et al., 2021.
Marpissa muscosa (Clerck, 1757): Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1978, 1979; Nikolić & Polenec,

1981; Ćurčić et al., 1999b, 2004; Tomić & Grbić, 2008; Grbić et al., 2011, 2021; Stanković, 2012; Petrović, 2014; Gajić & Grbić, 2016; Geci & Naumova, 2021b.
Marpissa nivoyi (Lucas, 1846): Stanković, 2012.
Marpissa pomatia (Walckenaer, 1802): Sisojević & Miller, 1979; Nikolić & Polenec, 1981.
Marpissa radiata (Grube, 1859): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Grbić & Savić, 2010; Gajić & Grbić, 2016.
Mendoza canestrinii (Ninni, 1868): Grbić et al., 2011, 2021; Stanković, 2012; Gajić & Grbić, 2016; Grbić & Stanković, 2022; Geci et al., 2025a.
Myrmarachne formicaria (De Geer, 1778): Bresjančeva, 1907; Drensky, 1936; Nikolić & Polenec, 1981; Ćurčić et al., 2004; Grbić & Savić, 2010; Gajić & Grbić, 2016; Geci et al., 2025a.
Neon levis (Simon, 1871): Nikolić & Polenec, 1981; Deltshev et al., 1998; Geci & Naumova, 2021b.
Neon rayi (Simon, 1875): Nikolić & Polenec, 1981.
Neon reticulatus (Blackwall, 1853): Bresjančeva, 1907; Sisojević & Miller, 1979; Nikolić & Polenec, 1981; Ćurčić et al., 2000a, 2000b, 2003, 2004; Grbić & Savić, 2010; Dudić et al., 2011; Grbić et al., 2011, 2019; Gajić & Grbić, 2016; Grapci-Kotori et al., 2022; Grbić & Hänggi, 2022.
Neon valentulus (Falconer, 1912): Dudić et al., 2011.
Pellenes nigrociliatus (Simon, 1875): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Grbić & Savić, 2010; Grbić et al., 2011, 2019, 2021; Geci & Naumova, 2021b.
Pellenes seriatus (Thorell, 1875): Geci & Naumova, 2021b; Stanković, 2023.
Pellenes tripunctatus (Walckenaer, 1802): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Stanković, 2012.
Philaeus chrysops (Poda, 1761): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Grbić & Savić, 2010; Grbić et al., 2011, 2019, 2021; Geci et al., 2023.
Phintella castriesiana (Grube, 1861): Chyzer & Kulczyński, 1897; Sisojević & Miller, 1978, 1979; Nikolić & Polenec, 1981; Grbić & Savić, 2010; Grbić et al., 2011; Stanković, 2012.
Phlegra fasciata (Hahn, 1826): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Stanković, 2012; Vrenozi & Jäger, 2013; Grbić et al., 2015, 2021; Grbić & Häggi, 2022; Geci et al., 2023.
Pseudeuophrys erratica (Walckenaer, 1826): Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1978, 1979; Nikolić & Polenec, 1981; Tomić & Grbić, 2008; Stanković, 2012.
Pseudeuophrys lanigera (Simon, 1871): Stanković, 2010, 2012.
Pseudeuophrys obsoleta (Simon, 1868): Grbić & Savić, 2010; Gajić & Grbić, 2016; Stanković, 2023.
Pseudeuophrys vafra (Blackwall, 1867): Komnenov & Pavićević, 2009.
Pseudicius encarpatus (Walckenaer, 1802): Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1978, 1979, 1985; Nikolić & Polenec, 1981; Tomić & Grbić, 2008; Grbić et al., 2011; Gajić & Grbić, 2016.
Pseudomogrus vittatus (Thorell, 1875): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
Saitis barbipes (Simon, 1868): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
Salticus cingulatus (Panzer, 1797): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
Salticus mutabilis (Lucas, 1846): Nikolić & Polenec, 1981; Tomić & Grbić, 2008.
Salticus scenicus (Clerck, 1757): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1979; Nikolić & Polenec, 1981; Dudić et al., 2011; Grbić et al., 2011; Stanković, 2012; Geci et al., 2023.
Salticus zebraneus (C. L. Koch, 1837): Chyzer & Kulczyński, 1897; Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1978, 1979; Nikolić & Polenec, 1981; Tomić & Grbić, 2008; Gajić & Grbić, 2016.
Sibianor aurocinctus (Ohlert, 1865): Grbić et al., 2011; Dudić et al., 2013; Geci & Naumova, 2021b; Grbić & Hänggi, 2022.
Sibianor tantulus (Simon, 1868): temporarily - Nentwig et al., 2025.
Sittisas saxicola (C. L. Koch, 1846): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
**Synagales dalmaticus* (Keyserling, 1863): Vrenozi & Jäger, 2013.
Synageles hilarulus (C.L.Koch, 1846): Grbić & Savić, 2010; Stanković, 2023.
Synageles venator (Lucas, 1836): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Grbić & Savić, 2010.
Talavera aequipes (O. Pickard-Cambridge, 1871): Dudić et al., 2013; Grbić et al., 2015, 2021.
Talavera aperta (Miller, 1971): Grbić et al., 2015, 2021.
**Talavera petrensis* (C. L. Koch, 1837): Geci et al., 2025a.
Yllenus arenarius (Menge, 1868): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
Family SCYTODIDAE
Scytodes thoracica (Latreille, 1802): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Tomić & Grbić, 2008; Komnenov & Pavićević, 2009; Dudić et al., 2011; Gajić & Grbić, 2016; Geci & Naumova, 2021b; Stanković, 2023.
Family SEGESTRIIDAE
Segestria bavarica (C. L. Koch, 1843): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1978; Nikolić & Polenec, 1981; Deltshev et al., 2003; Tomić & Grbić 2008; Grbić & Hänggi, 2022.
Segestria florentina (Rossi, 1790): Komnenov & Pavićević, 2008, 2009; Stanković, 2023.

Segestria senoculata (Linnaeus, 1758): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Komnenov & Pavićević, 2009; Geci & Naumova, 2021b; Grapci-Kotori et al., 2022; Geci et al., 2023.
Family SPARASSIDAE
Micrommata virescens (Clerck, 1757): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Kolosváry, 1938, 1940b; Sisojević & Miller, 1978, 1979, 1985; Nikolić & Polenec, 1981; Tomić & Grbić, 2008; Grbić et al., 2011, 2015, 2021; Geci & Naumova, 2021b; Grbić & Stanković, 2022; Geci et al., 2023; Stanković, 2023.
Family TETRAGNATHIDAE
Meta menardi (Latreille, 1804): Fage, 1931; Kratochvíl, 1934; Drensky, 1936; Ćurčić, 1969; Nikolić & Polenec, 1981; Deltshev et al., 1996, 1997; Ćurčić et al., 1999a, 2000b, 2003, 2004; Pavićević et al., 2011; Petrović, 2014; Naumova et al., 2016; Geci & Naumova, 2021b.
Metellina mengei (Blackwall, 1870): Stojićević, 1929; Drensky, 1936; Ćurčić, 1969; Nikolić & Polenec, 1981; Deltshev et al., 1996; Ćurčić et al., 2004; Dudić et al., 2011; Petrović, 2014; Grapci-Kotori et al., 2022; Grbić & Stanković, 2022; Stanković, 2023.
Metellina merianae (Scopoli, 1763): Bresjančeva, 1907; Stojićević, 1929; Fage, 1931; Kratochvíl, 1934; Drensky, 1936; Ćurčić, 1969; Nikolić & Polenec, 1981; Deltshev et al., 1996, 1997; Ćurčić et al., 1999a, 2000b, 2004; Grbić & Savić, 2010; Pavićević et al., 2011; Grbić, et al., 2011; Vrenozi & Jäger, 2013; Petrović, 2014; Naumova et al., 2016; Grbić & Stanković, 2022; Geci & Naumova, 2021b.
Metellina segmentata (Clerck, 1757): Stojićević, 1929; Drensky, 1936; Kolosváry, 1940; Sisojević & Miller, 1978, 1985; Nikolić & Polenec, 1981; Deltshev et al., 1996; Ćurčić et al., 2000b; Tomić, 2006; Tomić & Grbić, 2008; Dudić et al., 2011; Grbić et al., 2011; Grapci-Kotori et al., 2022; Grbić & Stanković, 2022; Geci et al., 2023.
Pachygnatha clercki (Sundevall, 1823): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Gajić & Grbić, 2016; Grbić et al., 2021; Grbić & Hänggi, 2022.
Pachygnatha degeeri (Sundevall, 1830): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Grbić & Savić, 2010; Grbić et al., 2011, 2021; Dudić et al., 2013; Gajić & Grbić, 2016; Grbić & Stanković, 2022; Stanković, 2023.
Pachygnatha listeri (Sundevall, 1830): Gajić & Grbić, 2016.
Tetragnatha extensa (Linnaeus, 1758): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Kolosváry, 1938; Nikolić & Polenec, 1981; Dudić et al., 2011; Grbić et al., 2011, 2021; Petrović, 2014; Gajić & Grbić, 2016; Grbić & Stanković, 2022; Geci et al., 2023; Stanković, 2023.
Tetragnatha intermedia (Kulczyński, 1891): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
Tetragnatha isidis (Simon, 1880): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
Tetragnatha montana (Simon, 1874): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Grbić & Savić, 2010; Dudić et al., 2011; Grbić et al., 2011, 2021; Gajić & Grbić, 2016; Grbić & Stanković, 2022; Stanković, 2023.
Tetragnatha nigrita (Lendl, 1886): Chyzer & Kulczyński, 1897; Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Tomić & Grbić, 2008; Petrović, 2014; Gajić & Grbić, 2016.
Tetragnatha obtusa (C. L. Koch, 1837): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Grbić et al., 2011; Stanković, 2023.
Tetragnatha pinicola (L. Koch, 1870): Bresjančeva, 1907; Drensky, 1936; Nikolić & Polenec, 1981; Sisojević & Miller, 1985; Dudić et al., 2011, 2013; Gajić & Grbić, 2016.
Tetragnatha striata (L. Koch 1862): Grbić & Savić, 2010; Grbić & Stanković, 2022; Geci et al., 2023.
Familiy THERIDIIDAE
Anelosimus pulchellus (Walckenaer, 1802): Nikolić & Polenac, 1981.
Anelosimus vittatus (C. L. Koch, 1836): Stojićević, 1929; Drensky, 1936.
***Argyrodes argyrodes* (Walckenaer, 1841): temporarily - Nentwig et al., 2025.
Asagena meriodionalis (Kulczyński, 1894): Stojićević, 1929; Nikolić & Polenec, 1981; Geci & Naumova, 2021b; Grbić et al., 2021.
Asagena phalerata (Panzer, 1801): Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1979; Nikolić & Polenec, 1981; Knoflach, 1996; Grbić & Savić, 2010; Dudić et al., 2013; Grbić et al., 2015, 2021; Gajić & Grbić, 2016; Geci & Naumova, 2021b; Grbić & Hänggi, 2022; Grbić & Stanković, 2022; Stanković, 2023.
Crustulina guttata (Wider, 1834): Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1979; Nikolić & Polenec, 1981; Tomić, 2006; Gajić & Grbić, 2016; Geci & Naumova, 2021b; Grbić & Stanković, 2022.
Cryptachaea riparia (Blackwall, 1834): Bresjančeva, 1907; Drensky, 1936; Sisojević & Miller, 1979; Nikolić & Polenec, 1981; Dudić et al., 2011; Grbić et al., 2011, 2021.
Dipoena braccata (C. L. Koch, 1841): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
Dipoena croatica (Chyzer, 1894): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
Dipoena erythropus (Simon, 1881): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Grbić et al., 2015.
Dipoena melanogaster (C. L. Koch, 1837): Chyzer & Kulczyński, 1894, 1897; Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1978, 1985; Nikolić & Polenec, 1981; Tomić & Grbić, 2008; Grbić et al., 2011, 2019; Grbić & Häggi, 2022.
**Dipoena torva* (Thorell, 1875): Geci et al., 2025a.
***Enoplognatha afrodite* (Hippa & Oksala, 1983): temporarily - Nentwig et al., 2025.
Enoplognatha latimana (Hippa & Oksala, 1982): Ćurčić et al., 2000a; Grbić & Savić, 2010; Grbić et al., 2011, 2015; Dudić et al., 2013; Stanković, 2023; Geci et al., 2025a.

Enoplognatha mordax (Thorell, 1875): Dudić et al., 2013.

Enoplognatha ovata (Clerck, 1757): Chyzer & Kulczyński, 1894; Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1978, 1979, 1985; Nikolić & Polenec, 1981; Ćurčić et al., 2000b; Tomić & Grbić, 2008; Dudić et al., 2011; Grbić et al., 2011, 2019; Gajić & Grbić, 2016; Grbić & Stanković, 2022; Geci et al., 2023; Stanković, 2023.

Enoplognatha thoracica (Hahn, 1833): Chyzer & Kulczyński, 1897; Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1978; Nikolić & Polenec, 1981; Tomić & Grbić, 2008; Dudić et al., 2011, 2013; Grbić et al., 2015, 2021.

Episinus angulatus (Blackwall, 1836): Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1978; Nikolić & Polenec, 1981; Tomić & Grbić, 2008; Grbić et al., 2011; Grbić et al., 2019.

Episinus maculipes (Cavanna, 1876): Grbić et al., 2015; Grbić & Hänggi, 2022.

Episinus truncatus (Latreille, 1809): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Grbić & Savić, 2010; Dudić et al., 2011; Grbić et al., 2011, 2015, 2019, 2021; Gajić & Grbić, 2016; Grbić & Hänggi, 2022; Grbić & Stanković, 2022; Stanković, 2023.

Euryopis flavomaculata (C. L. Koch, 1836): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Ćurčić et al., 2003; Grbić et al., 2021; Grbić & Hänggi, 2022.

Euryopis quinqueguttata (Thorell, 1875): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Grbić et al., 2011, 2019, 2021.

Heterotheridion nigrovariegatum (Simon, 1873): Grbić & Savić, 2010; Grbić et al., 2021.

Kochiura aulica (C. L. Koch, 1838): Bresjančeva, 1907; Nikolić & Polenac, 1981.

****Lasaeola convexa*** (Blackwall, 1870): temporarily - Nentwig et al., 2025.

Lasaeola prona (Menge, 1868): Grbić & Hänggi, 2022.

Neottiura bimaculata (Linnaeus, 1767): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Sisojević & Miller, 1985; Grbić & Savić, 2010; Grbić et al., 2011, 2019; Grbić & Hänggi, 2022; Stanković, 2023.

Neottiura suaveolens (Simon, 1879): Grbić & Savić, 2010; Grbić et al., 2015.

Parasteatoda lunata (Clerck, 1757): Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1978, 1979, 1985; Nikolić & Polenec, 1981; Deltshev et al., 1998; Tomić & Grbić, 2008; Grbić et al., 2011, 2019, 2021; Geci et al., 2023.

Parasteatoda simulans (Thorell, 1875): Nikolić & Polenec, 1981; Stanković, 2023.

Parasteatoda tepidariorum (C. L. Koch, 1841): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Komnenov & Pavićević, 2009; Grbić & Savić, 2010; Dudić et al., 2011; Grbić & Stanković, 2022; Stanković, 2023; Geci et al., 2024.

Pholcomma gibbum (Westring, 1851): Deltshev et al., 1996; Ćurčić et al., 2003.

Phycosoma inornatum (O. Pickard-Cambridge, 1861): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.

Phylloneta impressa (L. Koch, 1881): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Grbić & Savić, 2010; Grbić et al., 2011, 2015, 2019, 2021; Stanković, 2023.

Phylloneta sisyphia (Clerck, 1757): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Grapci-Kotori et al., 2022; Geci et al., 2023.

Platnickina nigropunctata (Lucas, 1846): Geci & Naumova, 2021b.

Platnickina tincta (Walckenaer, 1802): Chyzer & Kulczyński, 1894, 1897; Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1979; Nikolić & Polenec, 1981; Tomić & Grbić, 2008; Dudić et al., 2011; Grbić et al., 2011, 2019, 2021; Grapci-Kotori et al., 2022.

Robertus arundineti (O. Pickard–Cambridge, 1871): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Dudić et al., 2013.

Robertus frivaldszkyi (Chyzer, 1894): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.

Robertus lividus (Blackwall, 1836): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Ćurčić et al., 2000a, 2000b, 2003; Tomić, 2006; Grbić & Savić, 2010; Dudić et al., 2011; Grbić et al., 2021; Grapci-Kotori et al., 2022; Grbić & Hänggi, 2022.

Robertus mediterraneus (Eskov, 1987): Ćurčić et al., 2007.

Sardinidion blackwalli (O. Pickard-Cambridge, 1871): Stojićević, 1929; Drensky, 1936; Gajić & Grbić, 2016; Geci et al., 2025a.

Simitidion simile (C. L. Koch, 1836): Grbić et al., 2011, 2019.

Steatoda albomaculata (De Geer, 1778): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Grbić & Savić, 2010; Dudić et al., 2011, 2013; Grbić et al., 2011, 2019; Grapci-Kotori et al., 2022; Geci et al., 2023.

Steatoda bipunctata (Linnaeus, 1758): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Deltshev et al., 1998; Grapci-Kotori et al., 2022; Grbić & Stanković, 2022; Geci et al., 2023; Stanković, 2023.

Steatoda castanea (Clerck, 1757): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.

Steatoda grossa (C. L. Koch, 1838): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Komnenov & Pavićević, 2009; Grbić & Stanković, 2022; Stanković, 2023.

Steatoda paykulliana (Walckenaer, 1806): Grbić & Savić, 2010; Grbić et al., 2015; Grapci-Kotori et al., 2022; Grbić & Hänggi, 2022.

Steatoda triangulosa (Walckenaer, 1802): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Deltshev et al., 1996; Komnenov & Pavićević, 2009; Dudić et al., 2011; Petrović, 2014; Geci & Naumova 2021b; Grbić & Stanković, 2022; Stanković, 2023.

**Theridion betteni* (Wiehle, 1960): Geci et al., 2023.
Theridion familiare (O. Pickard–Cambridge, 1871): Nikolić & Polenec, 1981.
Theridion melanurum (Hahn, 1831): Bresjančeva, 1907; Stojićević, 1929; Sisojević & Miller, 1978; Nikolić & Polenec, 1981; Tomić & Grbić, 2008; Komnenov & Pavićević, 2009; Stanković, 2023.
Theridion mystaceum (L. Koch, 1870): Sisojević & Miller, 1978, 1979; Nikolić & Polenec, 1981; Tomić & Grbić, 2008.
Theridion pictum (Walckenaer, 1802): Bresjančeva, 1907; Drensky, 1936; Nikolić & Polenec, 1981; Dudić et al., 2011; Vrenozi & Jäger, 2013; Geci et al., 2023.
Theridion pinastri (L. Koch, 1872): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1978, 1979; Tomić & Grbić, 2008; Stanković, 2023.
Theridion uhligi (Martin, 1974): Grbić et al., 2021.
Theridion varians (Hahn, 1833): Chyzer & Kulczyński, 1894, 1897; Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1978, 1979, 1985; Nikolić & Polenec, 1981; Tomić & Grbić, 2008; Dudić et al., 2011; Grbić et al., 2011, 2019; Stanković, 2023.
Family THOMISIDAE
Bassaniodes bliteus (Simon, 1875): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
***Bassaniodes graecus* (C. L. Koch, 1837): temporarily - Nentwig et al., 2025.
Bassaniodes robustus (Hahn, 1832): Grbić et al., 2021.
Cozyptila blackwalli (Simon, 1875): Stojićević, 1929; Drensky, 1936; Šilhavý, 1944; Nikolić & Polenec, 1981; Ćurčić et al., 2000b, 2003; Tomić & Grbić, 2008; Grbić & Savić, 2010; Grbić et al., 2015; Gajić & Grbić, 2016; Grbić & Häggi, 2022.
Diaea dorsata (Fabricius, 1777): Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1978, 1985; Nikolić & Polenec, 1981; Ćurčić et al., 2004; Tomić & Grbić, 2008; Petrović, 2014; Geci et al., 2023; Stanković, 2023.
Diaea livens (Simon, 1876): Tomić & Grbić, 2008; Grbić et al., 2015; Geci & Naumova, 2021b.
Ebrechtella tricuspidata (Fabricius, 1775): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Kolosváry, 1938, 1940b; Sisojević & Miller, 1979; Nikolić & Polenec, 1981; Tomić & Grbić, 2008; Dudić et al., 2011; Grbić et al., 2011, 2019, 2021; Gajić & Grbić, 2016; Geci & Naumova, 2021b; Grbić & Stanković, 2022; Stanković, 2023.
Heriaeus graminicola (Doleschall, 1852): Grbić et al., 2011; Grbić & Stanković, 2022; Stanković, 2023.
Heriaeus hirtus (Latreille, 1819): Chyzer & Kulczyński, 1897; Nikolić & Polenec, 1981; Grbić & Savić, 2010; Stanković, 2023.
Heriaeus oblongus (Simon, 1918): Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1979; Nikolić & Polenec, 1981.
Misumena vatia (Clerck, 1757): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1978, 1979, 1985; Nikolić & Polenec, 1981; Tomić & Grbić, 2008; Dudić et al., 2011; Grbić et al., 2011, 2019, 2021; Gajić & Grbić, 2016; Geci & Naumova, 2021b; Geci et al., 2023; Stanković, 2023.
Ozyptila atomaria (Panzer, 1801): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Grbić & Savić, 2010; Grbić et al., 2015, 2021; Grbić & Hänggi, 2022; Grbić & Stanković, 2022; Geci et al., 2023.
Ozyptila brevipes (Hahn, 1826): Dudić et al., 2011; Grbić et al., 2021.
Ozyptila claveata (Walckenaer, 1837): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Dudić et al., 2011; Grbić et al., 2015; Grbić & Hänggi, 2022.
Ozyptila praticola (C. L. Koch, 1837): Kolosváry, 1938, 1940b; Sisojević & Miller, 1979; Nikolić & Polenec, 1981; Ćurčić et al., 2000a; Grbić et al., 2011, 2019, 2021; Dudić et al., 2013; Gajić & Grbić, 2016; Grbić & Hänggi, 2022; Grbić & Stanković, 2022.
Ozyptila rauda (Simon, 1875): Stojićević, 1929; Drensky, 1936; Kolosváry, 1938; Nikolić & Polenec, 1981.
Ozyptila scabricula (Westring, 1851): Grbić & Savić, 2010; Grbić et al., 2015, 2021; Grbić & Hänggi, 2022.
Ozyptila simplex (O. Pickard–Cambridge, 1862): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Grbić & Savić, 2010; Gajić & Grbić, 2016; Grbić et al., 2021.
Ozyptila trux (Blackwall, 1846): Grbić et al., 2021; Grapci-Kotori et al., 2022;
Pistius truncatus (Pallas, 1772): Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1978, 1979, 1985; Nikolić & Polenec, 1981; Tomić & Grbić, 2008; Grbić et al., 2021.
Psammitis marmorata (Thorell, 1875): Kolosváry, 1938; Sisojević & Miller, 1978, 1979; Nikolić & Polenec, 1981; Tomić & Grbić, 2008; Geci et al., 2023.
Psammitis ninnii (Thorell, 1872): Chyzer & Kulczyński, 1897; Tomić & Grbić, 2008.
Psammitis sabulosa (Hahn, 1832): Stojićević, 1929; Drensky, 1936; Šilhavý, 1944; Nikolić & Polenec, 1981; Ćurčić et al., 2003; Dudić et al., 2011; Petrović, 2014; Grbić et al., 2021; Geci et al., 2023.
Runcinia grammica (C. L. Koch, 1837): Chyzer & Kulczyński, 1897; Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Kolosváry, 1938; Nikolić & Polenec, 1981; Tomić & Grbić, 2008; Grbić et al., 2015, 2021; Geci & Naumova, 2021b; Stanković, 2023.
Spiracme lendli (Kulczyński, 1897): Grbić et al., 2011, 2019.
Spiracme striatipes (L. Koch, 1870): Bresjančeva, 1907; Drensky, 1936; Kolosváry, 1938; Nikolić & Polenec, 1981; Grbić & Savić, 2010; Grbić et al., 2021; Stanković, 2023.
Synema globosum (Fabricius, 1775): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1979; Nikolić & Polenec, 1981; Tomić & Grbić, 2008; Dudić et al., 2011; Grbić et al., 2011, 2015, 2019, 2021; Vrenozi & Jäger, 2013;

Petrović, 2014; Gajić & Grbić, 2016; Geci & Naumova, 2021b; Geci et al., 2023; Stanković, 2023.
Thomisus onustus (Walckenaer, 1805): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Tomić & Grbić, 2008; Dudić et al., 2011; Grbić et al., 2011, 2015, 2019, 2021; Vrenozi & Jäger, 2013; Geci & Naumova, 2021b; Stanković, 2023.
Tmarus piger (Walckenaer, 1802): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Kolosváry, 1938; Sisojević & Miller, 1978, 1979, 1985; Nikolić & Polenec, 1981; Tomić & Grbić, 2008; Dudić et al., 2011; Grbić et al., 2011, 2019, 2021; Vrenozi & Jäger, 2013; Gajić & Grbić, 2016; Geci & Naumova, 2021b.
Tmarus stellio (Simon, 1875): Sisojević & Miller, 1978; Nikolić & Polenec, 1981; Tomić & Grbić, 2008; Geci et al., 2023.
Xysticus acerbus (Thorell, 1872): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Komnenov & Pavićević, 2009; Grbić & Savić, 2010; Grbić et al., 2015; Geci & Naumova, 2021b; Grbić & Hänggi, 2022; Stanković, 2023.
Xysticus audax (Schrank, 1803): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Dudić et al., 2011; Vrenozi & Jäger, 2013; Grapci-Kotori et al., 2022; Geci et al., 2023.
Xysticus bifasciatus (C. L. Koch, 1837): Chyzer & Kulczyński, 1897; Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Tomić & Grbić, 2008; Dudić et al., 2011; Geci et al., 2023.
Xysticus cristatus (Clerck, 1757): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Šilhavý, 1944; Nikolić & Polenec, 1981; Dudić et al., 2011; Vrenozi & Jäger, 2013; Petrović, 2014; Grbić et al., 2021; Stanković, 2023.
Xysticus desidiosus (Simon, 1875): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
Xysticus erraticus (Blackwall, 1834): Stojićević, 1929; Drensky, 1936; Šilhavý, 1944; Nikolić & Polenec, 1981; Petrović, 2014; Grbić et al., 2021; Grapci-Kotori et al., 2022; Geci et al., 2023.
**Xysticus gallicus* (Simon, 1875): Geci et al., 2023.
Xysticus ferrugineus (Menge, 1876): Kolosváry, 1938, 1940b; Šilhavý, 1944; Nikolić & Polenec, 1981.
Xysticus kempeleni (Thorell, 1872): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Grbić & Savić, 2010; Dudić et al., 2013; Grbić et al., 2015, 2021; Grbić & Hänggi, 2022.
Xysticus kochi (Thorell, 1872): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Šilhavý, 1944; Sisojević & Miller, 1979, 1985; Nikolić & Polenec, 1981; Komnenov & Pavićević, 2009; Grbić & Savić, 2010; Grbić et al., 2011, 2015, 2019, 2021; Dudić et al., 2013; Vrenozi & Jäger, 2013; Gajić & Grbić, 2016; Grbić & Hänggi, 2022; Grbić & Stanković, 2022; Geci et al., 2023; Stanković, 2023.
Xysticus lanio (C. L. Koch, 1835): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Šilhavý, 1944; Sisojević & Miller, 1978, 1979, 1985; Nikolić & Polenec, 1981; Ćurčić et al., 2003, 2004; Tomić & Grbić, 2008; Grbić et al., 2015.
Xysticus lineatus (Westring, 1851): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
Xysticus luctator (L. Koch, 1870): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1978, 1979; Tomić & Grbić, 2008; Komnenov & Pavićević, 2009; Grbić et al., 2011, 2019, 2021; Gajić & Grbić, 2016; Grbić & Stanković, 2022.
Xysticus luctuosus (Blackwall, 1836): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Dudić et al., 2013.
**Xysticus macedonicus* (Šilhavý, 1944): Geci et al., 2023.
Xysticus ulmi (Hahn, 1831): Bresjančeva, 1907; Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1978, 1985; Nikolić & Polenec, 1981; Grbić et al., 2011, 2021.
Family TITANOECIDAE
Titanoeca schineri (L. Koch, 1872): Nikolić & Polenec, 1981; Grbić et al., 2011, 2019, 2021; Grbić & Hänggi, 2022.
Titanoeca spominima (Taczanowski, 1866): Grbić et al., 2021.
Titanoeca tristis (L. Koch, 1872): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
Titanoeca veteranica (Herman, 1879): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
Family TRACHELIDAE
Cetonana laticeps (Canestrini, 1868): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Grbić & Savić, 2010; Gajić & Grbić, 2016.
**Paratrachelas maculatus* (Thorell, 1875): Geci & Naumova, 2021b.
Family ULOBORIDAE
Hyptiotes paradoxus (C. L. Koch, 1834): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Grbić & Savić, 2010; Dudić et al., 2011; Grbić et al., 2011, 2019.
Uloborus walckenaerius (Latreille, 1806): Chyzer & Kulczyński, 1897; Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Tomić & Grbić, 2008; Dudić et al., 2011; Grbić et al., 2021.
Family ZODARIIDAE
Zodarion aculeatum (Chuzer, 1897): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
Zodarion germanicum (C. L. Koch, 1837): Chyzer & Kulczyński, 1897; Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1978, 1979; Nikolić & Polenec, 1981; Tomić & Grbić, 2008; Grbić et al., 2011, 2015, 2019, 2021; Grbić & Hänggi, 2022.
Zodarion graecum (C. L. Koch, 1843): Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981.
**Zodarion ohridense* (Wunderlich, 1973): Geci et al., 2025a.
**Zodarion scutatum* (Wunderlich, 1980): Geci et al., 2025a.
Family ZOROPSIDAE
Zoropsis spinimana (Dufour, 1820): Grbić & Marinković, 2023.

*species registered only in the southern Serbian province of Kosovo and Metohija.
**species with temporary reference.

Best represented are the families Linyphiidae (199 species), Gnaphosidae (78), Salticidae (71), Lycosidae (68), Araneidae (54), Theridiidae (54) and Thomisidae (45) (Table 2). The genera with the largest number of species are: Pardosa (28), Clubiona (20), Zelotes (17), Xysticus (16), Alopecosa (14) and Centromerus (14).

Table 2. The family composition in the spider fauna of Serbia.

Family	No. of species	Family	No. of species	Family	No. of species
Agelenidae	30	Hahniidae	4	Pisauridae	1
Amaurobiidae	5	Leptonetidae	2	Salticidae	71
Anyphaenidae	1	Linyphiidae	199	Scytodidae	1
Araneidae	54	Liocranidae	7	Segestriidae	3
Atypidae	3	Lycosidae	68	Sparassidae	1
Cheiracanthiidae	9	Mimetidae	5	Tetragnathidae	15
Cicurinidae	2	Miturgidae	7	Theridiidae	54
Clubionidae	21	Nemesiidae	1	Thomisidae	45
Cybaeidae	4	Nesticidae	3	Titanoecidae	4
Dictynidae	16	Oecobiidae	2	Trachelidae	2
Dolomedidae	2	Oxyopidae	3	Uloboridae	2
Dysderidae	21	Philodromidae	27	Zodariidae	5
Eresidae	2	Pholcidae	6	Zoropsidae	1
Gnaphosidae	78	Phrurolithidae	3	41 families	790

Below are given some comments for the species removed from the list:

Lycosoides flavomaculata Lucas, 1846 (record: Nikolić & Polenc, 1981), records from the Balkans and from Turkey removed in the sense of Bosmans et al. (2022).

Porrhoclubiona decora Blackwall, 1859 (records: Stojićević, 1929; Drensky, 1936; Nikolić & Polenc, 1981), citations from Portugal, Italy and the Balkans probably refer to other species of the genevensis group (Bosmans et al., 2017b).

Mastigusa macrophthalma Kulczyński, 1897 (records: Deltshev et al., 1997; Ćurčić et al., 2000b; Dudić et al., 2011), removed from the list by Castellucci et al. (2024).

Dysdera erythrina Walckenaer, 1802 (records: Bresjančeva, 1907; Drensky, 1936; Nikolić & Polenec, 1981; Dudić et al., 2011) and *Dysdera ninnii* Canestrini, 1868 (records: Stojićević, 1929; Drensky, 1936; Sisojević & Miller, 1979; Nikolić & Polenec, 1981; Ćurčić et al., 2000b, 2003; Tomić, 2006; Gajić & Grbić, 2016; Grbić & Savić, 2010), according to Řezáč et al. (2014, 2018b), misidentifcation records or have to be confirmed.

Harpactea incerta Brignoli, 1979: as *H.* prope *incerta* (Ćurčić et al., 2000b).

Oedothorax subniger Bosenberg, 1902 (records: Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981) has been removed from the list. *Oedothorax subniger* is nomen dubium. Suggested identifications for this species have been *Gonatium rubens* Blackwall, 1833 and *Hylyphantes graminicola* Sundevall, 1830 (Breitling et al., 2015).

Alopecosa barbipes Sundevall, 1833 (syn. *Alopecosa accentuata* Latreille, 1817) (records: Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981; Grbić & Savić, 2010), has been misidentified, probably *Alopecosa farinosa*. According to Nentvig et al. (2025) records from the Balkans are doubtful and the species has been removed from the list. Therefore, records of *A. barbipes* (or *A. accentuata*) have been interpreted as *Alopecosa farinosa*.

Xysticus boesenbergi Charitonov, 1928 (records: Stojićević, 1929; Drensky, 1936; Nikolić & Polenec, 1981) has been removed from the list. *Xysticus boesenbergi* is nomen dubium. According to Breitling et al. (2015), the name *X. boesenbergi* was suggested as a replacement name for *X. concinnus* Bösenberg, 1902 (not *X. concinnus* Kroneberg, 1875). But the species *X. concinnus* Bösenberg, 1902 is not on the list of European spiders.

The record of *Xisticus mongolicus* Schenkel, 1963 by Grbić et al. (2019) belongs to the species *Spiracme lendli* Kulczyński, 1897 (Galle-Szpisjak et al., 2024).

The species *Eratigena picta* Simon, 1870 is listed, but according to Bolzern et al. (2013b) records from the Balkan region may be doubtful.

The following species are registered in Serbia, but not listed for Serbia on the website „Spiders of Europe“ (Nentwig et al., 2025): Agelenidae (*Eratigena picta, Tegenaria parietina*), Araneidae (*Zygiella keyserlingi*), Atypidae (*Atypus affinis*), Cheiracanthiidae (*Cheiracanthium erraticum*), Clubionidae (*Clubiona subsultans*), Dictynidae (*Brigittea civica*), Dysderidae (*Dasumia kusceri*), Gnaphosidae (*Gnaphosa modestior, Civizelotes gracilis, Micaria sociabilis, Drassodes cupreus*), Linyphiidae (*Bathyphantes parvulus Bolyphantes luteolus, Entelecara erythropus, Poeciloneta variegata, Porrhomma rosenhaueri, Typhochrestus digitatus, Walckenaeria capito*), Lycosidae (*Lycosa tarantula, Pardosa blanda*), Mimetidae (*Ero flammeola*), Salticidae (*Neon valentulus*).

The species with the temporary reference - Nentwig et al., 2025, are given below: Agelenidae (*Histopona conveniens, H. dubia*), Anapidae (*Comaroma simoni, Zangherella relicta*), Araneidae (*Glyptogona sextuberculata*), Dysderidae (*Dasumia chyzeri, Dysdera dubrovninnii, D. granulata, D. kollari, D. spinicrus, Parastalita stygia, Stalagtia hercegovinensis*), Gnaphosidae (*Drassodes striatus, Pterotricha lentiginosa*), Leptonetidae (*Barusia hofferi*), Linyphiidae (*Porrhomma profundum, Troglohyphantes lesserti, T. troglodytes*), Philodromidae (*Philodromus fuscolimbatus*), Salticidae (*Euophrys rufibarbis*), Theridiidae (*Argyrodes argyrodes, Enoplognatha afrodite, Lasaeola convexa*), Thomisidae (*Bassaniodes graecus*). These species should be understood conditionally, confirmed or removed from the list. It is likely that some of the mentioned species are not registered on the territory of Serbia.

4. Conclusion

This paper presents a comprehensive review of current data on the spider fauna (Araneae) of the Republic of Serbia, with a total of 790 recorded species from 41 families. These data confirm that Serbia has a rich and diverse spider fauna, which is primarily a consequence of its geographical location, climatic factors and habitat diversity. The results indicate the need for continued systematic research, especially in understudied regions and specific ecological niches. It is expected that further research, as well as the application of modern research methods, will lead to the discovery of new species, including potentially new taxa for science. The presented database represents a valuable resource for further zoogeographic, taxonomic and conservation research and lays the foundation for future additions and revisions.

Thanks and Information Note

The article complies with national and international research and publication ethics.

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Pumpkin Farming from Climate Change Adaptation Perspective: A Case Study in the Coastal Area of Vietnamese Mekong Delta

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Abstract

The impact of climate change in the coastal areas of Vietnamese Mekong Delta has prompted farmers *to switch from rice to other crops like pumpkin. This study was conducted in Tra Vinh in 2023 through secondary data analysis and direct interviews with 52 pumpkin-growing households to understand the adaptability of this new model. The research results showed that the pumpkin growing area in Tra Vinh increased from 1,145 hectares with a yield of 16.2 tons/ha/crop in 2020 to 1,349 hectares with a yield of 16.4 tons/ha/crop in 2021. The average total cost of pumpkin growing was VND 44 million/ha/crop, which was higher that of rice growing (VND 14 million/ha/crop) according to one-sample T-test statistics at the 5% level (P=0.000). The total revenue, profit and financial efficiency of pumpkin cultivation were always higher than that of rice and the difference was significant at the 5% level. Regarding the climate change adaptation of pumpkin in the study area using a 1-5 Likert scale assessment, 1.9% of farmers rated it as average level, 71.2% rated it as high level and 26.9% rated it as very high level of adaptability. However, the expansion of pumpkin cultivation area faces two main challenges such as groundwater exploitation and unstable output prices of pumpkin. Therefore, research on water-saving cultivation techniques and post-harvest processing is necessary to help the community adapt sustainably in the future.*

Keywords: Adaptation, climate change, production, pumpkin, Vietnam

1. Introduction

The Mekong Delta is located in the southernmost part of Vietnam with an area of about 40,922 hectares (12% of Vietnam) and a population of 17.5 million people (17% of Vietnam). About 65% of the population lives in rural areas and relies on agriculture and aquaculture. In 2024, the Mekong Delta produce 24.5 million tons of rice (56% of Vietnam) and 4.1 million tons of aquaculture (71% of Vietnam) (National Statistics Office, 2024). This confirms that the Mekong Delta plays an important role in agricultural production, not only ensuring national food security but also having surplus for export to the world market (Binh et al., 2023). However, the Mekong Delta is considered one of the three most vulnerable deltas in the world to clime change impacts (IPCC, 2007). According to MONRE (2021), if sea levels rise by 100 cm, 47% of the delta area will be at risk of inundation. The areas with the highest risk of flooding are coastal provinces such as Ca Mau (80% of total areas at risk), Kien Giang 76%, Bac Lieu 62%, etc.

In recent years, droughts and saline intrusion in the Mekong Delta have occurred more frequently and caused damage to agriculture and farmer's livelihoods (Smajgl et al., 2015; Nguyen, 2017). Binh et al. (2021) reported that about 38% of the Mekong Delta area was

affected by saline intrusion at 4 g/l in the 2015-2016 dry season and increased to 41% in the 2019-2020 dry season. Due to the impact of climate change, some farmers have switched from rice cultivation to upland crops such as cucumber, watermelon, pumpkin, etc. This article aims to evaluate the efficiency of agricultural transformation from rice to pumpkin cultivation based on the perspective of climate change adaptation in the coastal areas of the Mekong Delta to have appropriate conversion proposals in the context of increasingly severe impacts of climate change.

2. Methodology

The research was conducted in Tra Vinh province because it is one of the coastal provinces affected by saline intrusion and climate change in the Vietnamese Mekong Delta. This is also the province with a model of converting from rice to pumpkin cultivation. The research steps are summarized as follows (and Figure 1):

- ***Step 1:*** The research team contacted the Department of Agriculture and Rural Development of Tra Vinh province to request data on pumpkin planted area, production and yield of the whole province and districts. Based on this data, some districts were selected for next step.
- ***Step 2:*** The research team did a preliminary visits to Tra Cu, Cau Ngang, Duyen Hai districts and Duyen Hai town to learn about the current status of pumpkin cultivation, thereby selecting potential communes for household survey. Based on the advice and introduction of the District Department of Agriculture and Rural Development as well as the Town Economic Department, 4 communes were selected including Ham Giang commune (Tra Cu district), Long Son and Vinh Kim communes (Cau Ngang district) and Long Huu commune (Duyen Hai town).
- ***Step 3:*** We did survey with pumpkin growing households. In total, 52 farmers were involved in the survey; of which, Cau Ngang 17, Tra Cu 16 and Duyen Hai 19 participants.
- ***Step 4:*** Quantitative data on household surveys (52 households) were entered into Excel and analyzed using SPSS software. Descriptive statistics were used to present general information. One sample T-test was applied to compare total costs, revenue, profit and financial efficiency between pumpkin and rice cultivation. Rice production data were gathered from Cam and Binh (2022).



Key informant interview in Tra Vinh province



Household survey (52)
- Cau Ngang: 17
- Tra Cu: 16
- Duyen Hai: 19



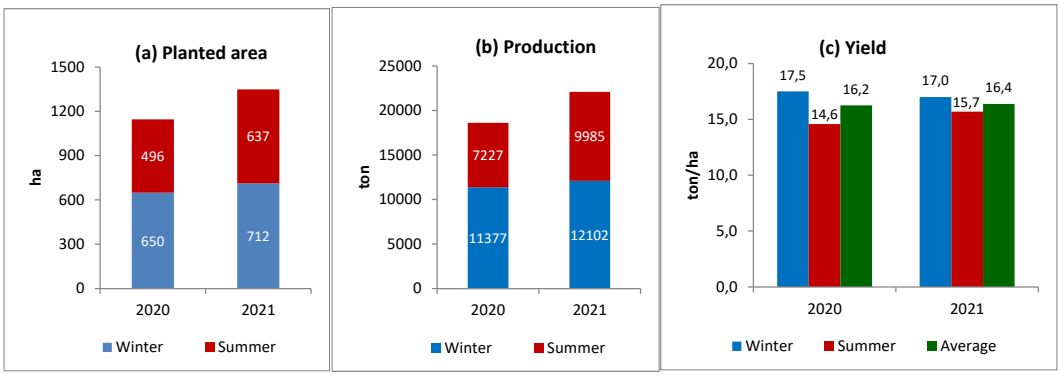
Transect walk and field observation

Figure 1. Some photos showing the research method in Tra Vinh province

3. Results and discussion

3.1. Pumpkin production in Tra Vinh

The survey results show that the planted areas, production and yield of pumpkin in Tra Vinh increased in the period of 2020 and 2021. Indeed, the planted area increased from 1,145 hectares in 2020 to 1,349 hectares in 2021, the production increased from 18,604 tons to 22,087 tons, and the average yield increased from 16.2 tons/ha/crop to 16.4 tons/ha/crop in the same period (Figure 2).



(Source: Data collected at Department of Agriculture and Rural Development)

Figure 2. Planted area, production and yield of pumpkin in Tra Vinh province

In Tra Vinh, pumpkin is grown in two crops: Winter and Summer, of which Winter is the main crop. In 2021, the pumpkin planted area in the whole province in the Winter crop was 712 hectares (accounting for 53%) and the production was 12,102 tons (accounting for 55%). The pumpkin yield in the Winter crop was higher than that in the Summer crop; for example, the Winter crop in 2021 reached 17.0 tons/ha but the Summer crop only reached 15.7 tons/ha (Figure 2c).

3.2. Household information and farming practice

This study directly surveyed 52 pumpkin-growing households, of which 17 households were in Cau Ngang district, 16 households in Tra Cu district and 19 households in Duyen Hai town. In terms of ethnicity, there were 13 Khmer households (accounting for 25% of the total number of households) and 39 Kinh households (75%). In terms of gender of household heads, there were 9 females (17%) and 43 males (83%). Some characteristics of pumpkin-growing households are presented in Table 1:

Table 1. Household characteristics in the surveyed area by district

Items	Districts			Total or Average
	Cau Ngang	Tra Cu	Duyen Hai	
Numbers of participants	17	16	19	52
Age of household head	$47,2^{a}$	$55,9^{b}$	$50,5^{ab}$	50,9
Year of schooling	$5,7^{ab}$	$3,5^{a}$	$7,6^{b}$	5,8
Years of resetlement	$43,4^{a}$	$52,9^{a}$	$45,7^{a}$	46,9
Family size	$3,4^{a}$	$4,4^{b}$	$4,1^{ab}$	3,9
Land area (m^2/household)	8.328^{a}	5.907^{a}	6.436^{a}	6.892

Note: In the same row comparing administrative units, the numbers following with the same letter are not significantly different through Duncan test at 5% significance level.

- The average age of the household head is 50.9 years old and there is a difference between districts through Duncan test at the 5% significance level, the lowest in Cau Ngang (47.2 years old) and the highest in Tra Cu (55.9 years old);
- The education level of the household head is relatively low and there is a difference between districts through statistics, the lowest education level is in Tra Cu district (average only 3.5 years) and the highest in Duyen Hai town (average 7.6 years);
- The number of years the household head has settled in the locality is 46.9 years and there is no difference between districts;
- The average number of household members is 3.9 people/household and there is a statistical difference, the district with the highest number of members is Tra Cu (4.4 people/household) and the lowest is Cau Ngang (3.4 people/household);
- The average total land area per household in the study area is 6,892 m^2. This indicator does not differ between districts.

In general, pumpkin growing households are people who have lived in the locality for a long time, are relatively old, have low education and have small cultivated land area (only 0.7 ha/household).



Figure 3. Picture showing three common pumpkin varieties in Tra Vinh province

In terms of seasonal calendar, farmers can plant all year round but the most common planting times are October-December (Winter crop) and January-March (Summer crop). The three popular varieties of pumpkin are long-fruited, gourd and high-yield round varieties (Figure 3). The average yield of pumpkin is about 16.0 tons/ha/crop and there is no big difference between varieties. In addition to the fruit, farmers also harvest flowers and shoots.

3.3. Financial efficiency

The results of the financial efficiency analysis of pumpkin cultivation in Tra Vinh province show that the average total cost is 44.1 million VND/ha/crop (1 USD equal to 27,000 VND); in which the cost of fertilizer accounts for the highest proportion (15.1 million/ha/crop, equivalent to 34.1% of the total cost), followed by the cost of seeds 19.1%, the cost of mulch and straw 11.0%, the cost of pesticides 9.0%, the cost of land preparation 8.2%, the cost of hired labor 7.7%, the cost of irrigation 6.4%, the cost of herbicides 3.7% and other costs

0.8%. The total revenue reaches an average of 130 million VND/ha/crop; in which the revenue from pumpkin fruit is 76.2%, from pumpkin flowers 23.2% and pumpkin shoots only 0.6%. Thus, the average profit from growing pumpkin is 85.9 million VND/ha and the financial efficiency is 207%. It means that one VND of capital invested in growing pumpkin will yield 2.07 VND of profit.

Table 2 shows that the total costs, total revenue, total profit and financial efficiency of pumpkin are higher than rice. Indeed, the total costs of pumpkin is 44.1 compared to rice 14.0 million VND/ha/crop. The total revenue of pumpkin is 130 compared to rice 32.3 million VND/ha/crop. The total profit of pumpkin is 85.9 compared to rice 18.3 million VND/ha/crop. This leads to the financial efficiency of pumpkin reaching 207%, higher than rice only 131%. This shows that pumpkin cultivation is more efficient but the investment cost is also high. This may hinder the conversion for poor households, households that do not have enough financial capital.

Table 2. Comparison of financial efficiency between pumpkin and rice cultivation in Tra Vinh province

Items	Pumpkink	Rice	T-test value
Total costs (Million VND/ha/crop)	44.1	14.0	0.000
Total revenue (Million VND/ha/crop)	130.0	32.3	0.000
Total profit (Million VND/ha/crop)	85.9	18.3	0.000
Financial efficiency (%)	***207***	***131***	***0.000***

3.4. Assessment of climate change adaptation

Regarding the climate change adaptation of pumpkin in the study area using a 1-5 Likert scale assessment, the result depicts that only 1.9% of farmers rated it as average level, 71.2% rated it as high level and 26.9% rated it as very high level of adaptability.

This proves that pumpkin is a suitable crop for farmers to convert in the context of saline intrusion and climate change impacts in the study area. In fact, the area of pumpkin cultivation in Tra Vinh has also increased in recent years as presented. However, one of the problems is that farmers exploit groundwater to cultivate pumpkin. This leads to the consequence that groundwater resources are increasingly depleted, the risk of land subsidence is increasing. In addition, the expansion of acreage can cause supply to exceed demand, leading to low product prices, causing loss of profits for farmers. In addition, the rate of drifting pumpkins, poor quality pumpkins, and pumpkins that are not qualified to be sold to the market is also relatively high (14%). Therefore, long-term conversion must take into account the above problems.

4. Conclusion

Tra Vinh is a province with a fairly large pumpkin growing area. The production in 2021 was up to over 22 thousand tons. In the province, Cau Ngang, Tra Cu districts and Duyen Hai town are the places with the largest growing area. These three units alone account for 79% of the growing area and 75% of the pumpkin production of the whole province in 2021. In terms of season, farmers can grow all year round, but the most common planting times are Winter and Summer crops. The three popular pumpkin varieties are long-fruited pumpkin, gourd

pumpkin and high-yield round pumpkin. The average pumpkin yield is about 16.0 tons/ha/crop and there is no big difference between the varieties. In addition to the fruit, farmers also harvest pumpkin flowers and pumpkin shoots. In terms of profit, for each hectare of pumpkin, farmers earn an average profit of 86 million VND/crop, with a corresponding capital efficiency of 207%. It is higher than traditional practice of rice cultivation. Although the pumpkin production is large, there is no clear direction for future development. Prices are determined by traders, so they are very unstable. All products are sold fresh, unprocessed. The rate of lost and damaged pumpkins is up to 14%. Last but not least, over exploitation of ground water is happening. Therefore, finding stable output market, reducing post-harvest losses and processing pumpkin products, and having water-saving technique are necessary to maintain this livelihood for people growing pumpkins in Tra Vinh province.

Thanks and Information Note

The article complies with national and international research and publication ethics. All authors contributed equally to the article.

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Perception of Ecosystem Services Provided by Nature-Based Solutions (Nbs) to Address Tourism-Related Challenges in Coastal Cities: Aveiro (Pt) And Seferihisar (Tr)

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Abstract

Tourism facilitates the economic growth of coastal areas while also increasing pressures and vulnerability of such areas. Seasonal increases in visitor numbers lead to various problems, including inadequate infrastructure, excessive water use, waste management problems, ecosystem degradation, and deterioration of cultural heritage. While Nature-Based Solutions (NBS) are recognized as solutions to many fundamental urban challenges, they have not been well explored in terms of tourism pressures. In urban areas, NBS implementations often prioritize factors such as time, cost, and performance. NBS implementation offers multiple benefits by reducing tourism pressures and simultaneously increasing tourism attractiveness. This objective of this study is to assess the stakeholders' perception on ecosystem services provided by Nature-Based Solutions (NBS) to mitigate tourism-related pressures in coastal cities. This study presents a methodological approach to examine the role of ecosystem services provided by NBS in mitigating tourism-related pressures. This provides cities with the opportunity to identify NBS options that can help address the prevailing problems in their communities. The data obtained will enable the identification of the most effective NBS to address tourism pressures experienced by local communities.

Keywords: Nature-based solutions, sustainable tourism, coastal settlements, participatory approach, perception-based analysis.

Introduction

Tourism contributes to economic growth; however, the intense flow of tourists in coastal cities leads to environmental and social problems (Saavedra, Martí, & Planagumà, 2023). The seasonal increase in the number of visitors causes infrastructure deficiencies, increased water consumption, waste management problems, ecosystem degradation, coastal erosion, and cultural heritage damage (Cingolani, Barberá, Renison, & Barri, 2016; Piippo, Juntunen,

Kurppa, & Pongrácz, 2014; Yi, Tang, Yi, Yang, & Zhang, 2017; Wilson & Verlis, 2027). According to WWF, 80% of tourism activities take place in coastal areas. Considering that beaches and coral reefs are among the most popular destinations, these pressures become particularly evident in coastal settlements subject to high tourist flows, such as Aveiro (Central Portugal, Portugal) and Seferihisar (İzmir, Turkey) (Ip-Soo-Ching, Massingham, & Pomering, 2022; WWF, Metabolic, 2021; Steven, Addo, Llewellyn, & Ca, 2020). While acknowledging the limits of carrying capacity (Skiniti et al., 2024), balancing the supply and demand of tourist attractions is crucial. Particularly sensitive lagoon and coastal ecosystems are being degraded by uncontrolled tourism activities, threatening the long-term sustainability of these areas (Klerck & Baets, 2020). Coastal communities are subjected to pressures such as the overexploitation of natural resources (Ináci et al., 2025; Navarro-Murillo, Rico-Fernández, Barquero-Peralbo, Arias, & García-Ordiales, 2024; Wang et al., 2024). In many parts of the world, tourism is the primary source of economic income for coastal communities; however, overtourism is one of the most significant anthropogenic pressures on coastal areas (Flayou, Snoussi, & Raji, 2021; Lansu et al., 2024). The use of nature-based solutions (IUCN, 2016) contributes to increasing urban resilience by addressing challenges such as mitigating the impacts of climate change in cities (Zhu et al., 2020; Depietri & McPhearson) and reducing carbon emissions (Pan et al., 2023; Prado et al., 2024). While nature-based solutions (NBSs) are recognized as effective solutions to many fundamental urban challenges (Prado et al., 2024), they have not yet been thoroughly evaluated in addressing tourism pressures and tourism-related urban challenges in cities. NBSs can be a mitigating force against universal problems such as global warming and climate change, which are among the most fundamental challenges affecting the resilience of the tourism sector today. However, they can also contribute to reducing the pressures exerted by tourism on cities. It is envisioned that ecosystem services and nature-based solutions will be utilized to adapt to and reduce the increasing pressures of tourism in cities and, particularly, in coastal areas. However, not all ecosystem services will respond to all tourism pressures. Therefore, we seek to utilize ecosystem services—provided by NBS—that will reduce tourism's pressure on cities and coasts; to also identify perception-based nature-based solutions associated with ecosystem services; and ultimately, to enable tourism sustainability through solutions that minimize these pressures. The goal is not to make the tourism sector more resilient; it is to find ways to reduce or adapt to the pressures caused by tourism. The outcome of this process is to make the tourism sector sustainable, to build a resilient sector, and, consequently, to pave the way for the adoption of solutions through collective decision-making processes. Because solutions are context-specific and require the development of collective awareness throughout the process, the perceptions of individuals, other stakeholder (researcher, academics) especially indigenious, are essential. This study is conducted to evaluate the ecosystem services provided by NBS that respond to the challenges of tourism and the role of nature-based solutions associated with ecosystem services in adapting/reducing tourism pressure. The goal is not to make the tourism sector more resilient, but this will naturally occur when policies and practices are implemented to reduce these pressures. Therefore, rather than focusing on overcoming sectoral challenges, it is important to adopt solutions that reduce and adapt to tourism-related pressures. Efforts to alleviate tourism's pressure on cities, particularly coastal areas, offer a dual benefit. Implementing NBSs to reduce or adapt to these pressures can increase the tourist appeal of cities and generate economic benefits. In addition to economic gains, they also reduce the concentration of tourism in coastal areas, resulting in a more

homogeneous spatial distribution of tourist activities. This could help shift the focus from coastal areas to the urban center. When implementing NBSs in urban areas, decision-makers often prioritize concerns such as time, cost, and performance (Sowińska-Świerkosz & García, 2021). However, NBSs should not be designed solely based on administrative or financial criteria; they should also incorporate people-centered benefits and involve broader stakeholder participation. When the choice of solutions is limited solely to technical parameters, short-term, cost-effective, and high-performance expectations take precedence, and decision-makers overlook solutions that provide long-term benefits. Problem perceptions and preferred solutions may differ among urban residents. For example, older local residents may perceive tourism pressures primarily through sociocultural impacts (e.g., loss of tranquility or erosion of local identity), while those aged 18–25 may consider habitat degradation and marine pollution associated with beach activities and water sports as more critical environmental pressures. The selection of NBSs based solely on “perception” has not been considered to date. Specifically in coastal cities, identifying NBSs as solutions to tourism pressures by asking, "If there were no barriers or limitations, which solution would we choose and where would we implement it?" can reveal whether currently existing NBS types are truly compatible with the solutions desired by communities. Given that the criticality of nature conservation in the tourism sector is directly linked to human behavior (Flayou, Snoussi, & Raji, 2021; Lansu et al., 2024), mitigating the negative impacts of tourism on nature will depend on evaluating solutions shaped by human behavior and perceptions.

In the tourism literature, the concept of overtourism, associated with various problems such as climate change, air pollution, and economic pressures, has been examined in urban areas subject to high tourist density (Butler & Dodds, 2022; Goodwin, 2017; Gössling et al., 2018; Hospers, 2019; Koens, Postma, & Papp, 2018; UNWTO, 2018). The idea that nature-based protected areas can be protected from tourism through nature-based solutions (NBSs) was proposed by Mandic (Mandic, 2019; Mandic & Vukadin, 2021). However, studies examining the use of NBSs through stakeholder participation and perception-based approaches to alleviate tourism pressures in coastal areas or settlements exposed to overtourism are almost nonexistent. In the literature, stakeholders' selection of NBSs appears to be based primarily on objective criteria such as financial considerations, time, and efficiency (Sowińska-Świerkosz & García, 2021), while the influence of their own priorities and perceptions is insufficiently considered. Understanding the scope of NBSs in addressing tourism-related challenges and making “perception-based choices” is a crucial part of the co-creation process. On the other hand, the EC NBS Handbook (European Commission, 2021) overlooks the effectiveness of NBSs in addressing tourism-related challenges, thus revealing a gap in the literature.

A long-term study conducted in the Platte River Basin in Nebraska showed that the sense of ownership developed by local communities contributes to more effective management of the river, improved maintenance, and increased overall sustainability (Burbach, Eaton, Quimby, Babbitt, & Delozier, 2022). As Elinor Ostrom points out in her argument for commons management (Ostrom, 2016), local institutions and community-based rules often produce more efficient outcomes than centralized interventions. Solutions designed around commons foster a sense of collective governance, reduce implementation costs through shared knowledge, and contribute to long-term success. As the example illustrates, involving local

communities in the implementation process is crucial for the acceptance and adoption of proposed solutions.

Materıals and Methods

This study used an integrated mixed methods approach consisting of a systematic literature review from SCOPUS, identification of important academic articles using the snowball method, classification of relevant ecosystem services using the TEEB framework, identification of nature-based solutions (NBS) from relevant sources, and participatory stakeholder workshops and interviews to assess the feasibility and local acceptance of NBS provided by ecosystem services to reduce tourism-related pressures. The study is structured around three main questions:

1. **What are the pressures and challenges caused by tourism?**

   The pressures and challenges arising from tourism activities are identified in detail. For this purpose, a systematic literature review was conducted using the SCOPUS database and the following search string:

   TITLE-ABS-KEY ("sustainable tourism" AND "nbs" OR "nature-based solution*" OR "nature-based solution*")

   In addition, a snowball literature review approach is used, departing from the following key papers:

   - Rice (2020): *Nature-based solutions for urban development and tourism*
   - Mandic (2019): *Nature-based solutions for sustainable tourism development in protected natural areas: a review*
   - Almenar (2021): *Nexus between nature-based solutions, ecosystem services and urban challengesreferring to cited and citing papers.*

2. **Which ecosystem services can mitigate these pressures?**

   Explore which ecosystem services could address the identified pressures and challenges. The TEEB ecosystem services classification (TEEB, 2010) was adopted. The TEEB Classification was preferred because it offers a more understandable and simpler classification option.

3. **Which nature-based solutions (NBS) can provide these ecosystem services?**

Assess which NBS solutions can provide the ecosystem services identified to address these challenges. For this purpose, NBS types and characteristics were derived from INCCA (INCCA, 2023) and UNaLab (UNaLab, 2022).

A workshop approach was developed to determine the NBS selection based on stakeholder perceptions. The workshop process followed the following steps

i. Defining participant profiles
ii. Discussing tourism-related pressures and challenges
iii. Identifying ecosystem services that can mitigate these pressures
iv. Selecting relevant NBS types

v. Prioritizing NBSs based on participant assessment

Following the workshop, one-on-one interviews will be held in Seferihisar, a Cittaslow (slow city) city committed to sustainable policy principles, to assess solutions at a national scale. These interviews will involve municipal officials, local residents, and organizations operating in the tourism sector to assess the feasibility and suitability of the NBSs, previously identified within a theoretical framework, in the local context. The purpose of these discussions is to assess the local acceptance, feasibility, and potential effectiveness of the selected solutions in reducing tourism-related pressures.

Findings and Discussion

1. What are the pressures and challenges caused by tourism?

Anti-tourism reactions and tourism phobia in host communities resulting from overtourism are not new phenomena. The consequences of excessive tourism flows have been previously addressed by Doxey (1975), Butler (1980), and Mitchell (1998) (Seraphin, Gowreesunkar, Zaman, & Bourliataux-Lajoinie, 2019). The current problem is not only the sheer number of tourists but also the unbalanced temporal and spatial concentration of visitors due to peak periods in the same destinations (Smolčić Jurdana & Zmijanović, 2014; Walden-Schreiner et al., 2018). The EUROPARC Federation divides tourism carrying capacity into ecological, sociocultural, and psychological dimensions (Rogowski, Zawilińska, & Hibner, 2025). In some countries, such as Portugal, carrying capacity assessments have been formally integrated into protected area management (Monteiro & Pereira da Silva, 2012). Without preventative strategies, tourism growth exceeds these limits, resulting in overtourism, where destinations receive more tourists than they can sustainably accommodate (Li Jianpu, Weng, Pan, Li, & Wang, 2021). Koens, Postma, and Papp (2018) identified five main symptoms of overtourism. These symptoms can be summarized as dense urban areas, disturbances caused by visitors' tendency to litter and noise, the emergence of central districts as tourist hotspots, the loss of identity and a diminished sense of belonging among locals, excessive waste production, and environmental pressures. Cities often exhibit visible signs that tourism is becoming excessive (Jong, Joss, Schraven, Zhan, & Weijnen, 2015). Locals may develop negative attitudes due to overcrowding (Fleishman, Feitelson, & Salomon, 2004; Perdue, Long, & Kang, 1999; Riganti & Nijkamp, 2008; Stewart & David, 2017), while rising living costs, waste, congestion, and noise also become noticeable (Mason & Cheyne, 2000; Ehigiamusoe, 2020). All of this suggests that sample tourism cities host far more tourists than their carrying capacity. These issues contribute to urban touristification, museumification, and "Disneyfication," which weaken the functional and social character of city centers (Pasquinelli & Trunfio, 2020; Gravari-Barbas & Guinand, 2017). As the city's identity shifts, residents may feel alienated and develop hostile attitudes toward tourists (Peeters et al., 2018; Novy & Colomb, 2017; Martín, Martínez, & Fernández, 2018; Milano, 2017). Tourism does not follow a linear growth pattern (Po & Huang, 2008; Scarlett, 2021). After a certain threshold, negative externalities appear — including litter accumulation (Pickering, Hill, Newsome, & Leung, 2010; Zhong, Deng, Song, & Ding, 2011; Hu, Zhang, Wang, Yu, & Chu, 2019), non-degradable waste (Religa & Adach, 2020), and mobility congestion (Siano & Canale, 2022) — eventually reducing tourist satisfaction (Belsoy, Korir, & Yego, 2012; Ferreira & Harmse, 2014). The magnitude of impacts varies seasonally. In mountainous destinations, peak visitation occurs during winter (Erlebach & Romportl, 2021), while in

coastal regions, intensive summer activities such as scuba diving and snorkeling contribute to coral reef degradation (Giglio, Luiz, & Ferreira, 2020; Hawkins, Roberts, Tom, & Kalli, 1999; Krieger & Chadwick, 2012; Lamb, True, Piromvaragorn, & Willis, 2014). Anchoring further exacerbates reef damage (Giglio, Ternes, Mendes, Cordeiro, & Ferreira, 2017; Mason, Bozec, & Mumby, 2023), while chemical contamination and marine noise pollution also pose threats (McCloskey et al., 2023; Nedelec, Radford, Gatenby, & Davidson, 2022). Studies indicate that underwater photographers can damage reefs in nearly 90% of dives (Walters & Samways, 2001). Additionally, recreational marine tourism activities such as boat tours and whale watching may harm ecosystems and also negatively affect local communities and visitor experiences (Dearden, Bennett, & Rollins, 2007; Diedrich, Huguet, & Subirana, 2011; Meyer, Dale, Papastamatıou, Whitney, & Holland, 2009; Stockin, Lusseau, Binedell, Wiseman, & Orams, 2008; Thurstan, Hawkins, Neves, & Roberts, 2012; Bentz, Rodrigues, Dearden, Calado, & Lopes, 2015). Therefore, it is essential for urban destinations to regulate visitor numbers according to carrying capacity and to disperse tourist flows. The creation of distributed attraction points—so-called "tourist honey pot sites"—can help redistribute tourism pressure across the city (Rogowski, Zawilińska, & Hibner, 2025).

The challenges and pressures of tourism and uncontrolled, excessive tourism growth in the city can be listed as follows:

1.1. Overcrowded beaches (Oklevik, ve diğerleri, 2019; Mandic & Vukadin , 2021; Koens, Postma, & Papp, 2018; Pasquinelli & Trunfio, 2020; Siano & Canale, 2022; Koh & Fakfare, 2020; Belsoy, Korir, & Yego, 2012; Ferreira & Harmse, 2014)

It is the pressure created by tourism. In particular, in important historical sites and protected areas (Belsoy, Korir, & Yego, 2012; Ferreira & Harmse, 2014), heavy tourist traffic can be observed. According to the WWF report, 80% of tourism takes place in coastal areas (WWF, Metabolic, 2021). Therefore, in the summer months, intensive use of coastal areas can be observed. This can lead to negative experiences for all tourists who want to visit these areas. Sensitive ecosystems in coastal areas are becoming more vulnerable to natural disasters, storm surges, sea level rise, and climate change, combined with human pressures and infrastructure development (World Tourism Organization (UNWTO), 2018; Nazir N. Z., et. al.,2025)).

1.2. Seawater pollution. (Koens, Postma, & Papp, 2018; Joppe, 2019; Padma , Ramakrishna, & Rasoolimanesh, 2019). This is the pressure that tourism puts on cities. Due to the intensive use of coastal areas, especially during the summer months, water quality can decline due to recreational activities, and this heavy use can lead to water pollution. Tourists' waste production habits and seasonal activities can increase the amount of marine litter and waste washing ashore in coastal areas (Krelling, Williams, & Turra, 2017).

1.3. Air and noise pollution (Koens, Postma, & Papp, 2018; Pasquinelli & Trunfio, 2020; Mason & Cheyne, 2000; Ehigiamusoe, 2020) . In cities struggling with overtourism, traffic congestion, activity, and traffic-related noise, and thus air pollution, are unavoidable.

1.4. Coastal erosion. (Rogowski, Zawilińska, & Hibner, 2025; Rockström, ve diğerleri, 2009; Hedge, 2010; Barragan & Andres, 2015) It's one of the challenges facing

tourism. Tourism may not directly cause coastal erosion, but tourist preferences may vary in tourist destinations experiencing coastal erosion. Coastal erosion, harmful algal blooms, and sea level rise both affect tourism itself and trigger these problems (Bryant, 1988; Fish et al., 2008; Walkden & Dickson, 2008). The study by **Liu et al**. concluded that tourists are willing to protect the beach, and some tourists believe that local governments and businesses should take responsibility for protection (Liu, Liu, Zhang, Qu, & Yu, 2019).

1.5. **Marine life degradation.** (Giglio, Luiz, & Ferreira, 2020; Hawkins, Roberts, Tom, & Kalli, 1999; Krieger & Chadwick, 2012; Lamb, True, Piromvaragorn, & Willis, 2014; Giglio, Ternes, Mendes, Cordeiro, & Ferreira, 2017; Mason, Bozec, & Mumby, 2023; McCloskey, ve diğerleri, 2023; Nedelec, Radford, Gatenby, & Davidson, 2022; Firth, Farnworth, Fraser, & McQuatters-Gollop, 2023; Dearden, Bennett, & Rollins, 2007) (Diedrich, Huguet, & Subirana, 2011; Meyer, Dale, Papastamatıou, Whitney, & Holland, 2009; Stockin, Lusseau, Binedell, Wiseman, & Orams, 2008; Thurstan, Hawkins, Neves, & Roberts, 2012; Walters & Samways , 2001)Intensively conducted water sports and activities may negatively impact marine life, and it has been observed that amateur diving and underwater photography can harm the marine ecosystem (Walters & Samways , 2001).

1.6. **Loss of local identity.** (Martín, Martínez, & Fernández, 2018; Milano, Cheer, & Novelli, 2018; Peeters, et al., 2018; Seraphin, Gowreesunkar, Zaman, & Bourliataux-Lajoinie, 2019; Koens, Postma, & Papp, 2018; Koh & Fakfare, 2020; Jordan, 2018). Urban areas exposed to overtourism tend to experience changes in the social character of the city (Peeters et al., 2018). At the same time, local residents tend to feel alienated from their habitat. (Novy & Colomb, Protest and Resistance in the Tourist City, 2016; Milano, Cheer, & Novelli, 2018; Martín, Martínez, & Fernández, 2018).

1.7. **Heatwaves and microclimate shifts.** (Jiricka-Pürrer, Brandenburg, & Pröbstl-Haider, 2020; Yang, 2024) It's one of the challenges facing tourism. Extreme heat waves emerge in cities with intense tourism activity and also influence tourists' willingness to make reservations (Dubois, Ceron, Gössling, & Hall, 2016; Gómez-Martín, Armesto-López, & Martínez-Ibarra, 2017; Serquet & Rebetez, 2011). A study conducted by Ellex and others on Vienna tourists showed that 32.6% of participants had already adapted their travel plans due to the heat (Jiricka-Pürrer, Brandenburg, & Pröbstl-Haider, 2020). Additionally, tourists can contribute to the effects of climate change in the destinations they visit; therefore, there is a reciprocal relationship between tourism and climate change, with each significantly influencing the other (Sajjad & Chan, 2019; Su et al., 2015 (Jiricka-Pürrer, Brandenburg, & Pröbstl-Haider, 2020)).

1.8. **Overburdened infrastructure**. (Kurnaz & İpar, 2020; Jordan, 2018) Inadequate infrastructure is one of the challenges facing tourism. However, it has more to do with urban infrastructure planning than with tourism itself. Overconsumption, excessive water use, and heavy infrastructure loads can cause problems, especially during peak tourism periods. Local communities sharing the same infrastructure may experience electricity, water, and sewage problems. Just as cities have a carrying

capacity, so too does infrastructure; therefore, infrastructure planned for permanent residents can cause problems in cities subject to intense tourism.

1.9. **Degradation of cultural heritage** (Carrol, 2017) High tourist concentration, particularly in historic sites and cultural heritage areas, can lead to physical wear, deterioration, and structural degradation. Archaeological sites, monuments, traditional architecture, and historic urban fabrics may become damaged over time due to continuous visitor flow, physical contact, environmental pressures, and commercial use. This situation affects not only the material structures themselves but may also weaken the cultural identity and sense of belonging of local communities.

2. Which ecosystem services can mitigate these pressures?

The TEEB classification was adopted as the ecosystem service in this study because it provides a more accessible and clear structure compared to classifications that provide similar ecosystem services, such as CICES, MAES, or SEEA. Within this framework, ecosystem services that can respond to tourism-related pressures in urban and coastal environments were selected. While ecosystem service typologies are generally comprehensive and quite detailed, their relevance to tourism-related pressures varies. Therefore, the selection process focused on services that directly or indirectly contribute to reducing the negative impacts of tourism on cities. The existing literature contains limited studies linking tourism pressures to ecosystem service-based mitigation strategies. The question of which ecosystem services should be prioritized is context-dependent. Ecosystem service classifications should be tailored to the characteristics of the study area, and services unrelated to local ecological or sociocultural conditions should be excluded. Furthermore, to avoid conceptual overlap and ensure analytical precision, the distinctions between ecosystem functions, services, and their resulting benefits should be clarified (Hattam et al., 2015).

2.1. Provisioning

2.1.1. Food and Feed

Agricultural and marine ecosystems play a fundamental role in sustaining global food security. Currently, approximately 35% of terrestrial land area is devoted to agriculture and livestock production, with grazing lands covering roughly 26% (Millennium Ecosystem Assessment, 2005; FAO, 2009). Historically, more than 6,000 plant species have been cultivated for human use, yet contemporary food systems rely primarily on just 30 species, demonstrating a significant dependence on a narrow agricultural base (Williams & Haq, 2002).

Marine resources also represent a key source of nutrition. In 2006, global fisheries and aquaculture together produced around 110 million tons of fish, nearly half of which was derived from aquaculture (FAO, 2009). Fish provide at least 15% of the total animal protein consumed by nearly three billion people worldwide, and this proportion is likely higher in low-income regions where small-scale fisheries are significant but often underreported (FAO, 2009).

In the tourism context, local food systems play a prominent role, *particularly in destinations where gastronomic identity constitutes a cultural and economic asset*. Gastronomy tourism attracts visitors seeking authentic, location-specific culinary experiences, thereby

strengthening the connection between food production and tourism. However, this relationship can also intensify tourism-driven pressures. The promotion of local cuisine may increase tourist demand and seasonal visitor concentration, potentially amplifying environmental and socio-economic pressures rather than alleviating them (Acri, 2022).

2.1.2. Raw Materials

Ecosystems supply a wide range of raw materials essential for construction and energy production. Wood, biofuels, and plant-derived oils represent key resources obtained directly from both cultivated and wild plant species (TEEB, 2010).In addition to biological materials, abiotic resources such as sand, rock, and coastal dune formations are vital components of ecosystem services. Sand and rock serve as primary raw materials for construction, glass manufacturing, and various industrial processes. Coastal dunes, beyond their value as material reservoirs, perform crucial ecological functions. They act as natural protective barriers, reducing the impacts of wind erosion and buffering coastal zones against storm surges and sea-level rise. Moreover, dune systems provide unique habitats that support distinct forms of biodiversity, contributing to the ecological stability of both coastal and desert environments.

2.1.3. Fresh Water

Ecosystems influence water availability, regulate flow dynamics, and maintain water quality, forming a loop in the global hydrological cycle (Dudley & Stolton, 2003; Bruijnzeel, 2004). At the global scale, approximately 70% of freshwater resources are allocated to agricultural production, particularly livestock farming, demonstrating the dependence of food systems on stable ecosystem functioning. Forest ecosystems, in particular, contribute to hydrological regulation through evapotranspiration processes, which increase atmospheric moisture and facilitate precipitation formation. Research indicates that large-scale land-use modifications can disrupt regional and global rainfall regimes (Bruijnzeel, 2004). The biotic pump hypothesis (Makarieva, Gorshkov, & Li, 2006) proposes that continuous forest cover, such as in the Amazon and Congo basins, generates atmospheric pressure gradients that draw in moist air and sustain precipitation patterns. In this context, the Amazon “water pump” system has been identified as a key driver supporting both natural ecosystems and agricultural productivity across continental regions (Marengo et al., 2004).

Overall, ecosystems influence water resources through three interconnected mechanisms: water supply (total water yield and quantity), flow regulation (seasonal distribution and timing), and water purification (quality control through sediment retention and biological filtration) (Dudley & Stolton, 2003; Bruijnzeel, 2004; Brauman, Daily, Duarte, & Mooney, 2007). These functions are essential for sustaining human settlements, agricultural activities, and ecological resilience, particularly in regions experiencing tourism-driven pressure on freshwater availability.

2.2. Regulating & Maintenance

2.2.1. Local Climate and Air Quality Regulation

Urban ecosystems play a significant role in enhancing environmental quality and human well-being. According to Alberti et al. (2022), an urban green infrastructure system integrated with well-connected stormwater management solutions can mitigate pollution and improve air quality (Alberti, Silvio, Massini, Naldoni, & Scortecci, 2022). Vegetation contributes to

regulating microclimatic conditions, filtering pollutants, and reducing noise, thereby supporting healthier living environments in cities (Bolund & Hunhammar, 1999). Empirical research demonstrates that urban trees can substantially remove airborne pollutants; for example, vegetation in the Chicago metropolitan region has been estimated to eliminate approximately 5,500 tons of air pollutants annually, contributing to improved atmospheric quality (McPherson et al., 1997). Dense vegetation, such as shrub belts and large green plantings, can also absorb sound, reducing noise levels by approximately 3–6 dB(A) (Bolund & Hunhammar, 1999). Additionally, green roofs, parks, and vertical greenery provide thermal regulation benefits by alleviating the urban heat island effect, particularly in densely built environments and hot climate regions (Alexandri & Jones, 2008).

Urban green areas also function as carbon sinks. Studies from Stockholm suggest that urban ecosystems are capable of assimilating nearly 17% of the carbon dioxide produced by local anthropogenic activities (Jansson & Nohrstedt, 2001). Beyond environmental regulation, exposure to green spaces is associated with positive public health outcomes. For instance, access to vegetation has been linked to reduced childhood asthma rates (Lovasi, Quinn, Neckerman, Perzanowski, & Rundle, 2008) and improved overall health perception among urban residents (Maas et al., 2006).

2.2.2. Carbon Sequestration and Storage

The Earth's climate is moderated by the natural greenhouse effect, which maintains surface temperatures within a range suitable for sustaining life. A number of atmospheric components—including aerosols, clouds, and particulate matter—contribute to the reflection and absorption of incoming solar radiation. However, in recent decades, accelerated land-use changes and the intensified combustion of fossil fuels have increased the concentration of greenhouse gases, particularly carbon dioxide (CO_2), leading to global warming and climate instability. Ecosystems play a vital role in regulating atmospheric carbon. CO_2 is absorbed by vegetation and water bodies and subsequently stored in biomass and soils.

The capacity of soils to retain organic carbon constitutes an essential mechanism for climate regulation. Similarly, methane (CH_4) and nitrous oxide (N_2O) are moderated by microbial processes occurring within terrestrial ecosystems. Marine ecosystems further contribute to climate stabilization by functioning as major carbon sinks, facilitating long-term carbon burial in seabed sediments. Vegetation also influences the Earth's albedo, defined as the proportion of solar radiation reflected by land surfaces. Darker surfaces, such as those covered by dense evergreen forests, absorb more heat than lighter surfaces like snow or grasslands.

Consequently, afforestation in boreal regions may inadvertently enhance warming despite the carbon sequestration benefits from additional biomass. Moreover, aerosols represent another critical factor in climate regulation; they scatter solar radiation and act as nuclei for cloud formation, altering the amount of solar energy reaching the surface.

While the contribution of marine systems to aerosol production is well-established in climate models, increasing evidence indicates that forests emit substantial quantities of biogenic volatile organic compounds capable of forming aerosol particles. Thus, forests simultaneously function as carbon sinks and sources of aerosols while also exerting influence on surface albedo, highlighting their complex and dynamic role in climate regulation (Kulmala et al., 2004).

2.2.3. Moderation of Extreme Events

Extreme events—commonly referred to as natural hazards—are low-frequency occurrences capable of generating severe risks for human life, infrastructure, and socio-economic stability (TEEB, 2010). Ecosystems provide an essential moderating function against these events. Natural systems such as forests, mangrove belts, coral reefs, wetlands, and dune formations act as ecological buffers that reduce the impacts of coastal storms, hurricane surges, floods, landslides, wildfires, and avalanches by stabilizing soils, dissipating wave energy, and regulating water flow. The relevance of these regulating services becomes particularly pronounced in tourism-dependent coastal and island destinations, where large numbers of visitors are concentrated in hazard-prone zones. Coastal tourism infrastructure—hotels, marinas, promenades, and recreational beaches—is often located near shorelines that are directly exposed to storm surges, erosion, and sea-level rise. In such areas, the degradation of natural protective barriers (e.g., mangroves converted to beach resorts, coral reefs damaged by recreational diving) can dramatically increase vulnerability to extreme events. Therefore, maintaining and restoring these ecosystems is not only an environmental necessity but also a key component of risk reduction and destination resilience. However, the protective role of ecosystems varies depending on ecological conditions, location, and hazard intensity, and empirical evidence remains debated in some contexts. Additionally, many natural hazards are being intensified by tourism-related land-use change, such as deforestation for resort construction, wetland drainage for urban expansion, and increased impermeable surfaces that heighten flood risks.

2.2.4. Waste-Water Treatment

Ecosystems such as wetlands filter effluents. Through the biological activity of microorganisms in the soil, most waste is broken down. Thereby, pathogens (disease-causing microbes) are eliminated, and the level of nutrients and pollution is reduced.

According to Dzhambov & Dimitrova (2014), noise is one of the four major pollutants in the world. They suggest that urban green spaces can be used to mitigate pollution.

2.2.5. Erosion Prevention and Maintenance of Soil Fertility

Vegetation cover plays a crucial role in preventing soil erosion, as evidenced by historical events like the American Dust Bowl in the 1930s, where the combination of drought and insufficient vegetation led to severe wind erosion, damaging farmland and livelihoods (TEEB, 2010). The frequency of landslides appears to be on the rise, with land-use changes, especially deforestation, identified as contributing factors. In hilly areas, forests help prevent landslides by regulating soil moisture levels (Sidle, Ziegler, Negishi, & Turkelboom, 2006).

2.3. Habitat or Supporting Services

2.3.1. Habitats for Species

The life cycle of a species is supported by the products and behavior of other species, as well as the abiotic environment. Ecosystem products (such as nutrients and seeds) can be carried by wind, water, or animals (including humans) to support the life cycles of species in other areas. These interactions between ecosystems should be considered when assessing the ecological and economic importance of a region.

Migratory species use ecosystems for part of their life cycle. For example, salmon need clean, aerated, shallow water for courtship and egg-laying, and depend on these ecosystems for clean water and food for juvenile fish (e.g., Kunz 2004). Adult salmon also support other predatory species, and upon death, contribute organic matter to the river ecosystem. Migrating birds, such as geese, rely on ecosystems for grazing on their migration "flyways" and can shape vegetation composition through selective feeding, affecting competitive interactions and potentially increasing spatial heterogeneity (van den Wyngaert and Bobbink 2009; TEEB, 2010). Some migratory species have commercial value, and ecosystems providing reproductive habitats offer important "nursery services," such as mangroves, which support fish and crustaceans that are harvested far from their spawning areas. This nursery service should be considered when economically valuing mangrove ecosystems.

2.3.2. Maintenance of Genetic Diversity

Tourists pay to visit areas with rich biodiversity, such as tropical forests, coral reefs, or national parks, which provide income to local economies and help finance conservation efforts. According to the TEEB approach, ecosystem services like genetic diversity enhance the economic value of tourism because diverse species and habitats increase tourist appeal—for example, destinations where rare animal or plant species can be observed become more popular. However, overtourism threatens genetic diversity: high visitor flows can lead to habitat degradation, stress on species, or the spread of invasive species, causing genetic erosion. For instance, coastal tourism can reduce genetic diversity in coral reefs, which in turn diminishes ecosystem services and long-term tourism revenues.

2.4. Cultural

Cultural and social services refer to the aesthetic, spiritual, psychological, and other benefits that humans obtain from interactions with ecosystems. These interactions do not necessarily have to be direct; for example, it is possible to experience distant ecosystems virtually through media such as books, art, or television. Moreover, the contact with ecosystems does not have to be exotic or wild; common areas like urban gardens also provide these services (Butler & Oluoch-Kosura, 2006). Although the classification of such services is a broad subject of discussion, as in the Millennium Ecosystem Assessment, these services are often considered in two groups: i) spiritual, religious, aesthetic, and sense of place; ii) recreation, ecotourism, cultural heritage, and education.

It is difficult to assign an economic value to the services in the first group, but the second group is more suitable for traditional valuation methods. While the spiritual and aesthetic benefits of nature are valuable to all societies, this value may take on different dimensions in affluent and democratic societies. Biodiversity reinforces a society's sense of place and carries significant cultural value. Although recent research shows a decline in nature-based recreation in the US and Japan (Pergams & Zaradic, 2008), global interest in protected areas is increasing. Additionally, outdoor activities and wildlife tourism, which are areas that gain economic value depending on the functioning of ecosystems, are increasingly important (Wilson & Tisdell , 2003).

Biodiversity in urban areas plays an important role in enhancing human well-being. Green spaces provide psychological benefits and increase job satisfaction (Lee, Lee, Mjelde, & Kim, 2009). This can positively affect economic productivity. The value of properties located near

green areas has been shown to increase according to studies (Tyrväinen, 1997; Cho, Poudyal, & Roberts, 2008). Moreover, the benefits provided by ecosystems in architecture and urban planning for sustainable design should also be taken into account.

2.4.1. Recreation and Mental and Physical Health:

Engaging in physical activities such as walking or playing sports in green spaces not only promotes fitness but also provides opportunities for relaxation and stress relief. The contribution of green areas to mental and physical well-being is increasingly recognized, even though quantifying these benefits can be challenging (TEEB, 2010). Well-designed green spaces can serve dual purposes: they attract both local residents and tourists, while also helping to manage visitor flows by distributing tourist activity more evenly across the city and throughout peak seasons. By providing accessible recreational areas, urban planning can enhance public health, improve quality of life, and support sustainable tourism management simultaneously.

2.4.2. Tourism

Biodiversity and healthy ecosystems are fundamental drivers of various forms of tourism, including cultural, nature-based, and ecotourism. These forms of tourism contribute significantly to local and national economies, providing critical sources of income for many regions. For example, in 2008, global tourism revenues reached approximately USD 944 billion (see Chapter 5). Tourism also serves as an educational platform, increasing public awareness of the importance of biological diversity and ecosystem conservation. However, it is essential to acknowledge that tourism itself exerts pressures on natural areas. Excessive visitor numbers, especially in ecologically sensitive regions, can lead to habitat degradation, species disturbance, and resource depletion, creating significant conservation challenges. When tourism is carefully planned and managed to maintain a sustainable balance between use and preservation, it can continue to generate economic returns while enhancing the appeal of natural destinations. This approach creates a positive feedback loop, where well-managed tourism both supports conservation efforts and maintains ecosystem attractiveness for future visitors.

2.4.3. Aesthetic Appreciation and Inspiration for Culture, Art, and Design

Throughout human history, language, knowledge, and the natural environment have been closely interconnected. Biodiversity, ecosystems, and natural landscapes have served as key sources of inspiration for art, culture, and increasingly for scientific inquiry. These cultural and aesthetic services provided by ecosystems not only enrich human creativity but also contribute to tourism development. For instance, the marketing of handmade crafts, ornamental plants, and other cultural products—categorized under ecosystem services—can enhance the appeal of secondary tourism experiences such as local shops, galleries, and boutique markets (Acri, 2022). By integrating cultural and natural assets, destinations can attract visitors seeking authentic experiences, while simultaneously fostering the preservation of ecosystems that inspire art and design.

2.4.4. Spiritual Experience and Sense of Place

In numerous regions around the world, specific natural features, such as forests, caves, or mountains, hold spiritual or religious significance. These natural elements are deeply

embedded in major religions and traditional knowledge systems, with associated customs fostering a strong sense of belonging among local communities. Certain tourist destinations, including religious temples or sacred sites, possess such spiritual value. Tourism can support the preservation of these spiritually significant areas by encouraging respectful visitation. Moreover, engaging with these places allows visitors to strengthen their personal connection to nature, potentially heightening environmental awareness. Over time, these spiritually informed experiences can promote long-term conservation of ecosystems, as tourists develop greater sensitivity toward the natural environment (adapted from Butler & Oluoch-Kosura, 2006; TEEB, 2010).

2.5. Which nature-based solutions (NBS) can provide these services?

Nature-based solutions (NbS) in coastal areas play a crucial role in enhancing biodiversity, restoring natural landscapes, mitigating the impacts of climate change and sea-level rise, and minimizing the negative consequences of tourism (Klerck & Baets, 2020). The "building with nature" approach offers multiple benefits: (i) it facilitates transboundary connectivity among coastal ecosystems, expanding ecological stepping stones and existing habitats; (ii) it strengthens soil conditions through organic growth within urban areas; (iii) it contributes to raising groundwater levels; (iv) it provides a natural cooling effect that reduces urban temperatures; and (v) it establishes a resilient defensive barrier against climate-induced events such as floods, storm surges, and sea-level rise (Klerck & Baets, 2020). The use of native coastal species, the development of new green spaces, and the implementation of NbS-based coastal protection measures not only enhance biodiversity but also allow these anthropogenic interventions to generate economic benefits through tourism (Klerck & Baets, 2020). The planning and design of NbS should account for the specific natural features of each coastal city, including beaches, dunes, grass beds, sand barriers, protective embankments, and water bodies. Coastal sand is continuously transported by waves, tidal currents, and wind, resulting in erosion in some areas and accumulation in others. While sand accumulation traditionally reduces flood risk, it can pose challenges in more urbanized sections of the coastline (Klerck & Baets, 2020). Additional advantages of NbS include lower long-term costs, increased dune areas, enhanced recreational opportunities, and the capacity to respond to growing eco-tourism demands. For instance, a portion of an existing seawall may be converted into a grassy area to provide new tourist attractions, and the beach slope may be extended. Furthermore, sustainable and manageable vegetation, such as marram grass and other endemic species, can be introduced near current sea levels, providing a dynamic natural solution that adapts to future protection needs associated with rising sea levels. These practices promote biodiversity while enabling a broader range of recreational activities within the urban environment (Klerck & Baets, 2020). Green roofs represent another example of NbS; they can mitigate the urban heat island effect, regulate stormwater runoff, and enhance the climate resilience of buildings (Chrysoulakis, Somarakis, Stagakis, Mitraka, & Wong, 2021). In addition to improving stormwater management and air quality, green roofs create green spaces in urban areas, provide insulation, and reduce energy consumption (Hansen & Pauleit, 2014; Nazir N. Z. et al., 2025). In this way, the multifunctionality of NbS encourages efficient resource use and spatial optimization, offering both ecological and economic benefits.

We divided the UNaLAB report into six categories to examine how nature-based solutions (NbS) are addressed:

2.5.1. Constructed Wetlands & Built Structures for Water Management (Biofilter / Bioswale, Constructed Wetlands, Rain Gardens) (UNaLAB, 2022)

In urban areas, various structures that mimic natural processes have been developed to reduce flood risks, remove pollutants, and effectively manage water. These structures not only store and treat water but also provide environmental services. A bioswale is a linear, low-sloped trench covered with vegetation, typically located along roads or near impervious surfaces. This system absorbs, stores, and directs surface runoff, while pollutants and sediments are filtered out as water percolates through the plant and soil layers. Deep-rooted native plants are commonly preferred, as they enhance water management and support local biodiversity.

Air biofilters are used, especially in agriculture, sewage treatment plants, biogas, and composting facilities, to control biological waste gases. In these systems, bacteria and microorganisms residing on the filter medium break down odors and contaminants in the air. Similar principles are applied to treat stormwater and wastewater; the biofilm on filter media—often composed of sand or granular activated carbon—degrades nutrients and contaminants as water passes through (UNaLAB, 2022). Constructed wetlands are artificial wetlands designed to collect, treat, and store stormwater in urban areas. These systems adapt the processes of natural wetlands, with established vegetation, soil structure, and microbiological activity playing key roles in water purification and storage. They help maintain ecological balance in cities while creating habitats for local wildlife. Rain gardens are small-scale landscaped areas established in urban environments to capture runoff from roofs, roads, and other sealed surfaces. Stormwater is temporarily stored in rain gardens, where it either infiltrates into the ground or is directed into the sewage system (UNaLAB, 2022). This method helps prevent excessive water buildup and supports the natural water cycle. Together, these structures integrate natural processes into urban water management, reducing flood risks, purifying water, and supporting vital ecosystem services.

2.5.2. Green / Tree Network Structures (Green Corridors / Boulevards / Group of Trees / Single Tree Lines)

In urban areas, converting derelict infrastructures—such as abandoned railway lines—into linear parks forms an essential part of the city's green infrastructure network and helps re-naturalize urban spaces. Additionally, restoration along waterways and riverbanks often results in interconnected linear parks.

Boulevards offer an opportunity to increase urban tree cover and mitigate urban heat stress. Typically, trees are planted along streets, bicycle paths, and sidewalks; the canopies of trees on opposite sides often form an almost continuous cover, which protects, shades, and lowers the temperature of the street in between.

Clusters of trees that mimic a forest setting can be used in urban design to create shaded squares, public gathering spaces, or as contrasting elements in densely built areas and courtyard designs.

Single tree lines are arranged along one side of streets, bicycle paths, and sidewalks, significantly affecting the local microclimate. These trees absorb particulate matter, provide shade, and cool the air. Their overall impact depends on factors such as tree size, canopy coverage, planting density, species, tree health, location, availability of root water, and leaf area index (UNaLAB, 2022).

2.5.3. Natural/Semi-Natural Green/Blue Spaces (Daylighting; Ponds; Canals; Park & Gardens; Waterfront Park)

Natural and semi-natural green/blue spaces are important areas used in urban environments to enhance environmental resilience, improve water management, and promote social interaction. These types of spaces offer functions such as restoring the natural flow of water, increasing public engagement with nature, and supporting ecosystem services.

Daylighting refers to the process of uncovering buried watercourses, rivers, or drainage systems by removing the soil layers above them (UNaLAB, 2022). This practice creates space for rivers to expand, which can help reduce flood risks. Additionally, daylighting has positive environmental and aesthetic effects, contributing to healthier and more livable urban spaces.

Urban Gardening is a widely used method to provide garden spaces for citizens. These gardens are often semi-private, offering the possibility of renting individual plots or being managed by an association. Designed in raised beds, urban gardens can be established in courtyards or public spaces and are portable if needed. They provide sources of locally grown food, promote social interaction, and support community food security.

Residential Parks are part of a city's green infrastructure (GI) and serve as the closest entry points for nature-based recreation in residential areas. Larger GI elements, such as district parks, often combine various functions, such as sports fields, while smaller green spaces typically include playgrounds or connected green strips.

Waterfront Parks are areas designed to intentionally flood with water to reduce the impact of floods downstream. These parks help lower the peak of floodwaters by capturing and storing the water. This process minimizes the damage caused by floods along the downstream shoreline while preventing damage to the waterfront park itself.

2.5.4. Green Roofs/Walls

Green facades are divided into two types: facade-bound greening, which is part of the facade or uses the facade to fix panels and containers, and ground-based facade greening using climbing plants.

Noise barriers, also known as free-standing living walls, are constructions made of baskets or various elements covered/filled with soil substrate, designed to reduce noise emissions, such as along highly trafficked roads (UNaLAB, 2022).

Verticalization of green spaces can increase vegetated surfaces with many ecological services in urban environments. Free-standing living walls serve as adaptation measures for the urban heat island effect. They create spaces with high amenity value and potentially high biodiversity, while also reducing noise emissions (UNaLAB, 2022). They are suitable for reusing runoff water and evapotranspirating highly. With extensive vegetation, they can also endure long periods of drought.

Mobile Vertical Greenings consist of living wall modules that are fixed to a hook lift container platform. The vegetation cover is highly diverse, showcasing the high potential of living walls to increase amenity value and stimulate biodiversity. It can be used as a mobile demonstration for green infrastructure, a test feature, a temporary green installation, or as an open green office for information

Extensive Green Roofs consist of a thin layer of substrate and plants. These basic, lightweight systems are characterized by minimum maintenance and management after the system is established. Suitable plants for extensive green roofs include low-growing, rapidly spreading species such as succulents like sedums, herbs, wildflowers, grasses, or mosses. They can survive with minimal nutrient uptake and without additional nutrient supply.

Intensive Green Roofs are covered by a thick layer of substrate that allows the growth of larger plants, even regular trees. These roofs are often accessible to the public or for recreation. To enable human activities and the integration of larger plants, trees, and architectural elements, suitable rooftops need to be relatively flat.

2.5.5. Restoring / Protected Beach And Dunes (Restoring Mangroves, Beaches and Dunes Restoring Offshore Habitat, Limitation of Trampling Through Beach Access, Walkways, Planting Vegetation for Dune Stabilization)

Mangroves, beaches, and dunes are natural buffer systems that reduce the negative effects of storms, high water, and other environmental factors (UNaLAB, 2022). Restoring or preserving mangroves, beaches, or dunes not only provides the opportunity to create new habitats for species living in these environments but also helps restore the resilience of the ecological system to face flooding and erosion. In this way, beaches can be seen as natural waterfront parks, dunes as natural levees, and mangroves as natural breakwaters.

Most seagrass species form large “beds” of root and rhizome systems that provide habitat for thousands of marine species and help fix soil, reducing erosion (UNaLAB, 2022). Seagrass also slows down water currents and reduces wave energy, which in turn diminishes the impact of waves on the shoreline. Reefs serve as natural breakwaters that reduce coastal erosion by lowering wave energy.

A measure aimed at maintaining dune systems involves limiting access to the beach using artificial elements placed on the dunes (such as walkways). This measure protects the dunes, preventing potential sediment deficits due to improper use of the dune system, while simultaneously promoting the preservation of the ecosystems that support them.

A measure that involves the reinforcement, preservation, and/or stabilization of dune systems using natural strategies, particularly by planting vegetation along the dunes. Wind speed and direction are crucial factors in aeolian sediment transport. Vegetation facilitates the accumulation of sediments, acting as an obstacle to their movement.

2.5.6. Renewal And Strengthening of Coastal Structures (Feeding From Littoral Drift, Beach Nourishment, Reinforcement Of Dune Cord)

Various methods can be applied to protect and strengthen coastal areas. These methods are strategies aimed at compensating for sediment loss and enhancing the resilience of ecosystems.

- ***Feeding of Longshore Drift:***

To strengthen longshore drift, sediments from different sources are added to the coastal current. Sediments from offshore are collected from the seabed and transported to the shore using specialized dredging vessels. These sediments enhance the cross-sectional profile of the beach and, over time, contribute to the natural nourishment of the coastal stretch. Sediments

from onshore are transported to the beach using excavators and trucks, which strengthens the beach's cross-section. Sediments from estuaries and rivers, collected through dredging, are added to the drift using small dredges. These methods help preserve and stabilize the coastal stretch.

- ***Beach Nourishment:***

To address the sediment deficit, beach nourishment through offshore sediments involves transporting sediments from offshore areas to the beach using dredging vessels. This process strengthens the beach, protecting both structures and the dune system, and expands recreational areas. Beach nourishment with sediments from onshore deposits involves placing sediments directly on the beach from land-based sources, expanding the beach area, and protecting the dune system. Beach nourishment using sediments from dredging in estuaries and rivers involves collecting sediments through dredging and adding them to the beach. These methods enhance the beach's structure, protect coastal assets, and support longshore drift.

- ***Reinforcement of Dune Systems:***

To reinforce coastal dunes, using offshore sediments involves collecting sediments from the continental shelf and transporting them via dredging vessels and pipelines to the dunes. Reinforcement with sediments from onshore deposits is carried out by adding sediments from land-based sources to the dunes using excavators and trucks. This method strengthens dunes and makes them more resistant to storms. Dune reinforcement using dredged sediments from estuaries and rivers involves dredging near the shore and placing the sediments on the dunes with mechanical equipment. These operations help stabilize the dune systems and increase their resistance to extreme weather events.

2.6. Develop and test a workshop elicitation process

The process includes the steps of testing the theoretical framework, obtaining expert opinions, and examining the resulting outputs at the local level. Identifying the challenges caused by tourism based on perception, and understanding how nature-based solutions (NBS) are selected as responses through ecosystem services, are crucial for evaluating whether these preferences have local relevance. Understanding the practical challenges of many options that are theoretically feasible constitutes one of the key outcomes of this study.

Following the necessary approvals, the final stage will involve a focus group composed of researchers and academics familiar with the Seferihisar region from Aveiro University and nearby universities. This group will discuss and refine the theoretical framework, after which the results will be evaluated with local stakeholders residing in Seferihisar.

Conclusion and Recommendations

When implemented in cities that prioritize tourism as a primary source of economic revenue, nature-based solutions promote tourism by enhancing environmental quality and visual aesthetics. This contributes positively to urban economic development. However, implementing these solutions often involves governance complexity. For example, it is sometimes unclear whether a particular initiative falls under the jurisdiction of the municipality, water management institutions, or environmental agencies. This uncertainty can lead to overlapping jurisdictions and coordination problems among institutional actors, which

can hinder the process or even lead to negative outcomes. Therefore, when evaluating nature-based solutions, it is necessary to consider not only the environmental impacts but also the social aspect, taking into account the role of governance structures and political dynamics. Nature-based solutions should be developed within multi-stakeholder frameworks. For example, a municipality may initiate a green roof program, but if implementation depends on individual property owners, the governance structure becomes more fragmented and community-focused. In this case, implementing the solutions by a single institution would be inappropriate. Reshaping local power relations and focusing on the transformative capacity of nature-based solutions to foster participatory, bottom-up decision-making are as important as developing solutions. Nature-based solutions can reduce environmental pressures while also making places more attractive, potentially increasing tourist traffic. Therefore, whether the overall impact is positive depends on how the solutions are planned and managed. Nature-based solutions can also be used as a tool to manage increasing tourist pressure, while the economic capacity of the tourism sector may be amenable to co-financing the implementation of nature-based solutions. However, the limited attention paid to tourism in European Commission policy documents highlights a significant gap in this area. The impacts of nature-based solutions are location-dependent. For example, green roofs or vegetated facades may not always be visually perceived by tourists, and their impact may be limited in areas where air quality is already high. Therefore, it is important for decision-making processes to include the perspectives of local communities directly affected by tourism pressure. Time, cost, and performance concerns often lead to the preference for short-term solutions, which can overshadow long-term social and ecological benefits. While it's certainly unrealistic for cities whose economies rely heavily on tourism to completely eliminate tourism pressures, the idea that nature-based solutions can help mitigate these pressures in a balanced way is realistic. While tourism is a driver of environmental degradation, it's also a highly vulnerable sector. Polluted coastlines or overheated urban environments can rapidly reduce the attractiveness of destinations. Therefore, enhancing the resilience of natural systems despite tourism pressures is crucial for the long-term sustainability of the tourism sector. Future research should clarify which ecosystem services are effective in mitigating specific tourism-related pressures and determine which types of nature-based solutions are appropriate in different contexts. To achieve this, it's necessary to identify local barriers and opportunities and adopt a coordinated governance approach. There is no single, universal solution; perceptions of problem severity and decisions about the most effective interventions are shaped by local experiences and priorities.

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At the next stage of this study, a workshop will be organized with the participation of researchers from relevant departments of academic institutions such as Seferihisar Municipality, Dokuz Eylül University, İzmir Institute of Technology, and University of

Aveiro. This study is a reflection of the author's master's thesis. Theoretical framework, and subsequently, practical implementations will be evaluated through interviews conducted in the Seferihisar region. The outcomes of this process will be reported within the scope of the master's thesis. The study was approved by the ethics committee.

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Spatio-Temporal Assessment and Simulation of Carbon Dynamics Under Anthropogenic Pressure in Kainji Lake National Park, Nigeria

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Abstract

This study assessed the effect of anthropogenic activities on carbon sequestration dynamics in the Borgu and Zugurma sectors of Kainji Lake National Park, North Central Nigeria. Geospatial and field-based approaches were employed to evaluate changes in land use/land cover (LULC), biomass, and carbon storage between 1990 and 2024, and to project carbon trends to 2040. Landsat and Sentinel satellite imagery were analyzed using supervised classification and Normalized Difference Vegetation Index (NDVI) to quantify vegetation dynamics, while allometric models were applied to estimate above-ground biomass and carbon stocks across dominant land use types. Results revealed substantial declines in forest and woodland cover, especially in the Zugurma sector, primarily due to logging, overgrazing, and agricultural encroachment. Between 1990 and 2024, total carbon stock declined by approximately 30%, with higher losses recorded in disturbed landscapes. Simulations for 2040 suggest further carbon depletion if anthropogenic pressures persist unchecked. Conversely, the Borgu sector, with more effective protection and park management, exhibited relatively stable vegetation and greater carbon sequestration potential. The study demonstrates the applicability of remote sensing for long-term ecosystem monitoring and provides empirical evidence supporting REDD+ and climate resilience initiatives.

Keyword: Carbon sequestration, Anthropogenic activities, Remote sensing, Kainji Lake National Park, Land use/land cover, Climate change.

Introduction

Forests and protected areas play a vital role in global carbon cycling by absorbing and storing atmospheric carbon dioxide. In Nigeria, national parks such as Kainji Lake National Park (KLNP) serve as critical carbon sinks that support biodiversity and mitigate climate change impacts. However, increasing anthropogenic pressures including illegal logging, poaching, bush burning, and agricultural expansion have significantly altered the ecological integrity and carbon sequestration capacity of these ecosystems.

The Borgu and Zugurma sectors of KLNP represent contrasting conservation settings: Borgu receives stronger surveillance and management attention, whereas Zugurma faces higher human encroachment. Despite their importance, few studies have empirically quantified how human activities affect carbon storage in these areas. This study integrates geospatial analysis, biomass

estimation, and predictive modeling to evaluate the temporal and spatial variations of carbon stocks under anthropogenic influence and to forecast carbon dynamics up to 2040.

Materials and Methods

Study Area

Kainji Lake National Park lies between latitudes 9°40′N–10°30′N and longitudes 4°30′E–5°50′E, covering about 5,340.82 km² across Niger and Kwara States. It comprises Borgu and Zugurma sectors characterized by Guinea Savanna vegetation, ferruginous tropical soils, and distinct wet (April–October) and dry (November–March) seasons.

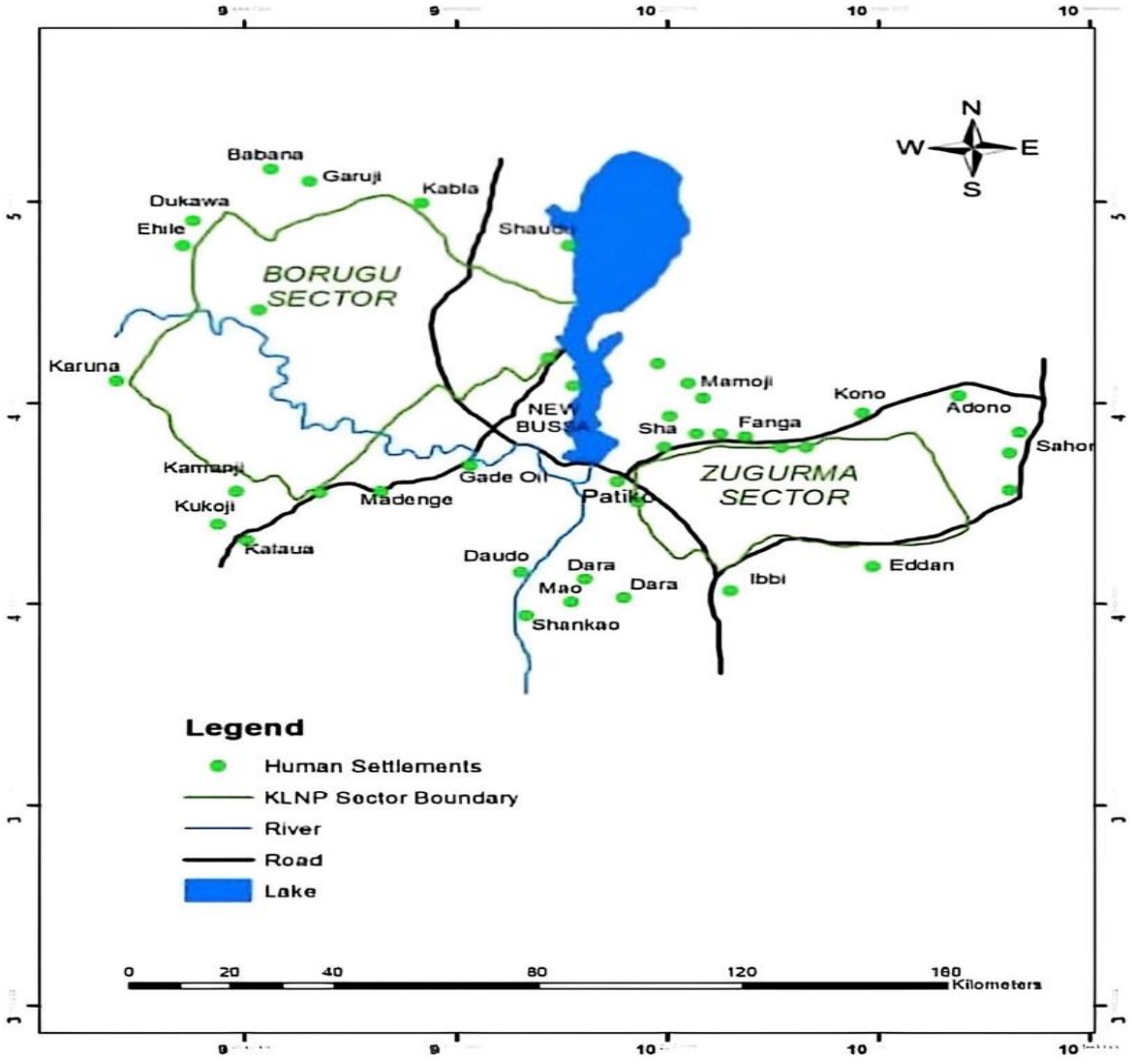


Figure 1. The Study Area (Source: Geography Department (GIS Lab) FUT Minna)

Data Sources

Landsat TM (1990), Landsat 8 OLI (2014), and Sentinel-2 MSI (2024) satellite imagery were acquired from USGS Earth Explorer. Ancillary datasets included Digital Elevation Models and field-based soil and vegetation data collected in 2024.

Table 1. Datasets Used listing imagery types, resolution, source, and acquisition years.

Dataset	Source	Resolution	Year(s)	Purpose
Landsat TM	USGS Earth Explorer	30m	1990	LULC baseline
Landsat 8 OLI	USGS Earth Explorer	30m	2014	Change detection
Sentinel-2 MSI	Copernicus Hub	10m	2024	Current status
Field Survey	Author	–	2024	Biomass and soil sampling

Data Processing and Analysis

Pre-processing involved geometric and atmospheric corrections. Supervised classification using the Maximum Likelihood algorithm in ArcGIS and ENVI software categorized land use/land cover into forest, woodland, grassland, cropland, and built-up areas. NDVI was computed to analyze vegetation health and density. Biomass and carbon stock were estimated using allometric equations adapted from IPCC (2006) guidelines. Future land cover and carbon stock projections for 2040 were modeled using the Land Change Modeler (LCM) in TerrSet software.

Results and Discussion

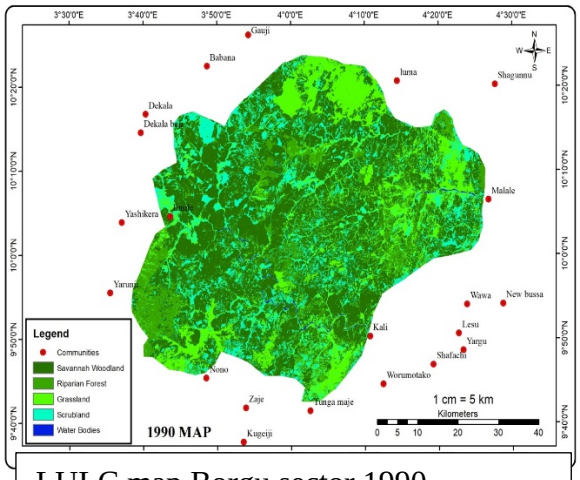
Land Use/Land Cover Changes

From 1990 to 2024, forest and woodland areas in Borgu declined by 12%, while Zugurma experienced a 26% reduction. Cropland and built-up areas expanded markedly, indicating intensified anthropogenic pressure.

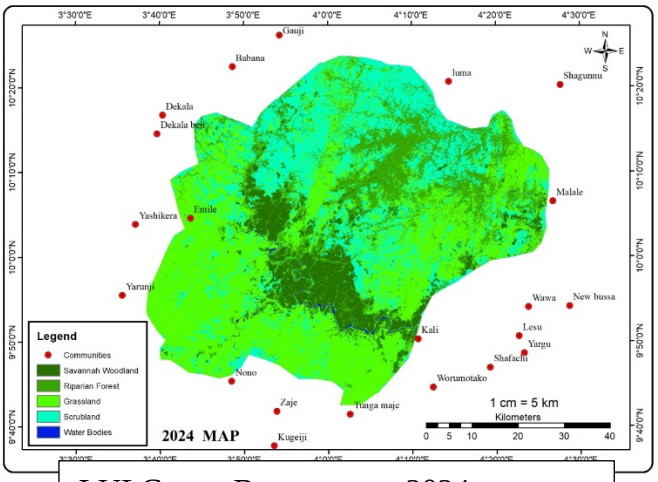
Table 2. LULC Distribution (Borgu and Zugurma, 1990–2024)

Land Use Type	Borgu 1990 (km^2)	Borgu 2024 (km^2)	Change (%)	Zugurma 1990 (km^2)	Zugurma 2024 (km^2)	Change (%)
Forest	1280	1125	-12.1	940	690	-26.6
Woodland	1560	1400	-10.3	1050	870	-17.1

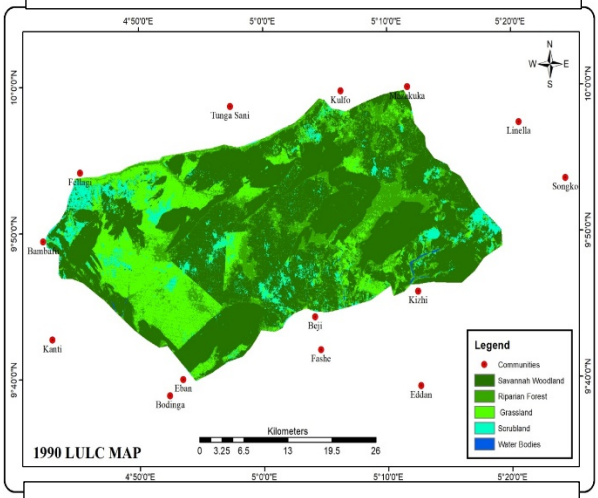
Land Use Type	Borgu 1990 (km²)	Borgu 2024 (km²)	Change (%)	Zugurma 1990 (km²)	Zugurma 2024 (km²)	Change (%)
Cropland	540	620	+14.8	380	470	+23.7
Grassland	710	780	+9.9	610	690	+13.1
Built-up	80	90	+12.5	60	70	+16.7



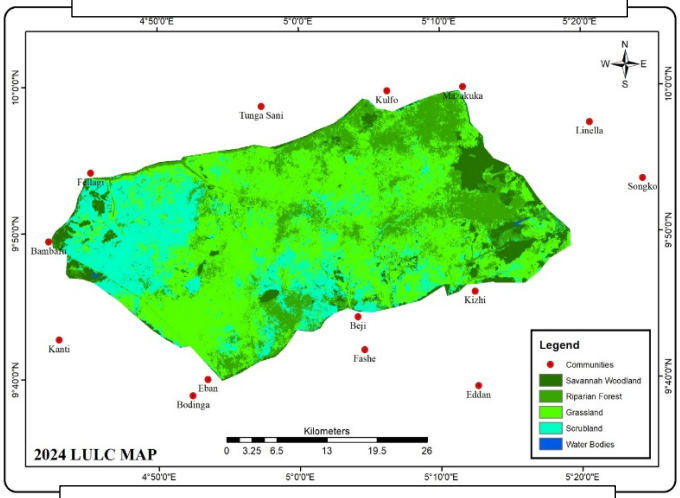
LULC map Borgu sector 1990



LULC map Borgu sector 2024



LULC map Zugurma sector 1990



LULC map Zugurma sector 2024

Figure 2. Land Use/Land Cover (LULC) maps of Borgu and Zugurma sectors of Kainji Lake National Park for 1990 and 2024, showing progressive loss of forest and woodland areas and expansion of cropland and built-up land.

Vegetation Health and NDVI Analysis

NDVI results showed a steady decline in vegetation vigor across both sectors. The mean NDVI value dropped from 0.62 in 1990 to 0.45 in 2024 in Zugurma, while Borgu retained a higher average of 0.56.

Table 3. NDVI statistics by sector

Sector	Mean NDVI (1990)	Mean NDVI (2014)	Mean NDVI (2024)
Borgu	0.61	0.57	0.56
Zugurma	0.62	0.49	0.45

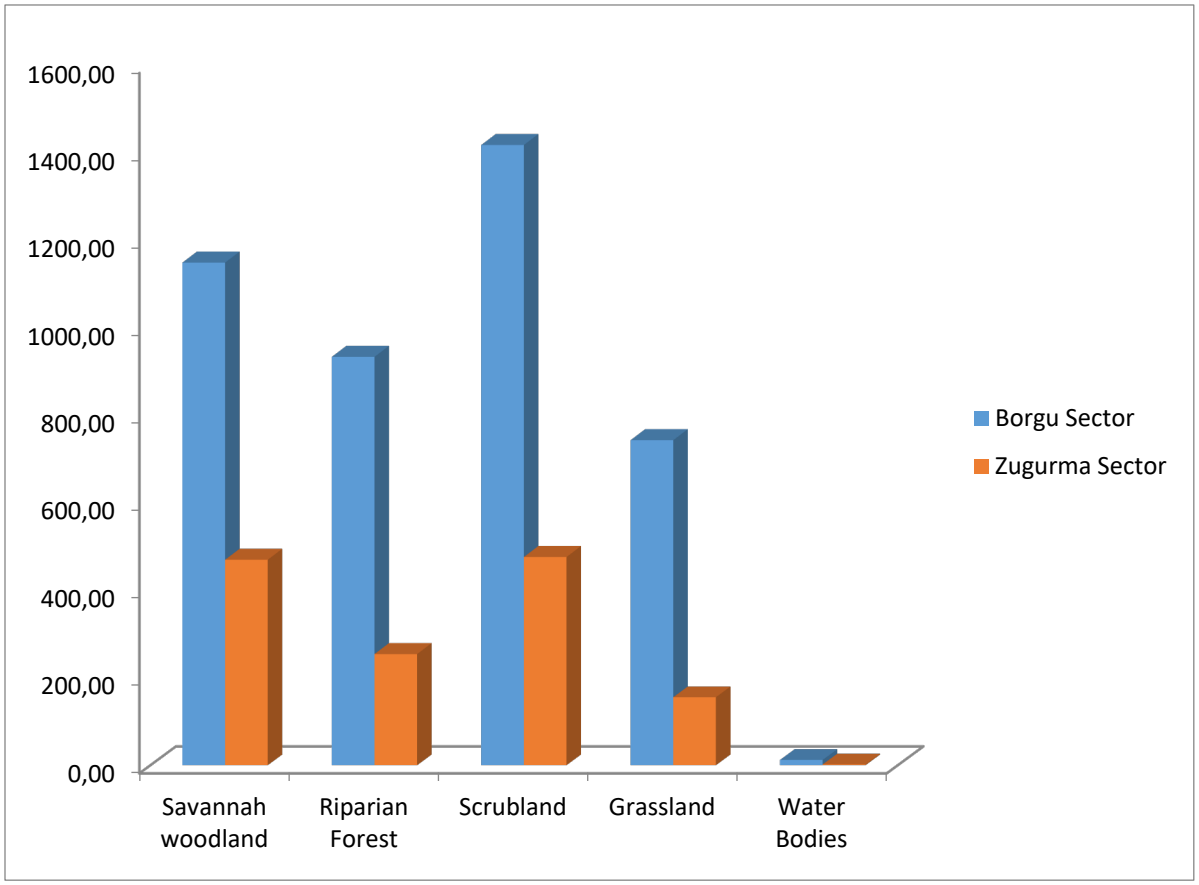


Figure 3. comparative trend charts between Borgu and Zugunma Sector

Biomass and Carbon Stock Dynamics

Estimated total biomass declined from 243.8 t/ha in 1990 to 178.4 t/ha in 2024, translating into a 30% reduction in carbon stock density. Woodland ecosystems exhibited the highest carbon storage potential, whereas grassland and cropland stored the least.

Table 4. Temporal change in above-ground biomass and carbon stock

Sector	1990	2014	2024	% Change
Borgu	243.8	216.5	205.4	−15.7
Zugurma	221.4	186.3	178.4	−19.4

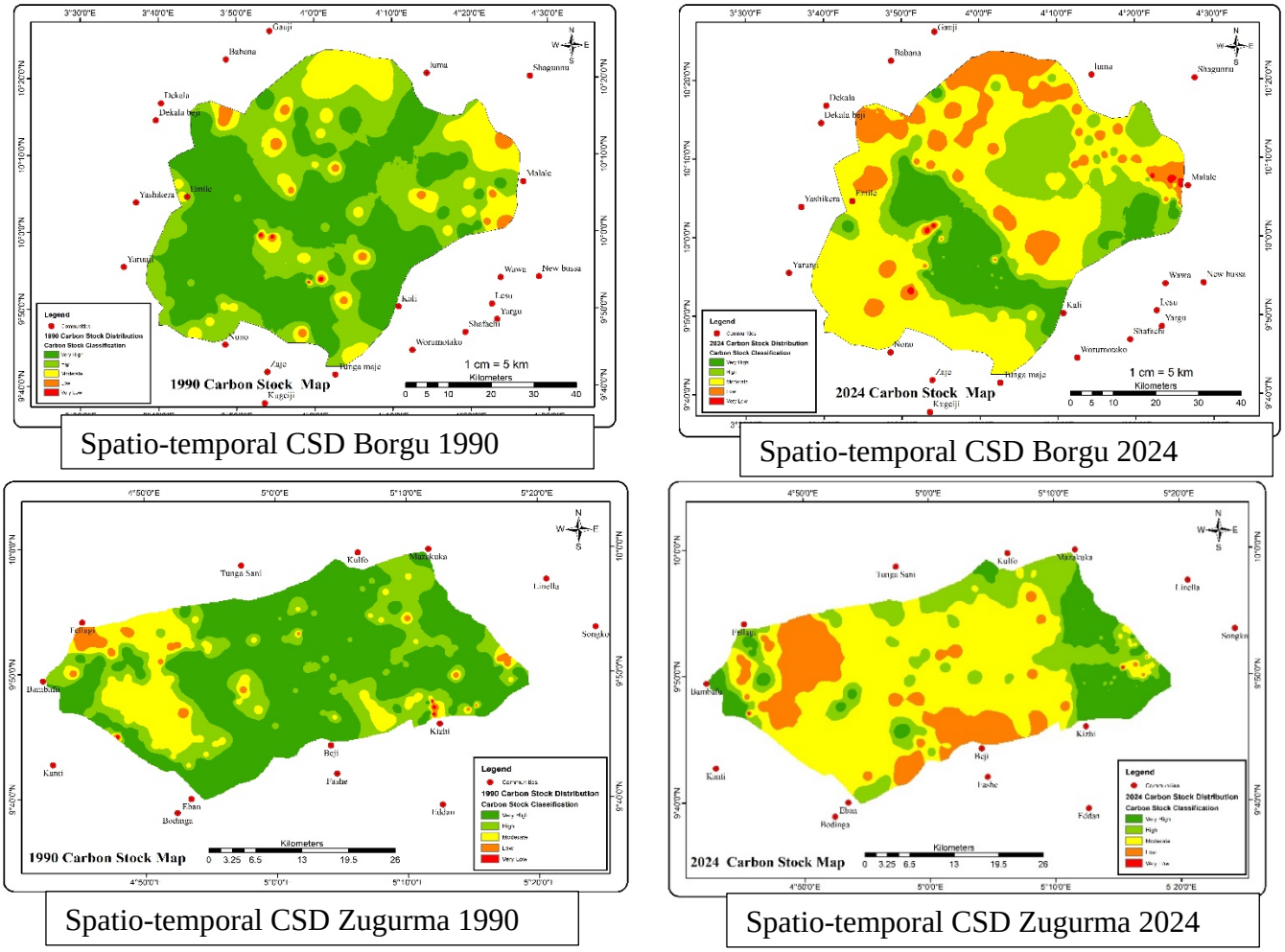
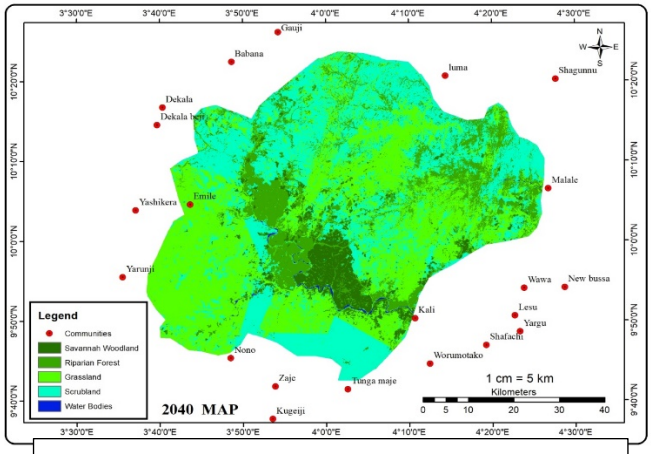


Figure 4. Spatial-temporal Carbon Stock Map for both Borgu and Zugurma sectors (1990–2024)

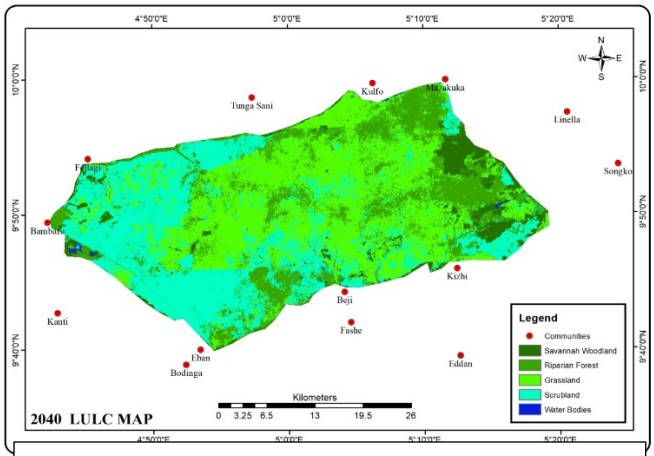
Future Projection

(2040)

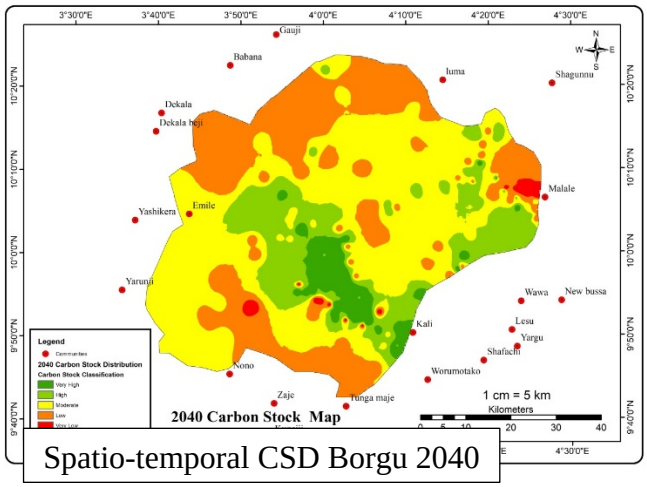
Simulation results predicted further deforestation and reduction in carbon stock by approximately 18% if current land use patterns persist. The Borgu sector demonstrated greater resilience, while the Zugurma sector is projected to lose substantial biomass by 2040 without conservation intervention.



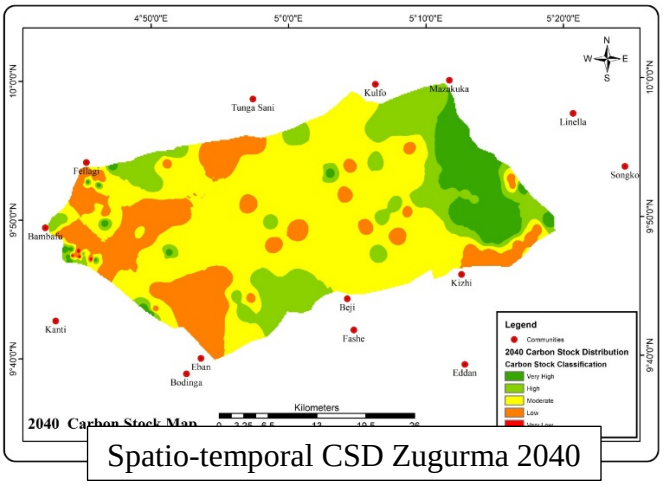
: Simulated 2040 Borgu Sector LULC Map



: Simulated 2040 Zugurma Sector LULC Map



Spatio-temporal CSD Borgu 2040



Spatio-temporal CSD Zugurma 2040

Figure 5: Stimulated LULC and carbon stock distribution map for both Borgu and Zugurma sectors 2040.

Conclusion and Recommendations

This study highlights the detrimental effects of anthropogenic activities on carbon sequestration in Kainji Lake National Park. Remote sensing analysis revealed progressive vegetation loss and carbon decline over three decades, particularly in Zugurma. Strengthening park surveillance, enforcing anti-encroachment regulations, and integrating community-based conservation strategies are recommended. Implementing REDD+ mechanisms and sustainable land management practices can enhance carbon recovery and contribute to Nigeria's climate-mitigation goals.

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Spatio-Temporal Changes in the Land Use and Vegetation Health of Two Protected Areas in North-Central Nigeria

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Abstract

Remote sensing (RS) has been widely employed for conservation and monitoring of protected areas. This study evaluated the land use and land cover (LULC), and vegetation changes of two protected areas in North-Central Nigeria: Jos wildlife Park (JWLP) and Pandam Wildlife Park (PWLP) from 1990 to 2024. This study utilized different Landsat satellite data to classify and assess the changes within the study period. LULC categories used vary with respect to the peculiarity of the identified land cover in each forest including forested area, riparian forest, built up and open land. The image classification involved supervised classification while different vegetation indices were calculated using the respective bands of the satellite data. The results revealed a slight increase in 1998 followed by a consistent decrease in the forested area of the JWLP from 1998-2024 representing a 38.8% (4329900 m^2) of the total area. However, the PWLP experienced a consistent decrease (47.68%) in riparian vegetation followed by a dramatic increase (266.23%) in the forested area from 1991 to 2024 constituting 29.95% of the total area. There were variations in the vegetation indices of the two protected areas. Most importantly, all the vegetations indices of the PWLP increased consistently from 1990 to 2024 which is an indication of the healthiness of the forest. By implication, JWLP appeared to have undergone some degree of encroachments which has led to the reduction in the forested areas. Periodic monitoring coupled with the enforcement of protection of these protected areas should be prioritized to forestall the further loss.

Keywords: Land use, NDVI, protected areas, remote sensing, vegetation

1. Introduction

In Nigeria, remote sensing has been successfully used to assess vegetation changes of protected and unprotected areas across various ecological zones (Adamu, 2019; Akomolafe & Anumeh, 2025; Akomolafe and Rahmad, 2020), thereby providing valuable insights for conservation planning and policymaking. National parks and protected forest reserves make up the bulk of the world's protected areas overall. About 2000 national parks and protected areas are distributed across the Sub-Saharan Africa's four regions (Northern, Central, Western, and Eastern), totalling up to over 3,200,000 km^2 of all of Africa's territory (Osabohien *et al.*, 2019).

Despite the importance of these protected areas as vital ecosystems, especially in Nigeria, they are experiencing rapid and unsustainable changes because of anthropogenic and natural factors.

Over the years, threats such as climate change, deforestation, illegal grazing, and agricultural encroachment have negatively impacted their vegetation health, thereby disrupting the ecosystem balance and impact important biological populations (Akomolafe & Anumeh, 2025).

Previous studies have indicated an alarming decline in forest cover within some of these protected areas in Nigeria. For instance, forest cover change was observed at several gazetted forests of Nasarawa State (Chunwate, 2024); a significant loss of forest cover at Ngel Nyaki forest reserve from 1990 to 2023 (Akomolafe & Anumeh, 2025). This rapid rate of deforestation threatens the habitat of numerous plant and animal species and compromises the forest's ecological functions. Despite the numerous studies done, there is still paucity of current, comprehensive data on the state of some of these forests and ongoing land use changes, which hampers effective forest management and conservation planning.

Most importantly, there has not been an updated record of the assessment of the changes in the land use and vegetation of Jos wildlife park (JWLP) and Pandam wildlife park (PWLP) in north-central Nigeria. Hence this study aimed at bridging this gap through a detailed spatio-temporal evaluation of the changes in land use and vegetation health of these two protected areas in north-central Nigeria in the last 30 years using remote sensing techniques.

2. Materials and Methods Study Area

Jos wildlife park (JWLP) is located in Jos, Plateau State, Nigeria (Figure 1). The park covers an area of 8 hectares and it's a home for variety of plants and wildlife species, including lions, elephants, giraffes and monkeys. The park offers educational programs and conservation efforts to help protect and preserve the wildlife within its boundaries. Pandam forest is located in Plateau State, Nigeria, approximately between latitudes 8°30' and 8°45' N and longitudes 8°30' and 8°45' E (Figure 2). The forest covers an area of approximately 2,240 hectares and is part of the Pandam Wildlife Park (PWLP). The region where the two parks are located is characterized by a tropical savanna climate (Köppen climate classification Aw) with distinct wet and dry seasons. The vegetation is primarily Guinea savanna woodland with a mix of grasslands and forest patches.

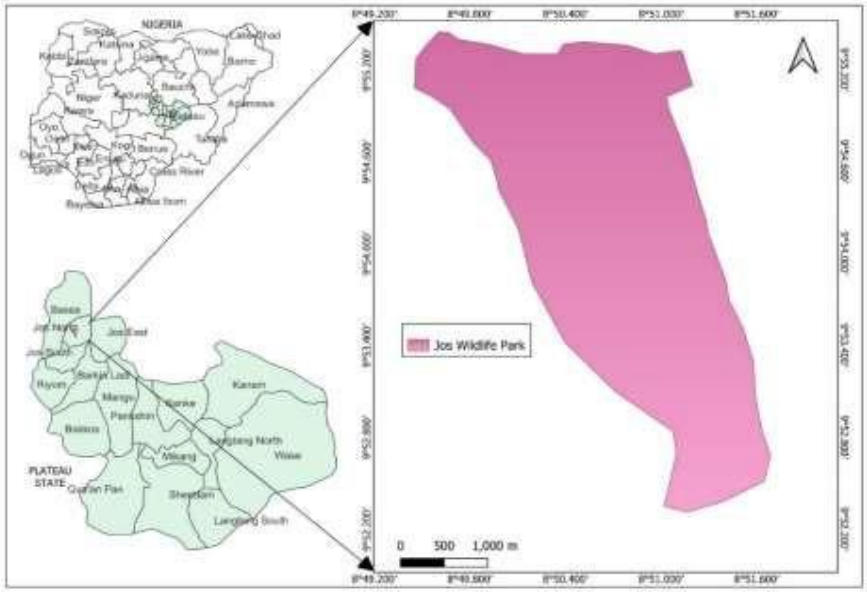


Figure 1. The study area map of Jos wildlife park

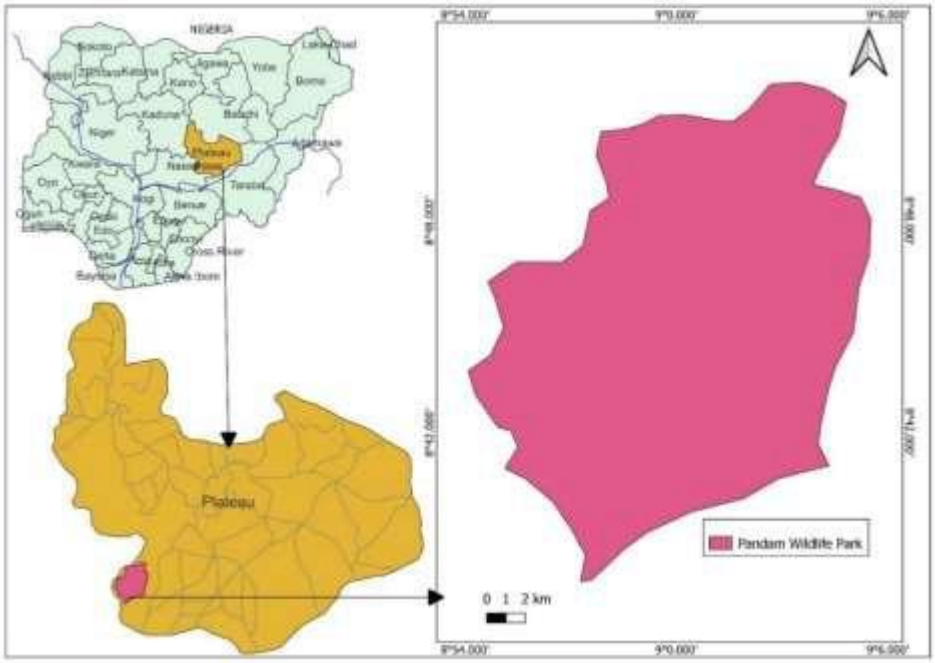


Figure 2. The study area map of Pandam wildlife park

Satellite Data Collection

This study utilized satellite data to analyze land use and vegetational changes in the two parks from 1990 to 2024. Primary data consisted of ground truth information collected through field

visits to the parks. A digital camera was used to capture photographs of different land use and land cover types to aid in image classification and accuracy assessment. The multi-temporal satellite imageries were downloaded from the USGS website (www.earthexplorer.usgs.gov) covering the study periods (Table 1).

Table 1. Characteristics of the Landsat satellite images used.

Satellite	Jos Wildlife Park				Pandam Wildlife Park		
Features	1990	1998	2014	2024	1991	2014	2024
Sensors	Landsat 4 TM+	Landsat 5 TM	Landsat 8 OLI_TIRS	Landsat 8 OLI_TIRS	Landsat 4 TM+	Landsat 8 OLI_TIRS	Landsat 8 OLI_TIRS
Path/row	188/053	188/053	188/053	188/053	188/054	188/054	188/054
Spatial Resolution	30 m	30 m	30 m	30 m	30 m	30 m	30 m
Date of acquisition	22/12/1990	18/11/1998	15/02/2014	27/02/2024	07/01/1991	14/01/2014	27/02/2024
Number of bands	7	7	11	11	7	11	11

Data Processing and Analysis

Georeferencing techniques

Image processing techniques were applied to improve the clarity of the image, making it easier to identify and categorize different land use types (Jande *et al*., 2019; Akomolafe & Rahmad, 2020). The boundary of the JWLP was used to isolate the area of interest within the larger image mosaic using QGIS 3.32.1. The image enhancement was done to ensure easier detection and classification of the land-use types (Jande *et al.*, 2019).

Land Use Classification

Land cover categories at the JWLP include forested area, built up and open land (Table 2). The Forested area class represents areas where the tree canopy density between 40% and above. Open land refers to areas with very low or no vegetation. This category includes rocky outcrops, barren lands, and abandoned agricultural fields. Built-up Areas encompass urban and rural regions, including farmhouses and other structures. Land cover categories at the PWLP include water body, forested area, riparian vegetation, built up and open land (Table 2). The riparian vegetation represents plant communities that grow along the banks of rivers, streams, lakes, or other water bodies. Water body is a region with natural or artificial ponds and lakes. These areas are characterized by the presence of water, either permanently or seasonally.

Table 2. Description of LULC Classes of the study area

LULC class	Description
Forested area	Forest with tree canopy density between 40% and above
Riparian vegetation	Plant communities that grow along the banks of rivers, streams, lakes, or other water bodies.
Open Land	Area with very low or no vegetation, rocky outcrops, barren land, abandoned land
Built Up	Urban Areas, Rural Areas, Farmhouses Water body Natural & Artificial ponds/lakes

The satellite image classification involved both unsupervised random selection of sample training points and supervised classifications of the LULC types as seen in Table 2. The determination of the rate and extent of change in the LULC of JWLP within the studied periods was carried out using the following equations (Akomolafe & Rahmad, 2020):

Changed area (C a) = T a (2^{nd} year) – T a (1^{st} year)..... (i)

Changed extent (C e) = C a / Ta (1^{st} year).....(ii)

Percentage of change = C e x 100… .....(iii)

Where (Ta) = total area

Accuracy Assessment

Accuracy assessment is a critical step in remote sensing analysis to evaluate the reliability and precision of classified land cover maps or vegetation indices. The results obtained from remote sensing data were compared with ground truth information collected from field surveys or higher-resolution imagery. The overall accuracy and Kappa coefficient metrics were used to describe the accuracy of the LULC classification. The kappa coefficient is a statistical measure of agreement between classified and reference data, correcting for the agreement that would be expected by chance alone. It considers both omission and commission error and provides a measure of classification accuracy that accounts for class imbalance.

Kappa Coefficient = (Overall Accuracy - Expected Accuracy) / (1 - Expected Accuracy).

Vegetation Change Analysis

The vegetation change analysis involved time-series analysis of vegetation indices, such as the Normalized Difference Vegetation Index (NDVI), Normalized Difference Water Index (NDWI), Enhanced Vegetation Index (EVI), Soil-Adjusted Vegetation Index (SLAVI) and Green Chlorophyll Index (GCI). Changes in vegetation greenness over different time periods were analyzed to identify trends and anomalies. The vegetation indices were calculated using the following formulas:

1. Normalized difference vegetation index (NDVI) = (NIR - Red) / (NIR + Red)

2. For Landsat 8/9: NDVI = (Band5 – Band4) / (Band5 + Band4) For Landsat 4/5: NDVI = (Band5 – Band4) / (Band5 + Band4)

3. Enhanced vegetation index (EVI) = 2.5 x ((Band Near Infrared – Band Red)/(Band Near Infrared + 6 x Band Red + 7.5 x Band Blue + 1))

   For Landsat 8: EVI = 2.5 x ((Band5 - Band4) / (Band5 + 6 x Band4 + 7.5 x Band2 + 1)) For Landsat 4/5: EVI = 2.5 x ((Band4 - Band3) / (Band4 + 6 x Band3 + 7.5 x Band 1 + 1))

4. Normalized difference water index (NDWI) = (Band Green – Band Near Infrared)/(Band Green + Band Near Infrared)

   For Landsat 4/5: NDWI = (Band2 - Band4) / (Band2 + Band4) For Landsat 8/9: NDWI = (Band3 - Band5) / (Band3 + Band5)

5. Specific Leaf Area Vegetation Index (SLAVI) = (Band Near Infrared)/(Band Red+ Band SWIR-1)

   For Landsat 8: SLAVI = ((Band 5))/((Band 4+ Band 6)) For Landsat 4&5: SLAVI = ((Band 4))/((Band 3+ Band 5))

   6. Green Chlorophyll Index (GCI) = Band 5/Band 3 - 1 for Landsat 8 For Landsat 8/9: GCI = Band 5/Band 3 - 1

   For Landsat 4&5: GCI = Band 4/Band2 – 1

3. Findings and Discussion

Land Use and Land Cover (LULC) Classification

The land use and land cover (LULC) change analysis revealed varying degrees of change among the categories of land use for the JWLP between 1990 and 2024 (Table 3 and Figure 3). In 1990, the JWLP had 6327000 m^2 of forested area, constituting 56.6% of the total area. This increased in 1998 to 66.0% and has consistently decreased from 2014 to 2024 whereby it represents 38.8% (4329900 m^2) of the total area. This also means 31.6% of the forested area has decreased significantly from 1991 to 2024 (Table 4). This indicates a severe loss of forest cover within the park. However, the area classified as built up in 1990 was 4173300 m^2, accounting for 37.4% of the total area. From 1990 to 1998, this built up area decreased to 3500100 m^2 and drastically decreased from 1998 to 2024 constituting 56.4% (6298200 m^2) of the total area. This represents a percentage increase of 50.9%.

This indicates a considerable expansion of built up area within the reserve. Overall, there has been a substantial loss of forested area, accompanied by a considerable increase in built up areas in JWLP. This is similar to the findings of Akomolafe & Anumeh (2025) who reported loss of forest cover on Ngel Nyaki forest reserve in Taraba State. The loss of forest land in any land-use classifications has been attributed to several anthropogenic activities such as logging and clearing of land for farming (Akomolafe & Rahmad, 2020).

Table 3. LULC area of Jos wildlife park

LULC CLASS	1990		1998		2014		2024	
	Area (m^2)	%	Area (m^2)	%	Area (m^2)	%	Area (m^2)	%
Forested area	6327000	56.6	7375500	66.0	6431400	57.6	4329900	38.8
Built up	4173300	37.4	3500100	31.3	4475700	40.1	6298200	56.4
Open land	670500	6.0	295200	2.6	263700	2.4	542700	4.9
Total	11170800	100	11170800	100	11170800	100	11170800	100

Table 4. Change in the LULC area of Jos wildlife park

LULC CLASS	1990-1998	1998-2014	2014-2024	1990-2024
	Change in area (%)	Change in area (%)	Change in area (%)	Change in area (%)
Forested area	16.6	-12.8	-32.7	-31.6
Built up	-16.1	27.9	40.7	50.9
Open land	-55.9	-10.7	105.8	-19.1
Total	-55.4	4.4	113.8	0.2

As for the LULC of the PWLP, the results revealed that in 1991, the PWLP had 239796000 m^2 of riparian vegetation, constituting 71.42% of the total area. This has consistently decreased from 2014 to 2024 whereby it represents 37.37% (125451900 m^2) of the total area. This also means 47.68% of the riparian vegetation has decreased significantly from 1991 to 2024 (Table 5 and Figure 4). This indicates a severe loss of riparian forest cover within the reserve. However, the area classified as forested in 1991 was 27455400 m^2, accounting for 8.18% of the total area. From 1991 to 2024, this forested area increased dramatically to 100550700 m^2, constituting 29.95% of the total area. This represents a percentage increase of 266.23% which indicates a considerable expansion of forested area within the reserve (Table 6).

Table 5. LULC area of Pandam Wildlife Park

LULC CLASS	1991		201		2024	
	Area (m^2)	%	Area (m^2)	%	Area (m	%
Water body	1346400	0.40	1403100	0.42	15813(	0.47
Riparian vegetation	239796000	71.42	130998600	39.02	1254519(	37.37
Forested area	27455400	8.18	79112700	23.56	1005507(	29.95
Open land	63017100	18.77	29121300	8.67	179829(	5.36
Built up	4119300	1.23	95098500	28.33	901674(	26.86
Total	335734200	100	335734200		3357342(	

Table 6. Change in the LULC area of Pandam Wildlife Park

LULC CLASS	1991-2014	2014-2024	1991-2024
	Change in area (%)	Change in area (%)	Change in area (%)
Water body	4.21	12.70	17.45
Riparian vegetation	-45.37	-4.23	-47.68
Forested area	188.15	27.09	266.23
Open land	-53.79	-38.25	-71.46
Built up	2208.60	-5.19	2088.90
Total	2301.8	-7.88	2253.44

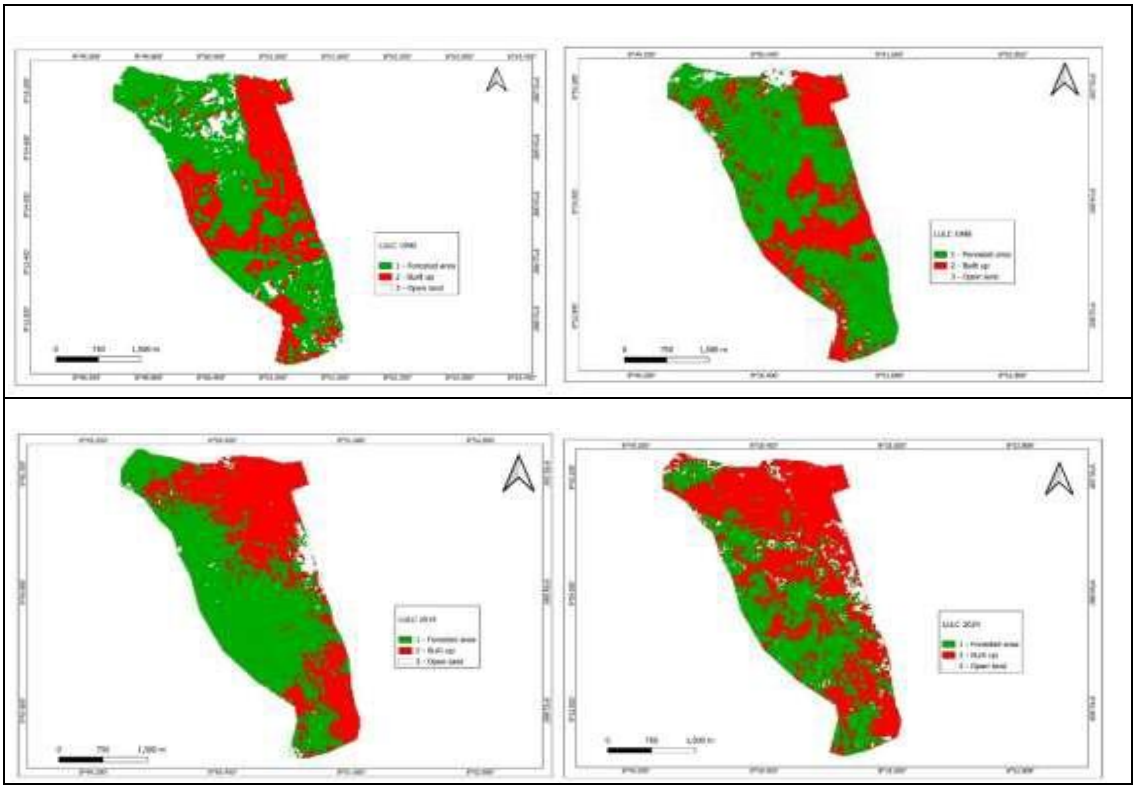


Figure 3. LULC of Jos Wildlife Park from 1990-2014

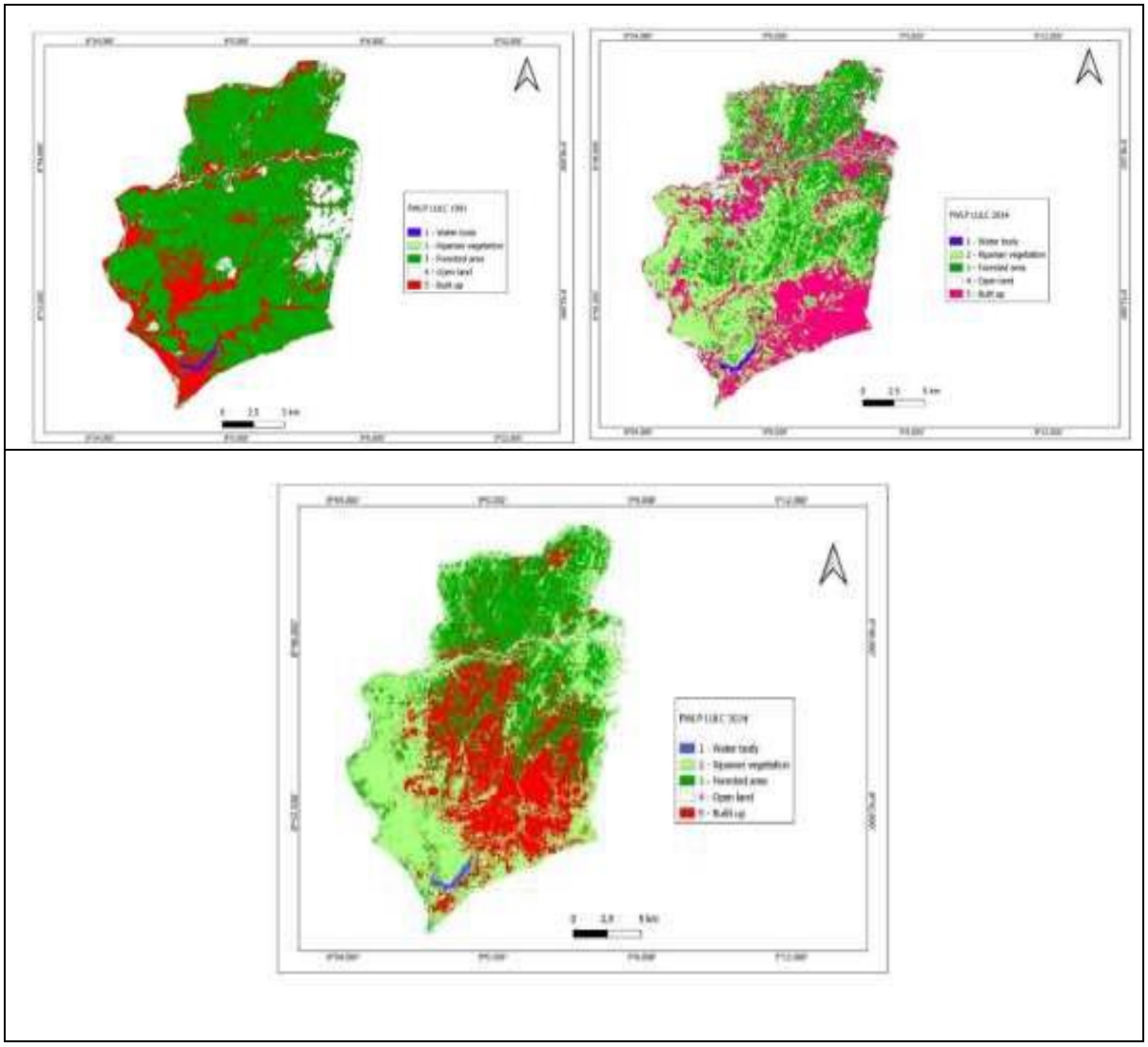


Figure 3. LULC of Jos Wildlife Park from 1990-2014

Accuracy of LULC classification

The accuracy assessments for both JWLP and PWLP include producer's accuracy, user's accuracy, kappa coefficient, and overall accuracy. All the producer's accuracies for all the LULC classes at JWLP and PWLP are above 70%, indicating the percentage of correctly classified pixels of the classes out of all reference pixels (Tables 7 and 8). The user's accuracies are exceptionally high between 80% and 99% while the kappa coefficients for all the classes are closer to 1, indicating almost perfect agreement between the classified results and reference data. The overall accuracy for all the classes is 84.3%. In the other periods, similar trends were observed. Other researchers have also used similar land-use classification methods in Northern Nigeria, and they reported higher degrees of classification accuracy (Adamu, 2019; Jande et al., 2019).

Table 7. Accuracy assessment showing the Kappa coefficient, producer, user, and overall accuracy for JWLP LULC classifications.

LULC class	Producer's accuracy	User's accuracy	Kappa coefficient	Overall accuracy (%)
		1990		
Forested area	72.12	99.00	0.89	84.3
Built up	73.13	84.21	0.92	
Open land	74.52	89.34	0.82	
		1998		
Forested area	73.12	99.00	0.95	89.41
Built up	74.43	85.91	0.82	
Open land	80.22	77.84	0.98	
		2014		
Forested area	78.12	94.12	0.99	88.52
Built up	71.21	79.80	0.89	
Open land	80.11	82.31	0.91	
		2024		
Forested area	75.12	90.12	0.89	85.20
Built up	79.21	75.80	0.95	
Open land	86.11	88.31	0.97	

Table 8. Accuracy assessment showing the Kappa coefficient, producer, user, and overall accuracy for PWLP LULC classifications

LULC class	Producer's accuracy	User's accuracy	Kappa coefficient	Overall accuracy (%)
		1991		
Water body	73.44	98.09	0.96	85.42
Riparian vegetation	79.89	87.60	0.82	
Forested area	74.12	100.00	1.00	
Open land	75.13	89.21	0.87	
Built up	79.82	91.32	0.79	
		2014		
Water body	73.80	99.76	0.99	79.41
Riparian vegetation	92.66	87.10	0.68	
Forested area	76.12	100.00	1.00	
Open land	77.43	88.91	0.87	
Built up	82.32	79.80	0.92	
		2024		
Water body	73.80	99.76	0.89	88.41
Riparian vegetation	92.66	87.10	0.68	
Forested area	78.12	94.12	0.99	
Open land	71.21	79.80	0.89	
Built up	80.11	82.31	0.91	

Vegetation Indices Change

Table 9 presents the mean values of the vegetation indices assessed for the JWLP in the years 1990 - 2024. In 1990, the mean NDVI for JWLP was 0.16 and from 1998 - 2024, the mean NDVI value had increased to 0.22. The EVI also increased slightly from 0.05 in 1990 to 0.10 in 2024. The mean SLAVI value increased from 0.50 in 1990 to 0.72 in 2024. From 1990 to 2024, the mean NDWI values consistently decreased from -0.17 to -0.21. The mean GCI value slightly increased from 0.59 in 1990 to 0.62 in 2024.

As for the PWLP, the mean NDVI value for PWLP was 0.05 in 1991 and from 2014 - 2024, the mean NDVI value had increased to 0.17 (Table 10). The EVI also increased slightly from 0.02 in 1991 to 0.09 in 2024. The SLAVI value increased from 0.48 in 1991 to 0.72 in 2024. From 1991to 2024, the mean NDWI values consistently decreased from -0.04 to -0.14. The mean GCI value increased from 0.19 in 1991 to 0.46 in 2024. These results show increased greenness and photosynthetic activity in the two protected areas.

Table 9. Mean of vegetation indices of JWLP within the study periods

Vegetation index	1990	1998	2014	2024
NDVI	0.16	0.19	0.17	0.22
EVI	0.05	0.06	0.07	0.10
SLAVI	0.50	0.49	0.64	0.72
NDWI	-0.17	-0.24	-0.16	-0.21
GCI	0.59	0.71	0.41	0.62

Table 10. Mean of vegetation indices of PWLP within the study periods

Vegetation index	1991	2014	2024
NDVI	0.05	0.16	0.17
EVI	0.02	0.07	0.09
SLAVI	0.48	0.69	0.72
NDWI	-0.04	-0.11	-0.14
GCI	0.19	0.36	0.46

4. Conclusion and Recommendations

These findings suggest key land-use shifts within both the JWLP and PWLP from 1990 to 2024. Early urban encroachment and infrastructure development dominated, likely driven by weak enforcement, dominated the study area. Forest regeneration likely explains the observed increase in the forest cover of PWLP, despite the loss of the riparian vegetations. However, all the vegetation indices showed a positive trend in plant health of both protected areas.

Thanks and Information Note

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Sustainable Consumption in Emerging Economies: Beyond Greenwashing in Marketing Practices

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Abstract

Sustainable consumption is increasingly being recognised as central to addressing global environmental and social challenges. However, in emerging economies, the expansion of sustainability-orientated marketing has been accompanied by the rise of greenwashing, where claims of responsibility often mask business-as-usual practices. Such misrepresentation not only distorts consumer choices but also undermines the legitimacy of marketing systems, weakens public trust, and limits progress toward genuine sustainability. This study develops a conceptual framework to explore how greenwashing operates within emerging economies and why systemic conditions such as regulatory gaps, limited consumer literacy, and institutional fragility create fertile ground for its persistence. Anchored in institutional and systems theory, the framework identifies the key drivers and consequences of greenwashing while outlining pathways for more authentic sustainable marketing practices. These include transparent communication, stronger regulatory oversight, and greater involvement of civic organisations in enhancing marketplace literacy. By shifting attention from firm-level branding to a broader marketing system, this study contributes to macromarketing scholarship by advancing a critical understanding of sustainability in contexts where the need for systemic reform is most acute.

Keywords: Sustainable consumption, greenwashing, emerging economies, marketing systems, institutional theory, consumer trust, micromarketing.

1.Introduction

Sustainable consumption has become a defining concern in global policy and academic discourse, reflecting the urgent need to align market activities with environmental and social well-being (United Nations, 2015). Marketing plays a crucial role in shaping consumption patterns; however, the promotion of sustainability has often been accompanied by an increase in greenwashing and the preparation of misleading or exaggerated claims about environmental responsibility (Delmas & Burbano, 2011; Lyon & Montgomery, 2015). While green marketing was initially framed as a positive step toward addressing ecological challenges, mounting evidence shows that deception performs not only to erode consumer trust but also to undermine the validity of marketing systems (Peattie & Crane, 2005; Testa et al., 2018). This issue is particularly pronounced in emerging economies, where rapid economic growth is coupled with institutional fragility, weak regulatory oversight, and limited consumer literacy (Sheth, 2011; Gupta & Kumar, 2020). In this context, sustainability claims often circulate without robust verification mechanisms, leaving consumers vulnerable to misrepresentation and making it difficult for genuine sustainable initiatives to gain traction. Unlike developed markets, where stricter legal frameworks and consumer activism provide checks, emerging markets reveal systemic vulnerabilities that allow greenwashing to persist at scale (Gatti et al., 2019). From a macroeconomic perspective, this phenomenon raises critical questions regarding the integrity of marketing systems and their capacity to contribute to societal well-being (Kilbourne, McDonagh, & Prothero, 1997; Layton, 2011).

Macromarketing scholars emphasise that marketing is not merely about firm-level exchanges but is embedded within broader systems of culture, regulation, and public policy. Greenwashing in emerging economies, therefore, should not be understood solely as a corporate communication issue but as a structural problem with implications for distributive justice, quality of life, and long-term sustainability (Hult, 2011; Varey, 2010). Against this backdrop, this study aims to develop a conceptual framework that examines how greenwashing operates within the marketing systems of emerging economies and explores potential pathways for moving beyond symbolic sustainability claims. By anchoring the analysis in institutional and systems theory, this study contributes to macromarketing scholarship by advancing a system-level understanding of sustainability challenges and offering insights for policymakers, practitioners, and civil society actors seeking to foster authentic sustainable consumption.

2. Literature Review

Sustainable Consumption and Marketing Systems

Sustainable consumption raises patterns of use that meet current needs without compromising the ability of future generations to meet their own (United Nations, 2015). Within marketing scholarship, sustainable consumption has been examined not only as individual consumer choice but also as a systemic outcome shaped by markets, institutions, and cultural norms (Kilbourne, McDonagh, & Prothero, 1997; Jackson, 2005). Macromarketing perspectives emphasise that consumption cannot be separated from the broader marketing system, which integrates the flow of goods, information, and values (Layton, 2011). Research shows that fostering sustainable consumption requires institutional alignment across businesses, governments, and civil society, particularly in contexts in which regulatory frameworks remain weak (Prothero et al., 2011).

Greenwashing and Its Societal Consequences

Greenwashing, defined as the act of ambiguous consumers regarding environmental practices or assistance, has become one of the most pressing challenges in sustainability marketing (Delmas & Burbano, 2011). Studies have documented a range of tactics, from vague eco-labels to the selective disclosure of positive outcomes, that allow firms to cultivate a “green” image without substantive change (Peattie & Crane, 2005; Lyon & Montgomery, 2015). Beyond misleading individual consumers, greenwashing undermines trust in markets, discourages genuine sustainable firms, and contributes to consumer cynicism (Walker & Wan, 2012; Testa et al., 2018). From a micromarketing perspective, this phenomenon represents a systemic failure in which information asymmetry and institutional weakness distort market outcomes (Hult, 2011).

Emerging Economies: Institutional Gaps and Consumer Vulnerability

Greenwashing dynamics are particularly acute in emerging economies. Rapid economic growth, expanding middle classes, and increasing consumer interest in sustainability have created fertile ground for sustainability marketing (Sheth, 2011). However, weak institutional frameworks, fragmented enforcement mechanisms, and low consumer literacy make these markets more vulnerable to deceptive claims (Gupta & Kumar, 2020; Gatti et al., 2019). Research also highlights those cultural and contextual factors, such as collectivist values or trust in informal networks, shape how consumers interpret sustainability messages (Belk, 2010; Khare, 2015). Consequently, greenwashing in emerging economies does not simply

reflect individual firm behaviour but reveals structural challenges in marketing systems where accountability is limited and regulation lags market expansion.

Toward a Macromarketing Perspective on Greenwashing

Macromarketing scholarship provides a critical lens for situating greenwashing in broader marketing systems. Rather than treating greenwashing as a communication or branding problem, macromarketing highlights its systemic implications for distributive justice, quality of life, and long-term market legitimacy (Kilbourne et al., 1997; Varey, 2010). Layton (2011) argued that marketing systems are embedded in cultural, institutional, and policy environments, making their health a matter of public interest. Applying this perspective to sustainability suggests that overcoming greenwashing requires coordinated interventions across multiple levels: regulatory reform, consumer literacy initiatives, civil society activism, and business accountability. This systemic view allows scholars and policymakers to move beyond the critiques of individual firms and toward a more comprehensive understanding of how marketing can hinder or advance sustainable consumption in emerging economies.

3. Theoretical Framework

Institutional Theory and Greenwashing

Institutional theory posits that administrative behaviour is strongly inclined by the formal and unceremonious rules, norms, and expectations in the environment (DiMaggio & Powell, 1983; Scott, 2014). Firms often engage in practices that seek legitimacy within their institutional context, and sustainability claims have become a common strategy for achieving legitimacy. In emerging economies, weak regulatory frameworks, limited enforcement, and fragmented governance create conditions under which symbolic sustainability, commonly manifested as greenwashing, can thrive (Delmas & Burbano, 2011; Gatti et al., 2019). By applying institutional theory, this study examines how firms' pursuit of legitimacy interacts with their structural vulnerabilities in emerging markets, shaping both the prevalence and impact of greenwashing. This theory explains why firms may prioritise image over substantive environmental performance when external pressures and institutional oversight are minimal.

Systems Theory and Marketing Systems

Systems theory views administrations and markets as interconnected components within a larger ecosystem of relationships, processes, and flows (von Bertalanffy, 1968; Checkland, 1999). Marketing is not merely a set of firm-level actions but a system that coordinates production, communication, distribution, and consumption within societal and environmental contexts (Layton, 2011; Hult, 2011). From this perspective, greenwashing is not only a firm-level issue but also a systemic phenomenon: misleading claims propagate through marketing channels, influence consumer behaviour, and ultimately affect the credibility of the marketing system. Systems theory provides a lens through which to analyse how feedback loops, regulatory gaps, consumer awareness, and institutional pressures interact to either perpetuate or mitigate greenwashing at the macro level.

Integrating Institutional and Systems Perspectives

By combining institutional and systems theories, the conceptual framework situates greenwashing within both structural and systemic contexts. Institutional theory highlights why firms may engage in greenwashing, while systems theory illuminates how these

practices ripple through marketing systems, affecting trust, consumer behaviour, and societal outcomes. This integration allows the framework to capture the drivers, moderators, and consequences of greenwashing in the emerging economies:

- Drivers: weak regulation, low consumer literacy, competitive pressures, and legitimacy-seeking behaviour.
- Moderators: cultural norms, NGO activism, transparency initiatives, media scrutiny.
- Consequences: Erosion of consumer trust, market inefficiencies, reduced quality of life, and diminished sustainability outcomes.

Conceptual Model Proposition

Building on these theoretical foundations, the paper proposes a conceptual model where:

1. Institutional weaknesses and legitimacy pressures drive greenwashing practices.
2. These practices operate within a marketing system, propagating misleading sustainability signals to consumers.
3. Systemic outcomes include both short-term firm gains and long-term societal risks (trust erosion and misallocation of resources).
4. Interventions at multiple levels of regulation, consumer literacy, and civil society engagement can mitigate greenwashing and foster sustainable consumption.

This integrated theoretical framework provides a macromarketing lens for studying sustainability beyond the firm, emphasising systemic reform and ethical responsibility in emerging economies.

4.Conceptual Framework

Key Constructs:

1. **Marketing Practices**

Green Marketing Strategies

Greenwashing Indicators

2. **Consumer Factors**

Awareness of Sustainability

Trust in Brands

Motivation to Consume Sustainably

3. **Contextual Factors**

Socio-Cultural Norms

Regulatory Environment

Economic Conditions

4. **Outcomes**

Sustainable Consumption Behaviour

Perceived Credibility of Brands

Resistance to Greenwashing

Propositions:

- P1: Authentic green marketing positively influences consumer trust and sustainable consumption.
- P2: Greenwashing negatively affects trust and diminishes sustainable consumption.
- P3: Consumer awareness and motivation moderate the effect of marketing practices on consumption behaviour.
- P4: Contextual factors in emerging economies (regulations, culture, and the economy) shape the influence of marketing on consumer perception and behaviour.

1. Overview of the Framework

The conceptual framework proposed in this study positions greenwashing as a systemic phenomenon within the marketing systems of emerging economies. Drawing on institutional and systems theories, the model illustrates how structural vulnerabilities, firm-level behaviours, and systemic interactions collectively shape sustainable consumption outcomes (DiMaggio & Powell, 1983; Layton, 2011). The framework emphasises that greenwashing is not merely a communication problem but a product of broader market and societal conditions, including regulatory gaps, consumer literacy, and cultural context (Delmas & Burbano, 2011; Gatti et al., 2019).

2. Components of the Framework

A. Drivers of Greenwashing

- **Institutional Pressures:** Firms seek legitimacy in weak regulatory environments, often prioritising images over real environmental performance (Scott, 2014; Delmas & Burbano, 2011).
- **Competitive Pressures:** In rapidly growing emerging markets, firms feel compelled to adopt sustainability claims to remain competitive (Gupta & Kumar, 2020).
- **Consumer Knowledge Gaps:** Low awareness or literacy about sustainability allows misleading claims to persist (Khare, 2015; Sheth, 2011).

B. System-Level Mediators/Moderators

- **Regulatory Oversight:** The strength of laws and enforcement mechanisms can moderate the prevalence of greenwashing (Gatti et al., 2019).
- **Civil Society & NGOs:** Advocacy organisations and the media play a role in promoting transparency and holding firms accountable (Testa et al., 2018).
- **Cultural and Social Norms:** Social expectations and values influence how sustainability claims are perceived and acted upon (Belk, 2010).

C. Outcomes

- **Short-term Firm Gains:** Positive brand image or sales from symbolic sustainability claims (Lyon & Montgomery, 2015).

- **Long-term Societal Impacts:** Erosion of trust, market inefficiencies, and challenges to authentic sustainable consumption (Walker & Wan, 2012; Hult, 2011).
- **Systemic Sustainability:** Degree to which marketing systems enable real environmental and social progress.

3. Flow of the Framework

1. **Drivers** → create incentives for firms to engage in greenwashing.
2. **Greenwashing Practices** → manifest through marketing messages, labels, and promotions.
3. **Mediators/Moderators** → influence whether greenwashing is exposed, mitigated, or amplified.
4. **Outcomes** → affect both firm-level performance and systemic societal trust and sustainability.

4. Visual Representation

- **Left:** Drivers of Greenwashing (Institutional Pressure, Competitive Pressure, Consumer Knowledge Gap)
- **Centre:** greenwashing practices (marketing claims, labels, and promotions)
- **Above/Side:** Moderators (Regulatory Oversight, NGOs, Cultural Norms)
- **Right:** Outcomes (short-term firm gains, long-term societal impacts, and systemic sustainability)
- Arrows connecting drivers → practices → outcomes, with moderators influencing the flow.

5. Theoretical Contribution

This framework extends macromarketing theory by:

- Integrating institutional and systems perspectives to study greenwashing in emerging economies.
- Highlighting the systemic implications of firm-level sustainability claims.
- Offering a foundation for empirical testing and policy intervention design.

6.Discussion

The conceptual framework proposed in this study offers a lens for understanding how greenwashing operates within the marketing systems of emerging economies and its broader societal consequences. By integrating recognised theory and systems theory, the agenda highlights that greenwashing is not merely a firm-level communication issue but a systemic phenomenon influenced by structural vulnerabilities, cultural norms, and regulatory gaps (DiMaggio & Powell, 1983; Layton, 2011). One key insight from the framework is that the drivers of greenwashing, such as weak institutional oversight, competitive pressures, and low consumer literacy, interact to create a fertile environment for symbolic sustainability claims (Delmas & Burbano, 2011; Gupta & Kumar, 2020). Firms may adopt environmentally friendly messaging as a strategy to gain legitimacy without making substantive operational

changes. While this can yield short-term brand advantages, it undermines trust in marketing systems and diminishes the potential for genuine sustainable consumption over time (Peattie & Crane, 2005; Lyon & Montgomery, 2015). The framework also underscores the importance of mediators and moderators in shaping outcomes. Regulatory mechanisms, civil society advocacy, and cultural norms can either amplify or mitigate the effects of greenwashing (Gatti et al., 2019; Testa et al., 2018). For example, active NGO campaigns or transparent labelling initiatives can pressure firms to align marketing claims with actual sustainability performance, restoring trust in the system. Similarly, consumer education and awareness programmes can empower individuals to make informed choices, reducing the efficacy of misleading claims (Khare, 2015; Sheth, 2011). From a macromarketing perspective, these insights emphasise the systemic nature of the challenge. Marketing systems are embedded within broader social, cultural, and institutional networks, and their health directly impacts societal well-being, equity, and long-term sustainability (Kilbourne, McDonagh, & Prothero, 1997; Hult, 2011). Addressing greenwashing therefore requires interventions at multiple levels policy, civil society, and corporate practice rather than focusing solely on individual firms or campaigns.

Finally, the framework highlights emerging economies as a critical context for this study. Unlike developed markets with stronger regulatory enforcement, these markets have systemic vulnerabilities that perpetuate greenwashing, making the design of context-specific interventions essential. By applying this framework, scholars can better understand the complex interaction between institutional pressures, market dynamics, and societal expectations that shape sustainable consumption outcomes, paving the way for both theoretical advancement and practical solutions.

7. Implications

The conceptual framework developed in this study has several important implications for theory, practice, and policy, highlighting how marketing systems in emerging economies can move beyond greenwashing to authentic sustainable consumption.

Theoretical Implications

From a scholarly perspective, this study advances the macromarketing theory by integrating institutional and systems perspectives to examine sustainability in emerging markets. Unlike traditional studies that focus primarily on firm-level strategies, this framework emphasises the systemic nature of greenwashing and its broader societal consequences (Kilbourne, McDonagh, & Prothero, 1997; Layton, 2011). By highlighting the interplay between institutional weaknesses, cultural norms, and systemic feedback loops, this study provides a robust lens for analysing how marketing practices influence trust, legitimacy, and long-term market sustainability (DiMaggio & Powell, 1983; Hult, 2011). This theoretical contribution lays the groundwork for future empirical testing and cross-country comparisons, particularly in contexts in which regulatory and institutional environments are evolving.

Practical Implications

For marketers and businesses, this framework underscores the importance of moving beyond symbolic sustainability claims. Firms operating in emerging economies should recognise that misleading environmental messaging may generate short-term brand gains but can erode consumer trust and system-wide legitimacy in the long run (Peattie & Crane, 2005; Lyon & Montgomery, 2015). Authentic sustainability initiatives backed by transparent reporting,

credible certifications, and stakeholder engagement can help firms build enduring legitimacy while contributing to societal well-being. Additionally, marketers can leverage consumer education programmes to foster marketplace literacy, empowering consumers to distinguish between genuine and misleading sustainability claims (Khare, 2015; Sheth, 2011).

Policy and Societal Implications

The framework also offers guidance for policymakers and civil society organisations. Stronger regulatory oversight, eco-label standards, and monitoring mechanisms are critical for curbing greenwashing and encouraging sustainable practices (Gatti et al., 2019; Testa et al., 2018). Civic organisations, NGOs, and the media can act as systemic checks, raising awareness, promoting transparency, and holding firms accountable. By addressing both the supply and demand sides of the market through corporate responsibility and informed consumers, emerging economies can strengthen their marketing systems and enhance the societal and environmental impact of consumption practices.

8. Conclusion

This study developed a conceptual framework to examine the systemic nature of greenwashing in emerging economies and its implications for sustainable consumption. By participating in institutional concepts and systems theory, this framework highlights how weak regulatory environments, low consumer literacy, and competitive pressures drive firms to engage in symbolic sustainability practices. At the same time, it shows how mediators such as civil society advocacy, cultural norms, and regulatory oversight can mitigate these effects, influencing both firm behaviour and broader societal outcomes. This study makes several important contributions to macromarketing scholarship.

First, it shifts the focus from micro-level firm strategies to the marketing system, emphasising how sustainability claims interact with societal structures and institutional conditions.

Second, it extends theoretical understanding by combining institutional and systems perspectives to explain both the drivers and significances of greenwashing in emerging markets.

Third, it provides a foundation for future empirical research, including cross-country comparisons, longitudinal studies, and the evaluation of policy interventions aimed at fostering authentic sustainable consumption.

From a practical and policy standpoint, the framework underscores the need for transparent corporate practices, robust regulations, and consumer literacy initiatives. Firms must move beyond superficial sustainability claims to build long-term legitimacy and contribute to societal well-being. Policymakers and civil society organisations play complementary roles by promoting accountability, monitoring sustainability claims, and educating consumers. Collectively, these actions can strengthen marketing systems and enable emerging economies to realise the potential for sustainable consumption.

This study provides a critical sympathetic view of sustainability in emerging markets, offering both theoretical and practical insights. By highlighting the systemic nature of greenwashing and identifying pathways for authentic sustainable marketing, it encourages scholars, practitioners, and policymakers to think beyond individual firms and toward broader, long-term societal outcomes.

Thanks and Information Note

The article complies with national and international research and publication ethics. All authors contributed equally to the article.

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Comparative *in Vitro* Antioxidant and Trypanocidal Activities of N-Hexane and Ethylacetate Extracts of *Azadirachta indica* on *Trypanosoma brucei brucei*

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Abstract

The parasitic disease known as trypanosomiasis remains a major health issue in Sub-Saharan Africa, affecting both humans and animals. In this study, phytochemical analysis, antioxidant analysis via ferric reducing antioxidant power, 2, 2-diphenyl-1-picrylhydrazyl and Inhibition of lipid peroxidation) as well as in vitro trypanocidal activities of n-hexane and ethylacetate extracts of Azadirachta indica (NAI and EAI) were carried out using standard methods. Blood obtained from infected donor mice was diluted with glucose phosphate buffered saline to contain 1x10^3 parasites. Exactly 20 µL of the blood sample contained parasite was incubated with varying concentrations of 62.5 µg/mL, 125 µg/mL, 250 µg/mL and 500 µg/mL of NAI and EAI in separate microtiter plates in triplicate for 190 minutes. The mixture was observed under microscope for parasite motility at 10 minutes intervals. Quantity of the phytochemicals are present in the following order; phenol > saponins > tannins > alkaloids > flavonoids in both samples while EAI showed high antioxidant activities. Complete cessation of the parasite motility was observed for all test concentrations within 190 minutes of the study. The most active extract was EAI which causes complete cessation within 50 minutes in 500 µg/mL while that of NAI was within 90 minutes in 500 µg/mL when compared with berenil that occurred within 10 minutes at 500 µg/ml. These results showed that EAI has high trypanocidal and antioxidant activities when compared with NAI. Hence, EAI could explored further for the treatment of African Animal Trypanosomiasis.

Keywords: *Azadirachta indica*, trypanosomiasis, antioxidant, trypanocidal activities.

1. Introduction

Trypanosomiasis also known as sleeping sickness is a parasitic disease caused by protozoan parasites of the genus *Trypanosoma* (Ibrahim *et al*., 2022). The disease is endemic to Sub-saharan Africa and is transmitted primarily by the bite of infected tsetse flies (*Glossina*

species). Human African Trypanosomiasis (HAT) manifests in two forms: the chronic form caused by *Trypanosoma brucei* gambiense, and the acute form caused by *Trypanosoma brucei* rhodesiense (Ibrahim *et al*., 2022; Madaki *et al*., 2022). This disease poses a significant public health challenge in many African countries, where poverty, limited healthcare infrastructure, and remote populations hinder effective treatment and control (Busari *et al*., 2014; Kayode *et al.*, 2020).

In livestock, trypanosomiasis, also known as Animal African Trypanosomiasis (AAT), leads to significant economic losses due to reduced productivity, weight loss, and mortality in cattle, sheep, goats, and other animals. The disease burden in both humans and livestock not only affects individual health but also hampers agricultural productivity, contributing to food insecurity and poverty in affected regions (Maichomo *et al.*, 2021).

The current treatment options for trypanosomiasis are limited to a few drugs such as suramin, pentamidine, melarsoprol, and eflornithine, all of which have significant drawbacks. These drugs are associated with severe side effects, including toxicity, and the need for prolonged hospitalization for their administration. Moreover, drug resistance has emerged as a growing concern, further limiting the effectiveness of these treatments (Kayode *et al.*, 2020). As a result, there is an urgent need to explore alternative therapies that are safe, effective, and affordable for populations in endemic areas.

In recent years, researchers have turned their attention to natural products and medicinal plants as potential sources of new trypanocidal agents. Plants have been used in traditional medicine for centuries and are known to contain bioactive compounds that possess antimicrobial, antifungal, antiviral, and antiparasitic properties. One such plant is *Azadirachta indica*, commonly known as neem. Neem has been widely used in Ayurvedic and African traditional medicine to treat a variety of ailments, including parasitic infections (Wylie and Merrel, 2021).

Neem leaves contain a wide range of bioactive compounds, including limonoids, flavonoids, triterpenoids, and azadirachtin, which have shown promise in preclinical studies for their antimicrobial and antiparasitic activities (Hamzah *et al*., 2025). Various parts of the neem tree, including the leaves, seeds, and bark, contain bioactive compounds that have been shown to possess antiparasitic, antimicrobial, and anti-inflammatory properties (Wasim *et al.*, 2023). Given the rich phytochemical profile of neem, its potential as a trypanocidal agent is an area of increasing interest (Wylie and Merrel, 2021). This study focuses on the *in vitro* trypanocidal activities of neem leaf extracts obtained using two solvents: n-hexane and ethylacetate, which are known for their efficacy in extracting different classes of bioactive compounds.

2. Materials and Methods

2.1 Materials

2.1.1 Plant material

Fresh *Azadirachta indica* leaves (neem) were obtained from Federal University of Technology, Gidan Kwano Campus, Minna, Niger State, Nigeria in July, 2023 and authenticated by Dr. O.A.Y. Daudu of the department of Biological Sciences, Federal University of Technology, Minna with voucher number FUT/PLB/MEL/001. The plant sample

was deposited in the herbarium of the department of Plant Biology, Federal University of Technology, Minna.

2.1.2 Chemicals and Reagents

The chemicals and reagents used includes: ethylacetate, n-hexane, dimethyl sulfoxide (DMSO), folin-ciocalteu's reagent, sodium carbonate, gallic acid, absolute methanol, aluminum chloride, sodium acetate, distilled water, folin-denis' reagent, standard tannic acid, petroleum ether, acetone-ethanol, ferrous sulphate, sulphuric acid, standard saponins, formaldehyde, acetate buffer, TPTZ solution, and ferric chloride solution, DPPH solution, linoleic acid, thiobarbituric acid, diminazene aceturate were all analytical standard.

2.1.3 Parasites

The parasite was sourced from stabilates preserved at the Nigerian Institute of Trypanosomiasis Research (NTR) in Kaduna, Kaduna State. It was maintained in the Animal House of the Department of Biochemistry, Federal University of Technology, Minna, through continuous passage into mice.

2.1.4 Site of Experiment

The experiment was conducted at the Centre of Genetic Engineering and Bioecology, Federal University of Technology, Minna, Bosso Campus. Minna is situated within the Southern Guinea Savanna region of Nigeria, at 9°33' N latitude and 9°37' E longitude.

2.2 Methods

2.2.1 Preparation of *Azadirachta indica* Leaves

The Azadirachta indica leaves were thoroughly washed with tap water to remove dirt and dried at 30 ℃. Thereafter, the plant leaves were reduced to powder using the Silver Crest 2L Industrial 8500W electric blender, and the powder form was kept inside a tight covered plastic container.

2.2.3 Extraction of Bioactive Compounds

Extraction of *Azadirachta indica* leaf was done as reported by Busari *et al.* (2025). Briefly, exactly 250 grams of *Azadirachta indica* leaf powder was weighed into 1000 mL volumetric flask. Afterwards, 750 mL of each solvent was separately poured into flask and mixture was properly agitated and left for 72 hours with occasional vortexing each day. After the 72 hours, the solvent was evaporated using a water bath under reduced pressure before finally lyophilized with freeze drier. The freeze-dried sample was stored in tight covered glass containers and refrigerated at 10℃.

2.2.4 Phytochemical Screening (Quantitative Test)

2.2.4.1 Determination of phenolic content

Each of the n-hexane and ethylacetate extract of *A. indica* was dissolved in 0.01 g of 10 cm^3 distilled water, and 0.5 cm^3 of this solution was oxidized using 2.5 cm^3 of 10% Folin-ciocalteu reagent. The solution was neutralized with the addition of 2 cm^3 of 7.5% sodium carbonate. This mixture was then incubated at 45°C for a duration of 40 minutes. Following incubation, its absorbance was measured at 765 nm using a UV spectrophotometer. A calibration curve was generated using standard gallic acid (Singleton *et al.*, 1999). This process was also carried out for the ethylacetate plant extract.

2.2.4.2 Determination of flavonoid content

In a test tube, 1.5 cm^3 of absolute methanol was combined with 0.1 cm^3 of 10% aluminum chloride, 0.1 cm^3 of 1 M sodium acetate, and 2.8 cm^3 of distilled water. Then, 0.5 cm^3 of the n-hexane plant extract in n-hexane was added. The resulting mixture was incubated at room temperature for 30 minutes, after which its absorbance was measured at 415 nm using a UV spectrophotometer. The above process was also carried out for the ethylacetate extract. Standard quercetin was used to prepare the calibration curve. (Chang *et al*., 2002).

2.2.4.3 Determination of tannin content

A 0.2 g of each sample of the plant extract was placed in a 50 cm^3 beaker, to which 20 cm^3 of 50% methanol was added. The beaker was then covered with parafilm and heated in an 80°C water bath for 1 hour. After heating, the mixture was thoroughly shaken to ensure uniform distribution and then filtered into a 100 cm^3 volumetric flask. To the filtered solution, 20 cm^3 of distilled water, 2.5 cm^3 of Folin-Denis reagent, and 10 cm^3 of sodium carbonate were added and mixed thoroughly. After standing at room temperature for 20 minutes, the solution developed a bluish-green color. The absorbance was taken at 760 nm using a UV-spectrophotometer. Standard tannic acid was used to prepare the calibration curve.

2.2.4.4 Determination of saponin content

A 0.5 g sample of the plant extract in n-hexane was weighed and dissolved in 20 cm^3 of 1N HCl, then heated in a water bath at 80°C for 4 hours. Once cooled, the mixture was filtered, and 50 cm^3 of petroleum ether was added. The ether layer was then separated and evaporated to dryness. The resulting dry residue was combined with 5 ml of a 1:1 acetone-ethanol mixture, 6 cm^3 of ferrous sulfate, and 2 cm^3 of concentrated sulfuric acid, and allowed to stand for 10 minutes. Absorbance was recorded at 490 nm. The same procedure was conducted for the ethylacetate extract, using standard saponins to establish the calibration curve (Oloyed, 2005).

2.2.4.5 Determination of alkaloid content

A 0.5 g sample of the n-hexane extract was weighed and dissolved in 5 cm^3 of a 1:1 mixture of 96% ethanol and 20% H_2SO_4, then filtered. One cm^3 of the filtrate was added to a test tube with 5 cm^3 of 60% H_2SO_4 and left to stand for 5 minutes. Following this, 5 cm^3 of 0.5% formaldehyde was added, and the mixture was kept at room temperature for 3 hours. Absorbance was measured at 565 nm. The same procedure was applied to the ethyl acetate extract, using the extinction coefficient of vincristine (E296, EtOH = 15136 M^{-1} cm^{-1}) as a reference for alkaloids (Oloyed, 2005).

2.2.5 Antioxidants Activities Assay

2.2.5.1 Ferric Reducing Antioxidant Assay

The FRAP reagent was prepared by mixing acetate buffer, TPTZ solution, and ferric chloride solution. The *Azadirachta indica* n-hexane extract was then added to the FRAP reagent, incubated for 30 minutes, and its absorbance was measured at 593 nm using a spectrometer. The antioxidant capacity was assessed by comparing the change in absorbance to that of the standard. The same procedure was followed for the ethylacetate extract of *Azadirachta indica*.

2.2.5.2 The 2,2-Diphenyl-1-picrylhydrazyl radical scavenging

A DPPH solution was prepared in methanol, to which the n-hexane extract was added and thoroughly mixed. The mixture was then incubated in the dark for 30 minutes, followed by absorbance measurement at 517 nm. This process was also applied to the ethyl acetate extract. The percentage of radical scavenging activity was calculated in comparison to a control.

2.2.5.3 The Inhibition of Lipid Peroxidation

Linoleic acid was homogenized mixed with each of the extract. The mixture was incubated at 37 °C for 30 minutes. Thiobarbituric acid (TBA) reagent was added to the mixture, each mixture was then heated to form a colored MDA-TBA complex (Malondialdehyde – Thiobarbituric)**.** The percentage of lipid peroxidation inhibition was calculated compared to a control.

2.2.6 Trypanocidal Study

2.2.6.1 Test Organism

The *Trypanosoma brucei brucei* was sourced from stabilates maintained at the Nigerian Institute of Trypanosomiasis Research (NITR) in Kaduna, Nigeria, and kept in the Animal House through repeated passaging in mice until required. Passages were conducted when parasitemia levels reached between 16 and 32 parasites per field, generally occurring 3 to 5 days post-infection. For each passage, 1×10^3 parasites in 0.1 to 0.2 mL of blood were injected intraperitoneally into mice that had been acclimated to laboratory conditions for two weeks. (Abedo *et al*., 2013).

2.2.6.2 *In vitro* Trypanocidal Activity

The *in vitro* trypanocidal activity assessment was conducted in quadruplicate using 96-well microtiter plates (Tewabe *et al.*, 2014). A 0.5 g sample of the n-hexane plant extract was dissolved in 10 ml of distilled water to create a 0.05 g/ml stock solution (equivalent to 50,000 µg/ml). From this stock, solutions of 500 µg/ml, 250 µg/ml, 125 µg/ml, and 62.5 µg/ml were prepared, resulting in four different concentrations. The same procedure was applied to the ethylacetate plant extract.

A 20 µl blood sample containing approximately 20–25 parasites per microscopic field was mixed with 5 µl of each test concentration, specifically 500 µg/ml, 250 µg/ml, 125 µg/ml, and 62.5 µg/ml, respectively. To verify that any effects observed were specifically from the extract, two control setups were established. The first control used Berenil (Diminazene aceturate, a reference drug) as the positive control, while the second control consisted of blood mixed with glucose-phosphate buffered saline as the negative control. Berenil was prepared to match the concentrations of the test solutions.

Each test mixture was incubated for 5 minutes in sealed microtiter plates at 37°C. Then, 2 µl of each test mixture was placed on separate microscope slides, covered with 7×22 mm cover slips, and the parasites were observed every 10 minutes for a total of 60 minutes, monitoring for any cessation or reduction in motility, using a 400 X Objective lens (Tewabe *et al*, 2014).

3. Findings and Dicussions

3.1 Quantitative phytochemical screening

The table below shows the phytochemical analysis of *Azadirachta indica* (neem) extracts. The analysis revealed significant differences in the concentrations of bioactive compounds between the n-hexane and ethylacetate extracts. The ethylacetate extract exhibited higher levels of phenols (134.49 ± 0.7 mg/g), tannins (42.81 ± 0.5 mg/g), saponins (101.85 ± 0.8 mg/g), and alkaloids (5.85 ± 0.2 mg/g) compared to the n-hexane extract. These compounds are known for their potent antioxidant, antiparasitic, and membrane-disrupting properties, which may explain the higher trypanocidal activity observed in the ethylacetate extract. While the n-hexane extract had higher flavonoid content (3.33 ± 0.4 mg/g), the overall lower concentrations of key phytochemicals suggest that the ethylacetate extract contains more bioactive compounds responsible for its stronger antitrypanosomal effects.

Table 1. Quantitative phytochemical composition of N-hexane and ethylacetate extract of *Azadirachta indica*

	Concentration (mg/100g)				
Sample	Phenols	Flavonoids	Tannins	Saponins	Alkaloids
NAI	114.73±0.6	3.33±0.4	30.43±0.5	87.01±0.2	4.05±0.8
EAI	134.49±0.7	1.39±0.5	42.81±0.5	101.85±0.8	5.85±0.2

NAI = n-hexane extract of *Azadirachta indica*, EAI = ethylacetate extract of *Azadirachta indica*

3.2 Antioxidants Activities of N-hexane and Ethylacetate extracts of *Azadirachta indica*

3.2.1 Ferric Reducing Antioxidant Power of N-hexane and Ethylacetate extracts of *Azadirachta indica*

The antioxidant capacities of the n-hexane and ethylacetate extracts of *Azadirachta indica* were evaluated using the FRAP assay at various concentrations (500 µg/ml, 250 µg/ml, 125 µg/ml, and 62.5 µg/ml), as presented in the table below. The results indicate that the ethylacetate extract exhibited stronger ferric reducing antioxidant power (FRAP) at all tested concentrations compared to the n-hexane extract. At the highest concentration (500 µg/ml), the ethylacetate extract showed the highest FRAP value (73.08±0.1), while the n-hexane extract displayed a lower value (65.45±0.3). As the concentration decreased, the FRAP values for both extracts reduced accordingly, with the ethylacetate extract maintaining higher activity even at the lowest concentration (62.5 µg/ml), where it recorded a FRAP value of 19.02±0.2 compared to 15.93±0.2 for the n-hexane extract. This suggests that the ethylacetate extract possesses superior antioxidant capacity, which may contribute to its higher trypanocidal activity.

Table 2. Ferric Reducing Antioxidant Power of N-hexane and Ethylacetate extracts of *Azadirachta indica*

Sample	**Concentrations**			
	500µg/ml	**250µg/ml**	**125µg/ml**	**62.5µg/ml**
NAI	65.45±0.3	51.20±0.3	31.82±0.2	15.93±0.2
EAI	73.08±0.1	59.21±0.3	44.93±0.2	19.02±0.2

NAI = n-hexane extract of *Azadirachta indica*, EAI = ethylacetate extract of *Azadirachta indica*

3.2.2 The 2, 2-Diphenyl-1-picrylhydrazyl of N-hexane and Ethylacetate extracts of *Azadirachta indica*

The DPPH (2,2-Diphenyl-1-picrylhydrazyl) assay was performed to assess the free radical scavenging capabilities of the n-hexane and ethylacetate extracts of *Azadirachta indica* at various concentrations (500 µg/ml, 250 µg/ml, 125 µg/ml, and 62.5 µg/ml). The ethylacetate extract showed stronger antioxidant activity across all concentrations compared to the n-hexane extract. At the highest concentration (500 µg/ml), the ethylacetate extract exhibited the highest DPPH radical scavenging activity (62.81±0.2), while the n-hexane extract had a lower activity (54.54±0.2). As the concentration decreased, the free radical scavenging ability of both extracts diminished. At the lowest concentration (62.5 µg/ml), the ethylacetate extract still showed higher activity (9.77±0.2) compared to the n-hexane extract (3.02±0.2). These results indicate that the ethylacetate extract possesses better antioxidant activity, which may contribute to its stronger trypanocidal efficacy.

Table 3. The 2,2-Diphenyl-1-picrylhydrazyl of N-hexane and Ethylacetate extracts of *Azadirachta indica*

Sample	**Concentration**			
	500 µg/ml	**250 µg/ml**	**125 µg/ml**	**62.5 µg/ml**
NAI	54.54±0.2	41.21±0.3	22.96±0.1	3.02±0.2
EAI	62.81±0.2	47.66±0.2	29.71±0.3	9.77±0.2

NAI = n-hexane extract of *Azadirachta indica*, EAI = ethylacetate extract of *Azadirachta indica*

3.2.3 The Inhibition of Lipid Peroxidation of N-hexane and Ethylacetate extracts of *Azadirachta indica*

The ILP (Inhibition of Lipid Peroxidation) assay was performed to assess the ability of n-hexane and ethylacetate extracts of *Azadirachta indica* to prevent lipid peroxidation at different concentrations (500 µg/ml, 250 µg/ml, 125 µg/ml, and 62.5 µg/ml). The ethylacetate extract exhibited stronger inhibitory effects on lipid peroxidation across all concentrations compared to the n-hexane extract. At 500 µg/ml, the ethylacetate extract demonstrated the highest inhibition (50.33±0.2), while the n-hexane extract showed lower inhibition (42.31±0.7). As the concentrations decreased, the inhibition of lipid peroxidation declined for both extracts. Even at the lowest concentration of 62.5 µg/ml, the ethylacetate extract maintained a higher inhibition value (3.12±0.2) compared to the n-hexane extract (1.54±0.1). These results indicate that the ethylacetate extract is more effective in preventing lipid peroxidation, likely due to its higher content of bioactive compounds, contributing to its overall antioxidant and trypanocidal activities.

Table 4. The Inhibition of Lipid Peroxidation of N-hexane and Ethylacetate extracts of *Azadirachta indica*

Sample	**Concentration**			
	500µg/ml	**250µg/ml**	**125µg/ml**	**62.5µg/ml**
NAI	42.31±0.7	32.91±0.2	19.32±0.2	1.54±0.1
EAI	50.33±0.2	37.29±0.2	26.22±0.2	3.12±0.2

NAI = n-hexane extract of *Azadirachta indica*, EAI = ethylacetate extract of *Azadirachta indica*

3.3 Effect of Different Concentrations of N-hexane and Ethylacetate Extracts of *Azadirachta indica* on Motility of *T. brucei brucei*

The Table 5 presents the effects of different concentrations of n-hexane and ethylacetate extracts of *Azadirachta indica* on the motility of *Trypanosoma brucei brucei*. At 500 µg/ml, the n-hexane extract ceased the parasite's motility after 90 minutes, while the ethylacetate extract was more effective, ceasing motility in 50 minutes. As the concentrations decreased, the time taken for motility cessation increased for both extracts but less effective than diminazene Aceturate which took 10 minutes cessation at the same concentration.

Table 5. Effect of N-hexane and Ethylacetate extracts of *Azadirachta indica* on Motility of *T. brucei brucei*

Test Substance	Time (Minutes) after which motility ceased with different concentrations of extracts Parasite motility (µg/ml)			
	500 µg/ml	250 µg/ml	125 µg/ml	62.5 µg/ml
AIN	90.40 ± 8.30	130.20 ± 10.60	180.40 ± 12.10	240.60 ± 15.50
AIE	50.40 ± 5.10	90.30 ± 6.10	150.40 ± 8.10	190.70 ± 10.10
Diminazene Aceturate	10.20 ± 1.15	10.50 ± 1.20	10.60 ± 1.30	30.80 ± 2.90

Value was expressed as the mean of triplicate ± standard deviation

NAI = n-hexane extract of *Azadirachta indica*, EAI = ethylacetate extract of *Azadirachta indica*

The findings showed higher antioxidant activates in EAI might be as a result of content of phenols, tannins and flavonoids. These compounds contain hydroxyl groups that can serve as reactive oxygen species quenchers (Busari *et al*., 2021). The same effect that was revealed by EAI on higher exhibition of trypanocidal effects might be due to higher phytochemicals such as flavonoids, tannins, phenolics, and alkaloids, which have been reported to possess strong antiprotozoal and antiparasitic properties (Rahman *et al.*, 2020). These phytochemicals are known for their ability to induce oxidative stress in parasites, disrupt cellular processes, and inhibit enzyme activities essential for parasite survival. The higher trypanocidal activity observed in the ethylacetate extract may be attributed to these compounds ability to interfere with the metabolism and reproduction of the parasite, ultimately leading to its death (Patel *et al.*, 2022). In fact, the site and number of hydroxyl groups on polyphenols are thought to be related to their relative toxicity to microorganisms, with evidence that increased hydroxylation results in increased toxicity (Eid *et al*., 2017). This explains why polyphenols present in neem were more effective in parasite reduction. The ability of the neem plant extract to lower the levels of parasitaemia can therefore be attributed to the toxic activity of polyphenols present in it. Indeed, polyphenols have been shown to have anti-trypanosomal activity (Eid *et al*., 2017).

Although, ability of NAI to show less trypanocidal activities than the ethylacetate extract suggests that less polar solvent could still extract potent compounds that can still play a role in combating *T. brucei brucei* existence. However, the superior performance of the ethylacetate extract suggests that the polar solvent could extract compounds from *A. indica* that may have a stronger affinity for intracellular targets within the parasite. This finding is consistent with

previous research indicating that *A. indica* extracts contain a variety of bioactive compounds with potential antitrypanosomal properties. This study reinforces the idea that *Azadirachta indica* could be a promising natural source of trypanocidal agents, with the ethyl acetate extract showing particularly strong activity in this regard (Rahman *et al.*, 2020).

4.Conclusion and Recommendations

Hence, *in vivo* antioxidants, trypanocidal and toxicities studies of ethylacetate extract should be carried out to affirm the antioxidant and trypanocidal effects as well as safety of the extract. The active compound(s) should also be isolated in order to obtain the trypanocidal drug candidate as well as to unravel the mechanism through which the isolated compound(s) exhibit their trypanocidal activities.

Conflict of Interest

Finally, all authors contributed equally to the article to the success of this article and no conflict of interest between the Authors.

Ethical Approaval

The article complies with national and international research and publication ethics. Although, Ethics Committee approval was not required for the study because it was an *in vitro* studies

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Antidiabetic Activities of Methanol Extract of *Polyalthia longifolia* Stem Bark in Alloxan-Induced Diabetes in Mice

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Abstract

Diabetes remains global health problems due to its fatal complications which lead to high mortality. This study aims at determining the antidiabetic activities of methanol extract of Polyalthia longifolia bark (MEPLB) in alloxan-induced diabetes in mice. Phytochemicals, acute toxicity and diabetic activities of MEPLB was determined using standard methods. Diabetes was induced by a single dose intraperitoneal administration of 180 mg/kg body weight (mg/kg bw.) of a freshly prepared alloxan monohydrate solution. After 72 hours of alloxan monohydrate injection, blood glucose level was recorded and mice with glucose level greater than 150 mg/dL was considered to be diabetic. Thereafter, the mice were randomized into six groups of eight animals each. First group contains non-diabetic mice that received 0.2 mL of Normal saline orally while the remaining group comprise diabetic group and received 0.2 mL of Normal saline, 0.5 mg/kg bw. of glibenclamide, 100, 200, and 400 mg/kg bw. of MEPLB orally respectively for twenty-one days. The blood glucose levels and the weight of the animals were monitored at 1week interval. On day twenty-two, the animals were euthanized under mild chloroform anesthesia and their blood was collected for liver functions, kidney functions markers and some haematological tests. Administration of alloxan significantly ($p < 0.05$) increased the blood glucose, liver functions, kidney functions markers, lipids profile and significantly ($p < 0.05$) reduced high density lipoprotein, carbonate, body weight, haemoglobin and red blood cells when compared with non-diabetic control. Treatment of the diabetic mice with 100, 200, and 400 mg/kg bw. of MEPLB reversed these changes caused by alloxan.

Keywords: *Polyalthia longifolia*, alloxan monohydrate, serum glucose, glibenclimide.

Introduction

Plant which is one of the sources of food can also serve as sources of non-food industrial products of which are grown in large quantities for the production of fine chemicals or specialized products (Ahad et al., 2021). Plants are now important components of traditional medicinal practices which are used for therapies and are also used in many major pharmaceutical drugs used in the defense against many diseases. Plants and plant-derived products contain both micro and macro minerals, fats, sugars, antioxidant and antimicrobial substances which are important for sustainability of life (Adaramola et al., 2017). Diabetes

mellitus (DM), a chronic metabolic disorder divided into two types: the first type which take place at childhood due to inheritance or deficiency in insulin secretion (defect of the insulin secretion from pancreatic β-cells) and the second type take place at adulthood due to deficiency in insulin receptors (insulin resistance) in the organs, usually caused by environmental factors such as nutrition and obesity. It is also characterized by elevated blood glucose levels resulting from defects in insulin secretion, insulin action, or both (Khazaei et al., 2020). The rising prevalence of diabetes necessitates the exploration of alternative and complementary therapies to manage and treat the condition effectively. Traditional medicinal plants have long been a source of potential therapeutic agents, offering a wealth of bioactive compounds with various pharmacological properties. The global prevalence of diabetes has been increasing at an alarming rate, posing significant health and economic burdens thereby leading to drastic lifestyle changes accompanying urbanization and westernization. In Nigeria, 1.9% with more than 1.5 million cases of diabetes mellitus has been reported. Polyalthia, a family of Annonaceae is a large genus of shrubs and trees distributed in tropics and subtropics which consist of 120 genera and more than 2000 species (Nair *et al.*, 2007). *Polyalthia longifolia* locally known as Seedha Ashoka in India and masquerade tree in Nigeria because of its shape (Anigboro et al., 2018), is one of the medicinal plants known for its therapeutic properties which possesses various activities such as hypoglycemic, antimicrobial, antioxidant, analgesic, and antitumor activities and used traditionally in India as a remedy for fever, gonorrhea, ulcer, skin diseases, and helminthiasis as reported by Dattatray et al. (2021).

Materials and Chemicals Used

The materials used in this study were maceration equipment, water bath, glassware, mortar and pestle, an electric balance, orbital shaker, desiccator, animal scales, syringes, rat cages, glucometers, glucose test strips, cotton wool and protective materials. The chemicals used consist of 99.55% methanol, chloroform, alloxan, normal saline, glibenclimide tablets.

Collection and Preparation of Plant Materials

Fresh bark of *Polyalthia longifolia* were collected May 5, 2024 from the botanical garden of Bauchi State University, Gadau. The plant was authenticated via its picture along with the bark in the Botany Department of the University. Afterwards, the plant materials were deposited at the University Herbarium and assigned a voucher No. BASUG-00169. The barks were dried under room temperature (30°C) before being reduced to powder using pestle and mortar. The powdered sample was kept inside the plastic container and kept in a laboratory cupboard for further usage.

Experimental Animals

Twelve (12) Albino rats weighing between 103 – 197 g and seventy-two (72) mice ranging from 27 – 42 g were obtained from the animal house in Vom, the South District of Jos, Plateau State Nigeria. The animals were kept in cages at a room temperature for three weeks to acclimatize and allowed access to food and water *ad-libitum*. The principles of laboratory animal care guidelines were followed as reported by Busari *et al*. (2015).

Plant Extract

Polyalthia longifolia bark powder of 200 g was weighed into a 1000 mL volumetric flask and 1000 mL of methanol was poured into the flask followed by vortexing. The volumetric flask was then covered with aluminum foil and the content of the beaker was shaken intermittently

at a room temperature (30℃) for 72 hours. The extracts solution was obtained by filtration using a muslin cloth and later concentrated using water bath (DK-600, British Standard) at 40℃.

Acute Toxicity Test (Lethality)

The mean lethal dose (LD_{50}) of the methanol extract was determined using Lork's method as described by Unuigbe *et al.* (2021) using 10,100,1000, 1600, 2900 and 5000 mg/kg of the test substance and observed for 24 hours for behavior as well as mortality

The LD_{50} is calculated by the following formula:

$$LD_{50} = \sqrt{(D_0 \times D_{100})}$$

D_0 = Highest dose that gave no mortality

D_{100} = Lowest dose that produced mortality

Induction of Diabetes Mellitus

Induction of diabetes was carried out as described by Busari *et al*. (2015) with little modification. Briefly, the rats were starved for 12 hours with free access to water. Diabetes was induced by a single dose intraperitoneal administration of 180 mg/kg body weight of a freshly prepared alloxan monohydrate solution intraperitoneally. After 72 hours of alloxan monohydrate injection, blood glucose level was recorded using Accu check glucometer. The mice with glucose level greater than 150 mg/dL was considered to be diabetic.

Animal Grouping

A total of forty-eight (48) Albino mice were used for the study. The mice were divided into six (6) groups of eight animals each.

Group 1 – Non-diabetic + 2 mL of normal saline (Normal control)

Group 2 – Diabetic + 0.5 mg/kg bw. of Glibenclamide. (Positive control)

Group 3 – Diabetic + 2 mL of normal saline (Negative control)

Groups 4, 5, and 6 – Diabetic + 100, 200, and 400 mg/kg body weight of methanol extract of *P. longifolia* bark (MELB) respectively.

Treatment of the Experimental Animals

The extracts were reconstituted in 70% distilled water and 30% Dimethyl Sulfoxide (DMSO). It was then administered orally on daily basis for 21 days and the fasting blood glucose level was determined after every 7 days (Day 0, 7, 14, and 21).

Collection of Blood Samples

On day 22, the animals were anaesthetized under mild chloroform and the blood sample was collected via cardiac puncture. The blood samples were collected in serum bottles, allowed to clot before being separated by centrifugation at 3000 rpm for 10 minutes. The serum was carefully collected using micropipette into another plain bottles. The blood samples were then refrigerated for further biochemical analysis.

Results

Acute Toxicity

The extract showed no mortality in the experimental animals after 24hours of oral administration. However, alertness, closing of eye, trembling and restlessness were the signed observed during the cage side observation within first thirty minutes. Thereafter, these signs disappear after one hour of extract administration.

Table 1. Phytochemical analysis of the *Polyalthia longifolia*

Phytochemicals	Inference
Alkaloids	+
Tannins	+
Saponins	+
Steroids	-
Flavonoids	-

+ = Present, - = Absent

Table 2. Body Weight Changes of Alloxan-induced Diabetes in Experimental Mice Treated with Methanol Extract of *Polyalthia longifolia* Bark

Group	D0	D7	D14	D21
G1	35.24 ± 0.02	31.37 ± 0.03	35.00 ± 0.02	31.80 ± 0.02
G2	32.57 ± 0.03	28.23 ± 0.02	33.97 ± 0.02	30.52 ± 0.02
G3	28.93 ± 1.17	26.20 ± 0.02	31.59 ± 0.03	29.21 ± 0.03
G4	34.22 ± 0.03	31.98 ± 0.03	36.35 ± 0.02	36.91 ± 0.03
G5	33.00 ± 0.03	31.75 ± 0.03	37.17 ± 0.03	36.84 ± 0.03
G6	35.23 ± 0.03	30.39 ± 0.03	37.64 ± 0.02	37.27 ± 0.03

G 1 = Normal control; G 2 = Positive control; G 3 = Negative control; G 4 = 100 mg/kg b.w of MELB; G 5 = 200 mg/kg b.w of MELB; G 6 = 400 mg/kg b.w. of MELB. Data are represented as average values ± Standard error mean. Values with different superscript vertically are significantly different ($P < 0.05$)

Table 3. Glucose Concentration (mg/dL) of Alloxan-induced Diabetes Experimental Mice Treated with Methanol Bark Extract of *Polyalthia longifolia*

	G 1	G 2	G 3	G 4	G 5	G 6
D 0	85.98 ± 0.07^{d}	109.53 ± 0.03^{a}	164.84 ± 0.29^{a}	125.93 ± 0.11^{b}	148.31 ± 0.10^{a}	206.55 ± 0.05^{a}
D 7	98.67 ± 0.03^{a}	96.96 ± 0.03^{b}	135.70 ± 0.02^{c}	170.77 ± 0.02^{a}	77.18 ± 0.02^{b}	68.02 ± 0.02^{b}
D 14	98.28 ± 0.03^{b}	94.50 ± 0.01^{c}	146.52 ± 0.01^{b}	107.21 ± 0.02^{c}	68.66 ± 0.01^{c}	68.03 ± 0.03^{b}
D 21	88.90 ± 0.04^{c}	82.02 ± 0.05^{d}	121.03 ± 0.03^{d}	98.98 ± 0.07^{d}	67.50 ± 0.01^{d}	65.52 ± 0.02^{c}

G 1 = Normal control; G 2 = Positive control; G 3 = Negative control; G 4 = 100 mg/kg b.w of MELB; G 5 = 200 mg/kg b.w of MELB; G 6 = 400 mg/kg b.w. of MELB. Data are represented as average values ± Standard error mean. Values with different superscript vertically are significantly different ($P < 0.05$)

Table 4. Liver Functions Biomarkers of Alloxan-induced Diabetes in Experimental Mice Treated with Methanol Extract of *Polyalthia longifolia* Bark

Group	ALP	Total Bilirubin	Albumin (g/dl)	Globulin g/dl	Albumin /Globulin
G 1	95.33 ± 0.58^{c}	0.60 ± 0.10	2.63 ± 0.06^{b}	4.83 ± 0.06^{a}	0.50 ± 0.03^{d}
G 2	115.00 ± 11.20^{d}	0.37 ± 0.16	3.20 ± 0.10^{a}	4.23 ± 0.12^{b}	0.70 ± 0.08^{c}
G 3	301.00 ± 21.20^{f}	0.87 ± 0.06	2.07 ± 0.12^{c}	1.77 ± 0.08^{d}	1.17 ± 0.06^{a}
G 4	217.00 ± 12.20^{b}	0.83 ± 0.13	1.53 ± 0.16^{d}	1.23 ± 0.16^{e}	1.27 ± 0.16^{a}
G 5	161.00 ± 13.00^{a}	0.80 ± 0.10	2.87 ± 0.22^{b}	3.23 ± 0.13^{c}	0.90 ± 0.14^{b}
G 6	105.00 ± 14.80^{d}	0.27 ± 0.06	2.73 ± 0.18^{b}	3.03 ± 0.26^{c}	0.90 ± 0.12^{b}

G 1 = Normal control; G 2 = Positive control; G 3 = Negative control; G 4 = 100 mg/kg b.w of MELB; G 5 = 200 mg/kg b.w of MELB; G 6 = 400 mg/kg b.w. of MELB. Data are represented as average values ± Standard error mean. Values with different superscript vertically are significantly different (P < 0.05)

Table 5. Lipid Profile (mg/dL) of Alloxan-induced Diabetes in Experimental Mice Treated with Methanol Extract of *Polyalthia longifolia* Bark

Group	Cholesterol	TAG	HDL	LDL	VLDL
G 1	77.80 ± 2.80	132.6 ± 0.115	49.50 ± 4.40	7.72 ± 1.22	15.40 ± 2.14
G 2	58.60 ± 3.10	106.20 ± 0.20	30.8 ± 2.82	1.96 ± 0.22	4.28 ± 0.90
G 3	69.67 ± 3.16	50.21 ± 0.21	46.56 ± 3.12	14.94 ± 1.24	4.28 ± 0.21
G 4	58.50 ± 1.80	73.75 ± 5.43	44.64 ± 4.60	9.32 ± 0.82	12.42 ± 1.24
G 5	58.70 ± 2.60	26.63 ± 0.58	44.82 ± 2.81	12.80 ± 2.18	14.18 ± 2.20
G 6	50.80 ± 3.80	88.53 ± 0.06	47.98 ± 3.52	1.72 ± 0.36	5.38 ± 0.18

G 1 = Normal control; G 2 = Positive control; G 3 = Negative control; G 4 = 100 mg/kg b.w of MELB; G 5 = 200 mg/kg b.w of MELB; G 6 = 400 mg/kg b.w. of MELB. Data are represented as average values ± Standard error mean. Values with different superscript vertically are significantly different (P < 0.05)

Table 6. Kidney Functions Biomarkers of Alloxan-induced Diabetes in Experimental Mice Treated with Methanol Extract of *Polyalthia longifolia* Bark

GRP	UREA	CREAT.	Na^+	K^+	Cl^-	HCO_3^-
G 1	31.17±0.15^f	0.36±0.10^a	147.67±0.58	17.10±0.10	104.10±1.00	25.00±1.00
G 2	44.47±0.15^e	0.32±0.20^a	142.13 ±1.12	17.63±0.15	105.0±10.50	20.33±0.58
G 3	54.47±0.15^b	1.30±0.10^a	177.33±1.52	28.07±0.06	137.20±12.60	18.667±0.57
G 4	44.67±0.31^a	0.39±0.05^a	156.23±3.21	19.63±0.25	105.20±13.00	23.33±4.04
G 5	36.47±0.42^d	0.37±0.07^a	150.0±6.30	18.87±0.12	104.60±7.20	26.33±0.18
G 6	33.50±0.36^c	0.33±0.03^a	153.3±12.16	18.30±0.10	104.67±8.16	22.33±0.58

G 1 = Normal control; G 2 = Positive control; G 3 = Negative control; G 4 = 100 mg/kg b.w of MELB; G 5 = 200 mg/kg b.w of MELB; G 6 = 400 mg/kg b.w. of MELB. Data are represented as average values ± Standard error mean. Values with different superscript vertically are significantly different (P < 0.05)

Table 6. Haemoglobin and Red Blood Cells of Alloxan-induced Diabetes in Experimental Mice Treated with Methanol Extract of *Polyalthia longifolia* Bark

GROUP	Hb	RBC
G1	27.37 ± 1.35^d	5.70 ± 1.20
G2	15.57 ± 1.12^e	2.97 ± 0.16
G3	10.53 ± 2.12^f	7.60 ± 0.53
2G4	33.13 ± 3.10^a	6.83 ± 0.58
G5	31.26 ± 4.10^b	6.17 ± 0.18
G6	28.67 ± 3.58^c	6.10 ± 0.12

G 1 = Normal control; G 2 = Positive control; G 3 = Negative control; G 4 = 100 mg/kg b.w of MELB; G 5 = 200 mg/kg b.w of MELB; G 6 = 400 mg/kg b.w. of MELB. Data are represented as average values ± Standard error mean. Values with different superscript vertically are significantly different ($P < 0.05$)

Discussions

The result of acute toxicity study indicated that the LD_{50} of the aqueous bark of *Polyalthia longifolia* is more than 5000 mg/kg body weight. The non-lethal effect produced with the high dose of this extract indicates that the bark extract of *P. longifolia* is relatively safe on acute oral exposure. It can therefore be concluded that *P. longifolia* bark extract is non-toxic which is in accordance with the study of Unuigbe *et al.,* (2021). Any chemical substance with LD_{50} estimate less than 3000-5000 mg/kg (oral route) could be considered of low toxicity and safe.

Herbal medicine has been used in treatment of various acute and chronic diseases worldwide and it is gaining popularity in developing countries (Unuigbe *et al.,* 2021). This is because plants contain chemical components termed as “phytochemicals” or “bioactive chemicals” (Ahad *et al.,* 2021). In this study, alloxan-induced diabetes stabilized on the 7th day of bark extract administration for experimental mice with higher doses (200 mg/kg and 400 mg/kg) and stabilized on the 14th day for experimental mice with low dose of the bark extraxt (100 mg/kg). The result indicated that there is significant reduction in the fasting blood glucose of the experimental mice giving daily oral administration of *Polyalthia longifolia*. After 21 days of bark extract administration, the FBG reduced by 21.4%, 54.5%, and 68.3% at 100, 200, and 400 mg/kg respectively while the group administered 10 mg/kg body weight of standard drug reduced to 25.1% after 21 days. The bark extract showed more potency than the standard drug (glibenclamide) especially at a higher dose. The observed anti-diabetic effects of *Polyalthia longifolia* indicate that the barks extract contain bioactive chemicals with potent anti-diabetic property.

Thanks and Information Note

The article complies with national and international research and publication ethics. All authors contributed equally to the article.

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Modeling Marketing Dynamics and Seller Behaviour: A Pilot Study on Sustainable Livestock Systems in Akwa Ibom State, Nigeria

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Abstract

The rising demand for ruminant meat in Nigeria underscores the central role of livestock markets in the country's food system. This pilot study models marketing dynamics and seller behaviour as a pathway to sustainable livestock systems, drawing on market-level data. The analysis employs descriptive statistics, variable definitions, and econometric models, including logit regressions for determinants of market participation (95% CI) and OLS estimates of sellers' price behaviour, to identify key drivers of market outcomes. Results from large-magnitude coefficients and marginal effects highlight the influence of herd size, market information access, and cooperative membership on participation probabilities, while distance and transaction costs emerge as constraints to effective engagement. The sellers' price equation reveals evidence of price erosion with higher sales volumes, pointing to structural inefficiencies in local markets. Overall, the study demonstrates that collective marketing arrangements, better information systems, and stronger institutional support can enhance market efficiency and seller welfare. As a preliminary investigation, the findings provide a foundation for larger-scale research and contribute to the academic discourse on sustainable livestock value chains in Nigeria. The findings suggest that while selling larger volumes may expose farmers to lower unit prices due to buyer bargaining power, strengthening cooperative structures and improving price information could help counter this effect. At the same time, efforts to reduce transaction costs and facilitate access to urban markets may enable farmers to capture higher prices, provided future studies confirm the existence of an urban premium.

Keywords: Goat marketing, marketing dynamics, seller behaviour, market participation, livestock value chains, sustainable livestock systems, akwa ıbom state.

1. Introduction

Livestock markets play a critical role in the livelihoods and food systems of many low- and middle-income countries, particularly in sub-Saharan Africa where small ruminants such as goats and sheep are vital sources of income, nutrition, and social security (Akinmoladun et al., 2019; FAO, 2021). In Nigeria, goats are especially important due to their adaptability, rapid turnover, and broad cultural acceptance, making them a cornerstone of meat supply across rural and urban communities (Ojo et al., 2021). However, the dynamics of goat marketing remain underexplored, particularly in Akwa Ibom State, where growing demand for animal protein has not been matched by efficient and sustainable market systems.

The marketing of goats in many Nigerian states, in particular Akwa Ibom state is largely informal, relying on traditional open markets, itinerant traders, and farm-gate transactions. Sellers face significant challenges including price volatility, absence of standard measures, high transportation costs, and weak bargaining power (Ike & Oti, 2022; Okonkwo et al., 2022). Market integration across regions remains limited, with prices often reflecting local

imbalances rather than efficient arbitrage. These inefficiencies reduce market transparency, undermine seller welfare, and weaken the potential for sustainable livestock value chains (Ayanwale et al., 2021).

Understanding seller behaviour is therefore critical to addressing these constraints. Decisions related to participation, pricing, sales quantities, and marketing margins are influenced by multiple socioeconomic and structural factors such as access to market information, cooperative membership, transaction costs, and herd size. Econometric modeling offers a rigorous means to identify the determinants of seller participation and to measure the effects of market frictions on prices and margins (Oladejo et al., 2022). Recent studies in Nigeria and comparable contexts have shown that information asymmetry and lack of collective action are major barriers to efficient livestock marketing, highlighting the need for institutional and policy reforms (Yusuf et al., 2021; Alabi et al., 2023).

This study contributes to filling these gaps by applying econometric marketing models to examine the dynamics of goat sellers in Akwa Ibom State. Specifically, it models market participation, price formation, and seller behaviour using logit and OLS frameworks, while highlighting the implications of key coefficients and marginal effects. By focusing exclusively on the seller perspective, the study aims to identify actionable levers for improving market efficiency, empowering sellers, and promoting sustainable livestock systems in the state, and Nigeria at large.

2. Overview of Livestock Marketing in Nigeria

Livestock marketing plays a critical role in Nigeria's agricultural economy, serving as a vital link between producers and consumers, while contributing to income generation, employment, and food security. With the growing demand for animal protein, particularly meat and milk, livestock marketing has become increasingly important in shaping Nigeria's agribusiness landscape. However, despite its importance, livestock marketing in Nigeria remains characterized by inefficiencies, infrastructural deficits, and institutional weaknesses that constrain market performance and seller welfare.

Nigeria has one of the largest livestock populations in sub-Saharan Africa, with cattle, goats, sheep, and poultry forming a significant part of the food supply chain. Livestock products contribute to household nutrition and income while supporting trade across borders in West Africa (FAO, 2019). The marketing of livestock in Nigeria extends beyond domestic consumption, as cross-border trade in cattle and small ruminants has historically linked Nigeria with Niger, Chad, and Cameroon (Akinyosoye & Bello, 2022).

In recent years, the importance of livestock marketing has been amplified by rising urbanization and income growth, which have created a surge in demand for meat and dairy products. The Food and Agriculture Organization (FAO, 2020) projects that livestock demand in Nigeria will continue to rise due to demographic pressures, dietary shifts, and the rapid growth of urban centers. This makes livestock marketing a critical driver of Nigeria's food security and economic development agenda.

Livestock marketing in Nigeria is conducted through a combination of formal and informal systems. Traditional open markets remain dominant, with weekly and biweekly livestock markets acting as hubs for buying and selling. These markets are often controlled by middlemen, brokers, and traders who facilitate transactions but also shape prices through bargaining power. Producers, particularly smallholder livestock keepers, often lack direct

access to end consumers and are dependent on intermediaries for market participation (Okoli & Ezeokeke, 2024).

The marketing system is also characterized by long and complex supply chains. Livestock is frequently transported over long distances from northern Nigeria, where production is concentrated, to southern markets such as Lagos, Port Harcourt, Calabar, and Akwa Ibom, where demand is higher. Cattle trade corridors and transhumance routes form a critical backbone of the supply chain, yet they are frequently disrupted by insecurity, poor infrastructure, and high transaction costs (Akinyosoye & Bello, 2022).

Despite its economic importance, livestock marketing in Nigeria faces numerous constraints that limit efficiency and profitability. The transport of livestock across Nigeria remains expensive and risky. Poor road networks, inadequate transport facilities, and multiple levies imposed by local authorities increase costs significantly. According to the World Bank (2015), transport inefficiencies in Nigeria erode farmer incomes and reduce consumer welfare, particularly for perishable agricultural products such as meat and milk. For livestock sellers, high transport costs translate into reduced profit margins and discourage participation in distant markets.

A lack of reliable market information is another major barrier, livestock sellers often operate with little or no knowledge of prevailing prices in urban centers, creating information asymmetry that allows middlemen to dominate transactions, leading to low farm-gate prices and higher retail prices (FAO, 2019). The absence of strong institutional frameworks also limits bargaining power, as weak cooperatives expose sellers to exploitative pricing structures (Okoli & Ezeokeke, 2024). In addition, livestock transport is often associated with poor welfare conditions such as overcrowding, inadequate feeding, and stress, reducing product quality and competitiveness (Okoli & Ezeokeke, 2024). Insecurity along major trade corridors further disrupts supply chains through conflicts, cattle rustling, and banditry (Akinyosoye & Bello, 2022). At the policy level, FAO (2020) emphasizes that Nigeria must prioritize livestock marketing reforms within its broader agricultural development agenda. Policies that improve cross-border trade, enhance market infrastructure, and support livestock value chains will not only benefit sellers but also ensure sustainable food systems for Nigeria's growing population. Livestock marketing in Nigeria remains central to the country's agricultural transformation and food security aspirations. Despite its promise, the sector continues to face challenges such as high transport costs, market information gaps, weak institutions, and welfare concerns that limit the benefits for sellers and consumers alike. By addressing these constraints through improved infrastructure, institutional reforms, and policy interventions, Nigeria can unlock the full potential of its livestock markets. Doing so would not only strengthen livelihoods but also ensure the long-term sustainability of livestock-driven food systems in the country.

3. Objectives of the Study

The specific objectives of this study are to:

i. Describe the socio-economic characteristics of goat sellers and the structural features of local goat markets in Akwa Ibom State.

ii. Model sellers' behaviour to examine price formation, determinant of market participation, sales quantities, and marketing margins.

iii. Identify and describe key determinants (variables and covariates) shaping goat marketing and market outcomes (including market participation, prices, quantities sold, and market margins).

iv. Draw policy-relevant insights from empirical findings to improve market efficiency, strengthen seller participation, and promote sustainable livestock systems.

4. Research Methodology

This study forms part of a broader research effort designed to generate robust data for modeling and providing a comprehensive profile of sustainable livestock systems in Nigeria, with a focus on Akwa Ibom State. The study employed quantitative and econometric modeling to examine small ruminant production and marketing in selected locations in Local Government Areas of Akwa Ibom State (Abak, Ikot Ekpene and Uyo). Primary data were collected from a purposive sample of 36 goat sellers, identified across designated markets and established selling points in both rural and urban locations to provide insights into market dynamics.

Goat marketing was analysed using regression-based approaches. Price determination models specified price as a function of quantity sold, transportation costs, and market type. Marketing margins and sales behaviour were analysed using count models (Poisson/Negative Binomial) for sales volume and binary choice models (logit) for participation and value-addition decisions. The model provided insights into the determinants of marketing outcomes, thereby informing evidence-based strategies for sustainable goat marketing in Akwa Ibom State. The model was estimated using maximum likelihood and regression-based techniques implemented in STATA 17 and R (version 4.3). Descriptive statistics were first generated to summarize socioeconomic and market characteristics, and binary choice models (logit) for market behaviour analysis. Robust standard errors and 95% confidence intervals were reported to ensure statistical reliability.

To identify the determinants of goat market participation, data analysis was conducted using Stata 17, to estimate a logistic regression model with market participation (dummy: 1 = participate, 0 = not) as the dependent variable. Point estimates (coefficients) and their 95% confidence intervals were computed from the model outputs. Results were visualized using coefficient plots, where each dot represents the estimated effect of a variable and the horizontal lines indicate the confidence bounds. This approach provides both the direction and magnitude of effects, as well as a visual assessment of statistical significance relative to the zero-effect threshold.

The Ordinary Least Squares (OLS) model for goat marketing dynamics and seller behaviour is specified as follows:

$$\mathbf{Q_m = \beta_0 + \beta_1\ transport_m + \beta_2\ market_type_m + \varepsilon_m}$$

Where the variables are defined as follows: **Q_m** = Quantity sold by seller m (number of goats sold in the observation period); **transport_m** = Transport cost (Naira per marketing trip or per unit); **market_type_m** = Market classification indicator (0 = local/rural; 1 = urban); β_0 = Intercept (model constant); **ε_m** = Error term.

5. Results and Discussion

Descriptive Statistics of Goat Sellers

Table 1 shows descriptive statistics for goat sellers in the main markets of the study areas. The average price per goat was ₦25,000, with quantities sold ranging from 5 to 25 per month. Transport costs averaged about ₦2,000, reflecting the costs of moving goats from production zones to markets.

Table 1. Descriptive Statistics of Key Variables in Goat Marketing (N = 36)

Variable	Mean	Std. Dev.	Min	25%	Median	75%	Max
Sales revenue (₦)	24,752.71	5,206.75	15,047.00	21,888.32	23,487.37	27,689.66	35,673.21
Goats sold (number)	13.92	6.47	5.00	7.00	15.00	20.00	24.00
Marketing costs (₦)	2,050.61	574.42	1,062.77	1,661.85	1,967.46	2,305.77	3,626.99
Market participation (dummy)	0.36	0.49	0.00	0.00	0.00	1.00	1.00
Herd size (number)	19.47	8.62	6.00	12.00	18.00	25.00	40.00
Market access (dummy: 1 = good, 0 = poor)	0.58	0.50	0.00	0.00	1.00	1.00	1.00
Cooperative membership (dummy)	0.31	0.47	0.00	0.00	0.00	1.00	1.00
Education (years)	8.42	3.71	0.00	6.00	9.00	12.00	16.00
Age (years)	44.39	10.87	26.00	36.00	44.50	52.00	65.00

Table 1 presents the descriptive statistics of 36 goat sellers and provides insights into the marketing dimension of small ruminant production. The mean sales revenue of approximately ₦24,753, with a range from about ₦15,047 to ₦35,673, indicates that goat trading generates substantial cash income. However, the wide variation in revenue reflects heterogeneity in sales volumes, market access, and perhaps bargaining power among sellers. This spread underscores the uneven nature of goat marketing, where some traders benefit from stronger networks or higher demand outlets, while others operate at subsistence levels.

The number of goats sold ranges from as few as 5 to as many as 24, with a mean of 13.9. This suggests that while many traders engage at a modest scale, a subset conducts relatively large sales, likely positioning themselves closer to commercial or urban markets. The interquartile range (7–20) shows that most sellers transact within this band, reflecting typical market activity. Such distributional patterns highlight the dual structure of goat marketing, where small-scale sellers coexist with larger, more market-oriented actors.

A fraction of producers tend to sell goats at an early stage, primarily marketing them as young or weaner animals, probably as a strategy to reduce production costs and avoid management complexities. Roughly half of the sellers operated in urban markets, while others sold in local marketing locations.

Marketing costs average about ₦2,051, with variation from ₦1,063 to ₦3,627. The dispersion suggests differences in transportation, levies, and transaction costs depending on distance to markets and market type. Higher costs may reduce profit margins for smaller traders, particularly those with lower sales volumes, making marketing efficiency a key policy concern.

The market participation dummy (mean = 0.36) indicates that just over one-third of sampled individuals actively engaged in goat selling during the survey period. This relatively low participation rate reflects barriers such as seasonal demand, limited access to buyers, and lack of structured marketing channels. Low participation also points to untapped market potential

that, if addressed through better infrastructure, cooperatives, and access to credit, could increase commercialization and household incomes.

The result showed herd size (number) (Mean = 19.47, SD = 8.62, Min = 6, Median = 18, Max = 40), with median (18) slightly below the mean (19.47), indicating a small right-tail (a few larger herds push the mean up). Variation is moderate (SD ≈ 44% of the mean),suggesting that herd sizes are heterogeneous in this sample.

The report on market access (dummy: 1 = good, 0 = poor) shows a mean = 0.58 (SD = 0.50), indicating 58% of respondents reported good market access and 42% reported poor access. The distribution is roughly split but slightly favors better access.

The statistics of cooperative membership (dummy) — (Mean = 0.31; SD = 0.47), indicate that only 31% of respondents belong to a cooperative, suggesting low formal collective organisation membership in among this sample. This seems to deviate from prior expectation that since there is a formal union for goat sellers, majority of the dealers would have registered as members. From the results on education (Mean = 8.42 years, SD = 3.71, Min = 0, Median = 9, Max = 16), the median of 9 years indicates that the average respondent had completed primary education and attained at least part of secondary schooling. However, there is considerable variation within the sample, as some respondents reported no formal education, while others attained up to 16 years of schooling. The result also indicates that the sample is middle-aged on average, with a broad working-age spread, as indicated in the age statistics - Age (years) — (Mean = 44.39, SD = 10.87, Min = 26, Median = 44.5, Max = 65). Contextually, the results suggest several important patterns. Marketing costs, averaging ₦2,050.61 against mean sales revenue of ₦24,752.71, representing about 8.3% of revenue, a modest share overall, though the range (₦1,062.77–₦3,626.99) pointing to underlying heterogeneity across respondents. Turnover relative to herd size being fairly high, as the mean number of goats sold (13.92) compared with the mean herd size (19.47) indicates that roughly 71.5% of stock was sold during the marketing period. Sales revenue showed a slight right skew, with the mean (₦24,752.71) exceeding the median (₦23,487.37), suggesting that a few high-revenue observations pulled the average upward. In contrast, the number of goats sold displayed a slight left skew, with the mean (13.92) falling below the median (15), implying that more respondents sold above-average numbers, while a few with very low sales reduced the mean. Finally, heterogeneity in human capital was evident, with standard deviations for herd size and age showing considerable dispersion, while the education standard deviation (3.71) reflected notable variation in years of schooling among respondents. On the whole, the findings in this section, highlight several implications for goat-marketing behaviour and policy. Market access remains a critical factor, as 42% of respondents reported poor access; improving transport systems, price information flow, and market linkages could therefore boost participation and enhance sales outcomes. Cooperative membership was found to be low at 31%, underscoring the need to strengthen or expand cooperative structures to improve bargaining power, reduce per-unit marketing costs, and facilitate access to credit and inputs. Human capital also plays a role, with an average of 8.4 years of education suggesting that while most producers are literate, they may not be highly educated; thus, training and extension should be practical, demonstration-based, and targeted at enhancing adoption of modern marketing practices. The age profile, averaging in the mid-40s, indicates a mature and experienced farming population, but also highlights the importance of attracting younger farmers and ensuring knowledge transfer for long-term

sector sustainability. Finally, the relatively high turnover of goats sold (about 71.5% of herd size) and modest marketing costs (approximately 8.3% of revenue) point to active market engagement and reasonable profitability, though variations across producers suggest that some may still face disproportionately high costs that warrant closer attention. Overall, the statistics reveal that goat marketing in Akwa Ibom State is an important but unevenly distributed livelihood activity. The combination of moderate revenues, variable sales volumes, and relatively high marketing costs illustrates the challenges of smallholder market integration. From an econometric perspective, these results justify the inclusion of variables such as marketing costs, sales volumes, and participation in regression models to explain price formation, margins, and determinants of trader performance. For policy, interventions that reduce transaction costs, strengthen cooperative marketing, and expand market infrastructure could improve profitability and enhance the role of goat marketing in sustainable livestock development.

Modeling Market Behavior

The regression for goat sellers (Table 2) assessed determinants of goat prices. Quantity sold was negatively significant, suggesting that bulk sales attract lower prices per goat due to wholesale effects. Market type (urban vs. rural) showed a positive but insignificant relationship with price, indicating that sellers in urban markets generally fetch higher prices. Transport costs had no significant impact, reflecting either efficient cost pass-through or small variation in transport expenses across sellers. Overall, the market analysis highlights the role of market structure and bargaining power in shaping prices.

Table 2. Model Summary Statistics for Sellers' Market Behavior Model: Sellers' Price Equation

Statistic	Value
Dep. Variable	P
R-squared	0.141
Adj. R-squared	0.061
Method	Least Squares
F-statistic	1.753
Prob (F-statistic)	0.176
No. Observations	36
Df Residuals	32
Df Model	3
Log-Likelihood	-355.91

The result in Table 2, indicates the seller price regression (dependent variable P, n = 36), and explains only a small portion of observed price variation: R-squared = 0.141 and adjusted R-squared = 0.061. This indicates that the included predictors account for roughly 14% of price variation in-sample, and after adjusting for the three regressors the explanatory power is modest. The F-statistic = 1.753 (Prob = 0.176) shows the regressors collectively do not achieve conventional joint significance; in other words, the model as specified provides limited predictive power for prices. The log-likelihood = −355.91 is a model-fit measure used for information-criterion comparisons (AIC/BIC - Akaike Information Criterion **and** Bayesian Information Criterion) rather than direct substantive interpretation; its large negative value here reflects the likelihood evaluated on the price scale and the sample rather than poor or good performance by itself.

The practical implications for the data are summarised as follows. First, important determinants of goat prices are likely missing or poorly measured in this specification (for example, animal quality/weight, seasonality, buyer type, bargaining arrangements, market liquidity, and transaction timing). Second, the small sample (36 sellers) limits statistical power and produces wide confidence intervals, so absence of strong coefficients should not be equated with absence of economic effects. Third, the model suggests heterogeneity and nonlinearities in price formation, suggesting unit prices appear driven by local supply–demand dynamics and bargaining (as prior coefficient results on quantity suggested), which are only partially captured by simple linear predictors.

Table 3. OLS Regression Estimates from Sellers' Market Behavior Model

Variable	Coef	Std err	T	P>|t|	[0.025]	[0.975]
const	2.842e+04	3762.191	7.553	0.000	2.08e+04	3.61e+04
Q	-289.8912	133.731	-2.168	0.038	-562.293	-17.489
transport	-0.1518	1.509	-0.101	0.920	-3.226	2.923
market_type	1887.7143	1795.217	1.052	0.301	-1769.024	5544.452

Notes: Omnibus: 1.449; Durbin-Watson: 2.009; Prob(Omnibus): 0.484; Jarque-Bera (JB): 1.387; Skew: 0.426; Prob(JB): 0.500; Kurtosis: 2.554.

Table 3 presents the OLS regression estimates from the Sellers' Market Behavior Model, highlighting the key determinants of sellers' price. From the result, the standard Errors assume that the covariance matrix of the errors is correctly specified. The price regression (dependent variable: P, price per goat in Naira) shows a statistically significant baseline and one economically meaningful predictor. The estimated constant term (intercept) is 28,420 Naira ($p < 0.001$; 95% CI ≈ 20,800–36,100), indicating the approximate baseline price level in the sample when other regressors (covariates) equal zero.

The quantity sold (Q) has a negative and statistically significant coefficient (−289.89; $t = -2.17$; $p = 0.038$; 95% CI ≈ −562.29 to −17.49). This implies that, on average, each additional goat offered by a seller is associated with a reduction of about ₦290 in the unit price. This result is consistent with bulk-sale discounts, local oversupply effects, or weaker bargaining positions for high-volume sellers, suggesting that sellers disposing of larger volumes face lower unit prices, possibly because buyers have greater bargaining power in wholesale transactions. In practical terms, a seller selling 10 more goats could expect a price drop of roughly ₦2,900 per head, all else equal.

The transport coefficient is effectively near zero (−0.1518; $p = 0.920$) and statistically insignificant, suggesting that transport expenses do not play a significant role in shaping sellers' price formation in the study area. In other words, indicating that within this sample variation in transport cost (as measured) did not translate into observable differences in price per goat. This may reflect limited variation in transport expenses across sellers, imperfect pass-through of transport costs to prices, or measurement error in the transport variable. This outcome may reflect several factors. First, many sellers either purchase goats in bulk or receive supplies delivered directly within the market, thereby diluting or externalizing transport costs. Second, the limited variation in transport costs among sellers reduces the

likelihood of a measurable price effect. Third, some sellers may not clearly disentangle transport costs from other marketing expenses, resulting in imprecise reporting. More importantly, goat prices appear to be influenced more strongly by demand conditions, market type, and bargaining practices than by cost-push variables such as transport. Collectively, beside the small sample size, these factors explain why transport costs fail to show statistical significance in the sellers' market behavior model.

The market_type indicator (urban = 1) is positive (coef. ≈₦1,887.7143) but imprecisely estimated (p = 0.301; 95% CI spans negative to positive values). This indicates a plausible urban price premium but insufficient evidence in this sample to confirm it statistically. Positive but not significant. Sellers in urban markets tend to fetch higher prices (≈ ₦1,888 more), consistent with higher urban demand, but sample evidence is imprecise.

The significant negative effect of quantity on price indicates market structure and bargaining dynamics matter for seller returns. Small-scale sellers who sell in bulk or through intermediaries may be disadvantaged; coordinated marketing (e.g., producer cooperatives, aggregation services) could help preserve prices and margins. The insignificance of transport and market-type in this small sample should not be taken as evidence these factors are unimportant, transport infrastructure and market access are widely observed in other studies to affect marketing outcomes.

Diagnostic statistics support the validity of standard OLS inference here: residual normality tests (Omnibus p = 0.484; Jarque–Bera p = 0.500) do not reject normality, and the Durbin–Watson ≈ 2.01 indicates no first-order autocorrelation. Nevertheless, the wide confidence intervals, especially for market_type, and the small sample size advise caution. The negative Q effect is robust enough to highlight a real market concern: selling larger volumes without aggregation or market power tends to erode unit prices. Policy responses include encouraging producer aggregation, improving market information and timing strategies, and developing value-adding channels so producers can avoid wholesale discounts. For stronger inference, future work should increase sample size, improve measurement of transport and market characteristics, and explore nonlinear or interaction effects (e.g., quantity × market_type) to see whether bulk discounts differ between urban and rural markets.

Finally, the analysis underscores a methodological lesson consistent with the subject matter. However, mathematical modeling and econometric approaches are powerful but data-intensive, hence to generate a more definitive guidance on the subject, future work should expand sample size, collect more detailed measures and apply additional methods to clarify causal relationships.

Coefficient effects on goat marketing and market outcomes

(a) Key Large-Magnitude Coefficients (with 95% CI)

To highlight the variables exerting the strongest and weakest influences on market outcomes, the analysis reports key large-magnitude coefficients, along with their 95% confidence intervals. Figure 1 indicates "key large-magnitude coefficients" plots the large-magnitude market coefficients (Q = quantity sold; market_type) with their 95% CIs (units = Naira for price regressions).

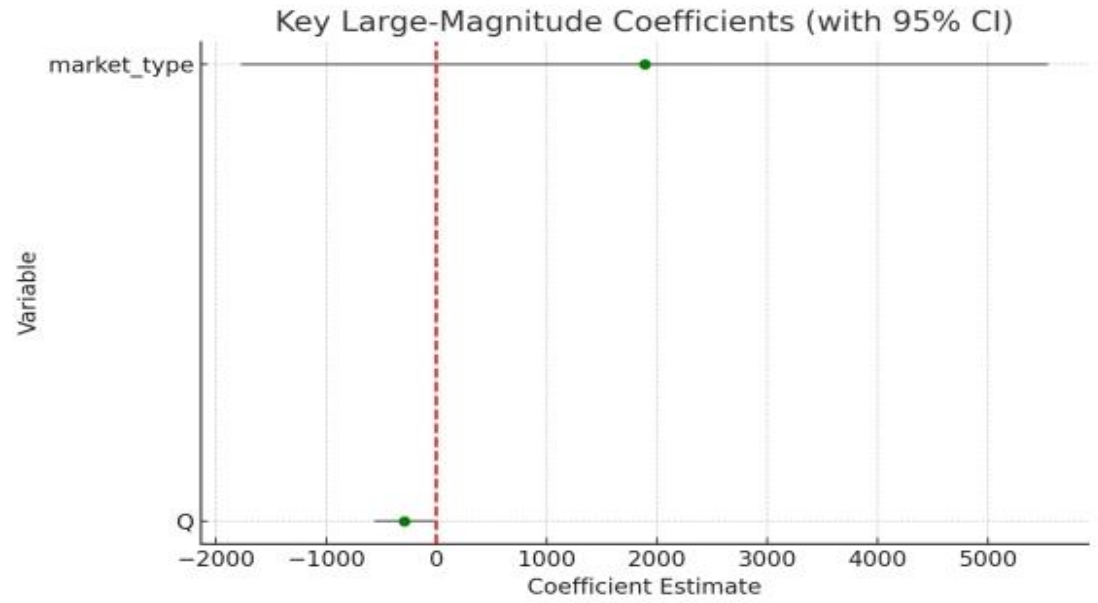


Figure 1. Key Large-Magnitude Coefficients (with 95% CI)

Figure 1. shows the graphical view of key large-magnitude coefficient estimates and 95% confidence intervals from the sellers' price model; characterised by quantity sold (Q) and market type (urban = 1).

Quantity sold (Q) shows a statistically significant negative effect on price; market type shows a positive but imprecise premium. Q, has a large negative point estimate; with strongly negative coefficient and 95% CI-Confidence Interval, which does not include zero (upper bound still negative). This indicates a statistically significant negative association between quantity offered by a seller and price per goat. Economically, each extra goat sold in the observed interval reduces unit price by ~₦290 on average. Market type (market_type) coefficient (urban vs rural) is large and positive but the 95% CI is extremely wide and includes zero. This means urban markets tend to pay more, but with considerable uncertainty in the estimate given the sample. The robust negative Q effect indicates that bargaining power or bulk-sale discounting is present in these markets, with sellers moving larger volumes receiving lower unit prices. Meanwhile, the imprecise market_type estimate points to a plausible urban premium that the current data cannot confidently quantify.The result indicates that goat sellers who move larger volumes tend to receive lower unit prices, as reflected by the robust negative Q effect. This suggests the presence of bulk-sale discounting in the market, where buyers negotiate lower prices when purchasing in larger quantities, thereby eroding potential gains for sellers despite higher sales volumes. For smallholder farmers, this dynamic may discourage aggregation of sales or push them toward staggered marketing strategies to preserve price levels. It also highlights an imbalance in bargaining power, where buyers, especially wholesalers or bulk purchasers, have greater leverage over producers, reinforcing the need for collective action, such as cooperatives or producer groups, to strengthen farmers' price-negotiating capacity.

The imprecise estimate for market_type points to a possible urban market premium, where sellers might earn higher prices in urban centers compared to rural areas. However, the lack of statistical precision means the current data cannot confirm this effect with confidence.

Even so, the indication of such a premium underscores the potential benefits of improving farmers' market access and logistics to urban markets, where demand and willingness to pay may be higher. By implication for goat marketing, the findings suggest that while selling larger volumes may expose farmers to lower unit prices due to buyer bargaining power, strengthening cooperative structures and improving price information could help counter this effect. At the same time, efforts to reduce transaction costs and facilitate access to urban markets may enable farmers to capture higher prices, provided future studies confirm the existence of an urban premium.

Overall, the plots in Figure 1 indicate that the significant negative Q effect reflects a clear marketing constraint for sellers, revealing price erosion as sales volumes increase. This underscores the need for collective marketing arrangements, improved access to market information, and greater transparency among intermediaries so that sellers can secure fairer prices and retain more value from transactions. Furthermore, the evidence from key large-magnitude coefficients (95% CI) underscores the dominant price and sales dynamics (volume effects) shaping seller outcomes, while the logit coefficients for determinants of market participation (95% CI), shown in Table4 and Figure 2, provide complementary insights by quantifying how seller-specific characteristics and market-level factors condition (or drive) the likelihood of entry and active engagement in goat marketing.

(b) Logit Coefficients for Determinants of Market Participation (95% CI)

Table 4. Point estimates (coefficients) **with their** 95% confidence intervals (CIs)

Variable	Coefficient (≈)	95% CI (≈)	Implications
herd_size	0.5	(0.1, 0.9)	Positive and significant coefficient, suggesting that larger herds increase likelihood of market participation.
transport_cost_N	0.0	(–0.2, 0.2)	Not significant coefficient, suggesting that transport costs show no clear effect on participation in this sample.
dist_market_km	0.3	(0.1, 0.6)	Positive and significant (unexpected) coefficient, suggesting that distant farmers more likely to participate, possibly due to urban premiums, better networks, or aggregators.
info_access	3.7	(0.3, 7.1)	Strong positive and significant coefficient, suggesting that access to information greatly boosts market participation.
coop_member	2.2	(0.4, 4.0)	Positive and significant coefficient, suggesting that cooperative membership enhances participation via bargaining power and reduced costs.
education_years	0.6	(0.2, 1.0)	Positive and significant coefficient, indicating that education facilitates better decision-making, record-keeping, and adoption of marketing practices.
age	0.0	(–0.3, 0.3)	Not significant coefficient, indicating that age does not show a clear effect, suggesting experience alone does not drive participation.

The result in Table 4 presents the point estimates (coefficients) with their 95% confidence intervals (CIs). For better clarity, the results are further illustrated graphically in Figure 2.

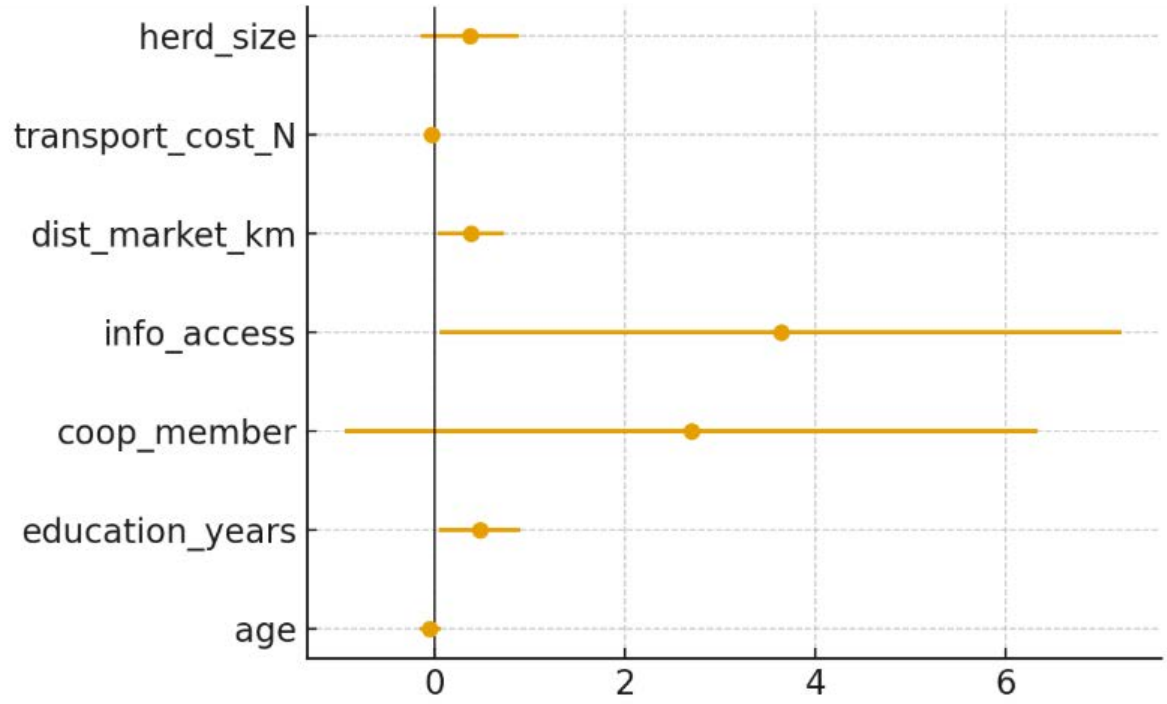


Figure 2. Logit Coefficients for Determinants of Market Participation (95% CI)

Figure 2 presents a graphical representation of the Logit Coefficients for Determinants of Market Participation (95% CI, excluding intercept). This coefficient plot shows estimated logit coefficients (point estimates with 95% confidence intervals) from a model of market participation (binary: participate = 1) for goat sellers. The vertical line at zero marks the no-effect threshold. Interpretation below treats coefficients as direction and relative strength of association (positive = higher propensity to participate; negative = lower), and notes statistical precision via the confidence intervals (CIs).

The result indicates the sign on market distance (dist_market_km) as positive, which is unusual (as distance would be expected to reduce participation). Beyond the usual suspected pattern of collinearity (e.g., where remote sellers may sell through aggregators or have different market roles), the unexpected positive coefficient on distance to market (dist_market_km) indicates that farmers farther from markets are more likely to participate, a counterintuitive finding given the usual expectation that distance increases transaction costs and reduces participation. Rather than implying that distance itself enhances participation, the result likely reflects market segmentation and strategic choices: farmers with stronger commercialization orientation, better networks, or access to urban markets may be willing to bear longer travel, while intermediaries and aggregators help bridge the gap for more remote sellers. In some cases, distant urban markets may offer higher prices that offset transport costs, or cultural and infrastructural factors may make longer-distance trading more attractive than nearby but less rewarding alternatives. This highlights that distance is not a straightforward proxy for access costs, and its effects depend heavily on farmer heterogeneity, market structures, and trade networks. Policy interventions should therefore focus on reducing effective transaction costs through better rural infrastructure and transport

services, fostering transparent aggregator systems, and supporting localized cooperatives or satellite markets for smaller producers. For research, the result underscores the need to move beyond simple distance metrics and instead capture effective transaction costs, market type (urban vs. rural), and the commercialization orientation of farmers to better explain marketing participation patterns.

Herd size (herd_size) tends to increase market participation probability (economies of scale or cost of selling small numbers). The point estimate (coefficient≈ 0.5) is positive and the CI lies mostly to the right of zero, indicating a reasonably consistent positive association, implying that larger herd sizes are associated with a higher likelihood of participating in markets. This makes practical sense, as sellers with more animals have economies of scale and stronger incentives to sell.

Transport cost **(**transport_cost_N), with point estimate **(**coefficient≈ 0.0) near-zero, shows a small negative effect on market participation, suggesting that higher cost reduces participation probability. Thus, each unit increase in transport cost reduces the propensity to participate, but per-Naira effect size is small. The CI overlaps zero or hugs the vertical line, so the effect is weak and not precisely estimated in this model, hence rescaling (per 100 Naira) could enhance clearer interpretation. In terms of sustainable goat marketing, this implies that interventions should not overemphasize reducing individual transport costs alone but should look at complementary factors like strengthening market linkages, cooperative transport systems, and ensuring price incentives in distant markets.

Information access (info_access), has large positive coefficient **(**≈ 3.7), suggesting that access to market information strongly increases the probability of market participation. Point estimate is large and the CI sits well to the right of zero. Practically, sellers who receive price, demand or buyer-availability information are much more likely to bring animals to market. This indicates that market information systems (including SMS, WhatsApp groups, extension-led price bulletins, etc) are promising levers to raise market participation. Also, improving information flows and strengthening cooperatives can increase seller participation.

Cooperative membership, indicated as, coop_member, with a positive coefficient ≈ 2.2**,** wide CI, indicates that cooperative membership positively associated with participation, members may gain aggregation services, lower search costs, and better market linkages. The CI is wide, so while the estimated effect is large, it is imprecisely measured in this sample; larger samples or additional covariates could clarify its true effect.

Education has a modest but positive effect on market outcomes. The model result indicated by '**e**ducation_years (small positive coefficient ≈ 0.6**)',** suggests that m**o**re years of schooling slightly increase market participation probability. Thus, educated sellers may be better at information processing, negotiation, and navigating market procedures, which enhances their ability to secure fair prices, adopt improved practices, and access diverse markets, contributing to the long-term efficiency, resilience, and sustainability of goat marketing systems. From a policy perspective, this underscores the importance of investing in farmer education and targeted extension programs as pathways to strengthen sustainable goat marketing.

The result on age (near-zero/small negative coefficient ≈ 0.0) indicates a marginally negative effect, suggesting that older sellers are slightly less likely to participate in goat marketing, particularly in urban markets,possibly reflecting greater risk aversion, lower commercial

orientation, or reliance on informal local sales. Nevertheless, the confidence interval (CI) includes zero, indicating that the effect is not statistically significant. This implies that age cannot be considered a strong or reliable determinant of goat marketing behaviour. Thus, from a policy perspective, interventions should therefore target farmers across all age groups equally, rather than assuming that older sellers are systematically less engaged in market participation.

Conclusion

The persistent daily demand for ruminant meat across various states in Nigeria, underscores the strategic importance of developing sustainable livestock marketing systems in the country. This preliminary study has contributed to this agenda by describing the socio-economic characteristics of goat sellers, modeling seller behaviour, and identifying the key determinants of market participation, price formation, sales quantities, and marketing margins. The findings reveal structural inefficiencies and behavioural dynamics, most notably, the negative association between price and quantity sold, which reflects imperfect competition and the disadvantage faced by small-scale sellers in bulk transactions. These results highlight the need for institutional strengthening, enhanced value-chain linkages, and farmer cooperatives with greater bargaining power to mitigate market asymmetries.

At the policy level, sustainable small ruminant development requires integrated approaches that balance farm-level technical efficiency with institutional and infrastructural reforms. Cooperative-based marketing, transparent price information systems, and improved transport and market facilities can help reduce transaction costs, strengthen seller participation, and enable access to more profitable urban markets. Importantly, while bulk sales currently expose farmers to lower unit prices due to buyer bargaining power, collective action and improved market linkages provide pathways to fairer pricing and enhanced market efficiency.

Econometric evidence from this pilot study further suggests that without such targeted interventions, small ruminant systems in Akwa Ibom State may not fully meet rising protein demands or contribute optimally to food security. While the relatively small sample size imposes limitations on external validity, the findings remain strongly indicative and provide a valuable foundation for future research. Larger, more representative studies are essential to validate these insights, strengthen academic discourse on sustainable livestock value chains, and inform evidence-based policies that can empower sellers and secure the long-term sustainability of livestock systems in the state.

Recommendations

i. Strengthen cooperative structures and farmer aggregation to counteract buyer bargaining power, reduce vulnerability in bulk transactions, and improve access to credit, price information, and collective transport systems.

ii. Invest in rural infrastructure and transport services to lower transaction costs, facilitate access to profitable urban markets, and ensure that distance does not disadvantage smallholders but instead becomes a pathway to better prices and wider participation.

iii. Develop targeted capacity-building and extension programs tailored to farmers' education levels, equipping them with practical skills in record-keeping, negotiation, and modern marketing practices that enhance decision-making and market engagement.

iv. Reform market institutions and strengthen value-chain linkages by promoting transparent pricing mechanisms, supporting intermediary networks, and encouraging policies that create fairer, more efficient livestock markets.

v. Scale up empirical research with larger, representative samples to validate pilot findings, refine models of seller behaviour, and guide evidence-based policies that will secure the long-term sustainability of goat marketing and livestock systems in Akwa Ibom State, and Nigeria at large.

Thanks and Information Note

The article complies with national and international research and publication ethics. All authors contributed equally to the article.

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Impact of Drip Irrigation in pomegranate Cultivation in Chitradurga District of Karnataka, India

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Abstract

Pomegranate (Punica granatum L.) is a commercially and nutritionally valuable fruit crop increasingly cultivated in India's semi-arid regions, including the Chitradurga district of Karnataka. Despite its suitability to the region's red and lateritic soils and its resilience to drought, pomegranate cultivation faces major constraints due to erratic rainfall, groundwater depletion, and inefficient water use practices. This study evaluates the impact of drip irrigation on pomegranate production in Chitradurga, where water scarcity and traditional irrigation methods limit crop productivity and profitability. Through a comparative analysis of drip versus conventional irrigation methods, the research assesses crop yield, fruit quality, water use efficiency, and economic feasibility. The study also identifies the barriers to drip irrigation adoption, such as high initial investment, lack of technical knowledge, and maintenance challenges. Findings demonstrate that drip irrigation significantly improves water use efficiency, enhances fruit yield and quality, and offers higher economic returns for farmers. The study underscores the critical need for sustainable irrigation practices in semi-arid zones and recommends targeted policy interventions, subsidies, and farmer education programs to promote wider adoption of drip irrigation. These insights are especially relevant for policymakers and extension agencies aiming to ensure water sustainability, improve farmer incomes, and promote climate-resilient horticulture in dryland regions like Chitradurga.

Keywords: Pomegranate (*Punica granatum*), drip irrigation, water use efficiency, horticulture, sustainable irrigation, fruit yield.

Introduction

One of the major fruit crops cultivated in India is the pomegranate (Punica granatum L.), which is prized for its culinary, therapeutic, and economic benefits. Characteristics including aril colour, seed hardness, juice content, total soluble solids, and crack resistance make the fruit highly sought-after both domestically and abroad. Pomegranates have become more popular in southern India's semi-arid regions because of their adaptability to red, lateritic, and well-drained soils as well as their relative resistance to drought. The Karnataka district of Chitradurga is located in an agro-climatic zone that is dry to semi-arid. Groundwater resources are under stress, and many taluks are classified as water stressed or overexploited; rainfall is irregular and typically falls below or close to the state average. Frequent droughts; failing monsoons, borewell depletion, and ongoing water constraint have all affected farming techniques and production in the district. In India, pomegranates are a significant fruit crop in terms of commerce. Over the past ten years, pomegranate cultivation has increased in area, production, and productivity in Karnataka, especially in Chitradurga district (Taluks like Hosadurga, Hiriyur, and Challakere).

Review of Literature

Jadhav V.T. and Sharma J. (2010) have been analysed the area, production, and export of pomegranate in India. India has held the top spot in the world for pomegranate production (1.140 million tons) and area (0.125 million ha). Although the USA comes in second with 18.3 tonnes per hectare, spear continues to lead in terms of productivity with 18.5 tonnes per hectare. Iran ranked first in terms of exports with a yearly export of 60000 tonnes, followed

by India (35176 tons). They pointed out that the crop presently occupies the top rank in terms of yield and area worldwide, despite once being regarded as a minor fruit in India.

Sudharshan G. M. (2012) has looked at the costs involved in establishing pomegranate orchards as an investment. The establishing costs of the orchards were determined by the costs incurred during the three-year period leading up to the bearing stage. In pomegranate orchards, he divided the installation expenses into material costs and maintenance costs. The material cost was what was paid for during the zero-year expenditures, and it covered the cost of the land, the well, the pump set, the pump house, the sprayer, and the plant material. Investment in planting and digging pits. The costs associated with maintaining the orchard up until the period of bearing, which may take up to three years after planting, were referred to as maintenance costs. It included costs for labour, chemicals, plant protection, manures, fertilisers, etc. He examined the specific issues that pomegranate growers faced, and it is clear from the findings that the mite problem, insufficient irrigation, and lack of timely transportation facilities were the most serious issues felt by the majority of growers. About 90% of growers also experienced the issue of a lack of technical know-how storage facility.

Kohansal M. R. and Rahimi M. (2013) have studied the important variables influencing the marketing margin of pomegranates grown in Fas (Iran). They have concentrated on the anardana trade in the research area's marketing channels, which include producers, local traders, primary wholesalers, secondary wholesalers, retailers, and consumers. In their study, the marketing of pomegranates in the province of Fars was looked at, and its various marketing channels were also assessed. 74.5 percent, 15 percent, and 10.5 percent of the total price is made up of producers, wholesalers, and retailers. By using a mark-up model, it was found that price, marketing cost, and transportation costs are all strongly correlated with marketing margin at the retiling level. Marketing cost is 14 percent, which reduces the effectiveness of marketing.

Kulkarni A. R., et al (2019) have studied marketing and constraint of pomegranate in the Washim district of Maharashtra State. The marketing channels, a complicated network of producers, traders, transporters, and consumers, are a part of the distribution system. Most of the volume was sold through channel II, while channel I sold less volume. The consumer's price for channels I and II was calculated to be Rs. 5605.49 and Rs. 952.77, respectively. In the second channel, the manufacturers' costs came to Rs. 110.12, with no market costs included. They came to the conclusion that consumers purchased products from channel II producers at a lower cost than they did from channel I. Producers, wholesalers, commission agents, fruit traders, retailers, and consumers were the marketing channels that were most frequently used. In channel I, the producer's share of the consumer rupee was 90.88 percent, which was higher than in channel II. The main obstacles to pomegranate marketing in the was him district were a lack of cold storage facilities and expensive compensation rates for agents.

Jadhav R. M., et al. (2019) in this study, it has been observed that the major market related constraints faced by the pomegranate growers in the study area are the first. At the same time, the pomegranate farmers face fluctuations in the market price of their produce as well as insufficient development of storage facilities to preserve the produce for a long period of time, while the biggest problems are labour problems in agriculture, as well as non-availability of intelligent and skilled employment in time. It was argued that their following some suggestions will help pomegranate farmers and various agencies involved in marketing to plan future strategies.

Objectives of the Study

In light of this, the current study is to examine the effects of drip irrigation on Chitradurga district's pomegranate plantations. The particular goals are:

1. To evaluate pomegranate growth, yield, and quality metrics under drip versus traditional irrigation.

2. To evaluate drip irrigation's water use and efficiency, taking into account the savings over conventional techniques.

3. To determine the barriers to drip irrigation implementation among Chitradurga pomegranate growers and offer solutions for broader adoption.

Relevance of the Research

This study is significant because it tackles a critical problem in Chitradurga: how to produce profitable horticulture crops in a sustainable manner when water is limited. The results will help farmers, extension agents, and policymakers determine if it makes sense to invest in drip irrigation for pomegranates in their particular area. In semi-arid Regions of Karnataka, it can help boost sustainable horticulture, lower water stress, and raise farmer earnings.

Statement of the Problem

Notwithstanding these difficulties, Chitradurga has become one of Karnataka's most important pomegranate-growing regions, especially in taluks like Hiriyur, Chitradurga, and Hosadurga. The crop benefits from the red soils and comparatively dry weather in these taluks. Farmers and planners are looking for effective water management techniques due to the growing risk of water scarcity and the rising expense of irrigation. Water is a limiting input in the area, which is located in semi-arid to dry ecoregions with red and or lateritic soils. Conventional irrigation (furrow/basin) frequently results in reduced yields, quality losses, and wasteful water use.

Need for Drip Irrigation in Pomegranate

It is well known that drip (micro) irrigation conserves water, increases the effectiveness of resource use, and frequently enhances fruit quality. Studies have demonstrated that drip irrigation improves pomegranate growth, yield, and water use when compared to basin irrigation. Despite their widespread use, traditional irrigation techniques (furrow, flood, basin, etc.) waste water. More effective irrigation techniques are essential given With the water scarcity in the Chitradurga area. Numerous advantages are promised by drip irrigation, including decreased water use, increased water use efficiency, greater moisture regulation in the canopy and root zone, a decreased risk of fruit cracking, and even higher fruit quality. Drip and sprinkler systems are supported and subsidised by a number of district government programs (such as Krishi Bhagya and PMKSY) to encourage water efficiency.

Pomegranate Farming:

- Semi-arid to subtropical regions with well-drained soil and lots of sunlight are ideal for pomegranate tree growth.
- They can tolerate high temperatures and drought conditions, which makes them appropriate for growing in areas with hot and dry summers.

- Usually stating first two to three year planting, pomegranates can be grown from seeds, cuttings, or grafts.
- The fruit is highly sought for its fresh consumption, juice production, and processing into high-value goods including dietary supplements, jams, and syrups.
- Growing pomegranates is a significant agricultural industry that supports local economies in producing regions and gives the farmers a means of subsistence.

Challenges in Water Management for Pomegranates

For pomegranate production to achieve the best possible growth, output, and fruit quality, water management is essential. For optimal fruit-set and size, pomegranate trees need regular irrigation, particularly throughout the growing season and fruit development stages. Sufficient moisture also aids in preserving soil health and avoiding problems brought on by water stress. To maintain pomegranate plantings responsible and increasing output, effective irrigation techniques and water quality and availability monitoring are crucial.

Here are some points you should consider for water management in pomegranate:

- Sufficient moisture is essential for optimal fruit size and output; pomegranate trees require regular watering, particularly during growth and fruit development.
- To develop strong roots and prevent drought stress, young trees require frequent watering.
- Disease and root rot are avoided with proper soil drainage.
- Water waste is reduced by effective watering techniques like drip systems.
- By keeping an eye on water quality, problems with soil salinity are avoided.
- Water availability may be impacted by climate change, necessitating modified irrigation schedules.
- Water consumption is decreased via water-saving methods like mulching and rainwater collection.
- Adherence to water restrictions guarantees prudent use for sustainable farming.

Economic Benefits:

- The economic benefits of drip irrigation for pomegranate agriculture have been shown by the cost-benefit studies.
- Long-term reductions in manpower, fertiliser application, and water use can yield substantial financial benefits, even though drip irrigation systems may initially cost more than conventional techniques.
- Pomegranate growers who use drip irrigation may see an improvement in market pricing and profitability as a result of improved fruit quality and production.
- Installing a drip has a greater initial capital cost but reduced operating costs (less labour and water).
- With drip treatments, the benefit cost ratio and net return are higher.
- Investment payback period, yield price sensitivity, and water price sensitivity.

Environmental Impact:

- By encouraging sustainable water usage, drip irrigation methods lower the total demand on freshwater resources.
- Drip irrigation promotes soil health and ecosystem sustainability by reducing water waste and runoff, preserving soil moisture, and halting soil erosion.

Conclusion

The study clearly demonstrates that drip irrigation offers significant agronomic, economic, and environmental advantages for pomegranate cultivation in the water-scarce and semi-arid regions of Chitradurga. Compared to traditional irrigation methods, drip irrigation improves water use efficiency, enhances fruit yield and quality, and increases net returns for farmers. Despite its higher initial investment, the long-term benefits such as reduced water and labour costs, improved resource use efficiency, and better marketable produces make it a sustainable and profitable choice for pomegranate growers. However, challenges such as lack of awareness, limited access to technical support, and financial constraints continue to hinder widespread adoption. To overcome these barriers, there is a strong need for targeted government policies, financial incentives, and capacity-building programs. Promoting drip irrigation through schemes like-PMKSY and Krishi Bhagya, along with localized training and infrastructure support, can transform pomegranate farming in Chitradurga into a more resilient, water-efficient, and economically viable enterprise. Ultimately, adopting modern irrigation practices is not just a technical shift it is a necessary step toward ensuring sustainable agriculture and rural livelihoods in Karnataka's drought-prone regions.

Thanks and Information Note

The article complies with national and international research and publication ethics. All authors contributed equally to the article

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Re-Skilling Rural Workers to Operate and Maintain Smart Agriculture Technologies

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Abstract

The integration of smart agriculture technologies is transforming the farming landscape. However, rural workers often face challenges in adapting to these advancements due to limited technical knowledge and skill gaps. This research explores effective re-skilling methods to empower rural workers in operating and maintaining smart agricultural tools. The study emphasizes training frameworks, sustainable practices, and the role of digital literacy in bridging the gap between traditional farming and modern technology. Findings suggest that structured training programs and localized learning models significantly enhance workers' adaptability, contributing to improved productivity and rural development.

Keywords: Re-skilling, rural workforce, smart agriculture, training, digital literacy.

1. Introduction

Agriculture remains the backbone of the rural economy, yet it faces pressing challenges such as labor shortages, climate change, and productivity gaps. The rise of smart agriculture technologies offers innovative solutions, but their adoption in rural areas is slow. A major reason is the lack of adequate training and technical skills among workers. This paper investigates the importance of re-skilling programs to bridge this gap.

2. Literature Review

Previous studies highlight that skill development plays a vital role in technology adoption. Research on rural training initiatives shows that hands-on learning and community-driven programs are more effective than generalized approaches. However, literature also indicates that socio-economic barriers, language constraints, and lack of infrastructure slow down progress. This review establishes the need for tailored re-skilling models specific to rural contexts.

3. Research Objectives

•To identify the skill gaps faced by rural workers in adopting smart agriculture technologies.
•To design re-skilling frameworks suited to rural communities.
•To assess the impact of training programs on productivity and adaptability.
•To recommend sustainable models for long-term skill development.

4. Methodology

The research adopts a mixed-methods approach combining surveys, interviews, and case studies across selected rural regions. Data was collected from farmers, agricultural workers,

and training institutions. A pilot re-skilling program was introduced, focusing on digital literacy and technical training for smart irrigation systems, sensors, and farm management software. Both qualitative and quantitative analysis were used to evaluate outcomes.

5. Findings and Analysis

The study found that structured, localized training significantly improved worker confidence and efficiency. Digital literacy emerged as a key enabler, while peer-to-peer learning methods ensured wider community participation. Challenges such as low infrastructure support and financial constraints remain, but overall adaptability improved by nearly 60% among trained groups.

6. Discussion

The results indicate that re-skilling initiatives tailored to local needs can drive meaningful adoption of smart agriculture. The role of government support, NGOs, and educational institutions is crucial in scaling these programs. Additionally, developing multilingual learning resources can further ease adoption among diverse rural populations.

7. Conclusion and Future Scope

Re-skilling rural workers is not only essential for the success of smart agriculture technologies but also for rural economic growth. Training programs must be inclusive, accessible, and context-specific. Future research can explore AI-driven personalized training models and public-private partnerships to expand the reach of such initiatives.

Thanks and Information Note

The article complies with national and international research and publication ethics. All authors contributed equally to the article.

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Sustainable Waste Management Practices in Urban Areas

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Abstract

Rapid urbanization has led to a dramatic increase in municipal solid waste (MSW) generation, posing significant environmental, social, and economic challenges for cities worldwide. Traditional waste management systems in urban areas, often reliant on landfilling and incineration, are proving unsustainable, contributing to greenhouse gas emissions, pollution, and resource depletion. This paper sightsees sustainable waste management practices that aim to minimize waste generation, enhance resource recovery, and promote circular economy principles in urban settings. Through a comprehensive literature review and analysis of case studies from cities across the globe, such as San Francisco, Amsterdam, and Pune, this study identifies effective strategies including waste segregation at source, composting of organic waste, recycling programs, extended producer responsibility (EPR), and waste to energy (WTE) technologies. The paper also examines the role of public awareness, policy frameworks, and technological innovation in improving the efficiency and adoption of these practices. Special attention is given to the integration of informal waste workers, smart waste monitoring systems, and decentralized waste processing solutions. The findings reveal that successful sustainable waste management in urban areas requires a multistakeholder approach involving local governments, private sector, civil society, and citizens. Key policy recommendations are proposed to support long term environmental sustainability, reduce landfill dependency, and create green jobs in the waste sector. By drawing on global best practices and identifying scalable solutions, this paper aims to contribute to the development of resilient and sustainable urban waste management systems aligned with the United Nations Sustainable Development Goals (SDGs), particularly SDG 11 and SDG 12.

Keywords: Sustainable waste management, urban waste, municipal solid waste (MSW), circular economy, waste segregation, recycling.

1. Introduction

Urbanization is accelerating globally, particularly in developing countries, resulting in a proportional rise in municipal solid waste (MSW) generation. According to estimates, cities produce millions of tonnes of waste annually, and much of this is handled by systems that are inefficient, polluting, or both. Conventional waste management strategies namely landfilling, open dumping, incineration have significant environmental costs, including greenhouse gas emissions, groundwater contamination, air pollution, and biodiversity loss. Such systems also often fail to recover value from waste materials that could be recycled, composted, or otherwise reused.

Sustainability in waste management is now widely argued to require a transition toward circular economy principles, where waste is seen not merely as refuse to dispose but as a resource to recover, reuse, recycle, or convert to energy. Sustainable MSW management (MSWM) involves integrating technical, social, regulatory, and economic dimensions: waste reduction, source separation, stakeholder engagement, enabling policies, infrastructure investment, informal sector inclusion, and innovation.

This paper reviews the literature on sustainable waste management practices in urban areas, focusing on identifying:

(i) strategies and practices that have shown success;
(ii) case studies illustrating those practices;
(iii) enablers and barriers; (iv) policy frameworks; and (v) recommendations that may apply in contexts such as Nigerian cities (or similar urban settings in developing regions).

2. Methodology

This review is based on systematic searches of academic and policy literature, case studies, reports from urban waste management authorities, and NGO documents. Key terms searched included "sustainable waste management," "municipal solid waste," "circular economy," "waste segregation at source," "extended producer responsibility," "waste to energy," "informal waste workers," and city-specific terms (e.g. San Francisco, Pune, Amsterdam). Sources were drawn from periods roughly between 2010 and 2025, emphasizing recent innovations, outcomes, and implementation experiences. Criteria for inclusion included documented quantitative or qualitative outcomes, replicable lessons, and relevance to urban contexts especially in developing countries.

3. Principles and Strategies of Sustainable Urban Waste Management

Sustainable urban waste management (SUWM) involves a set of interrelated principles and strategies. These are:

1. **Waste minimization and avoidance**: reducing material consumption, designing for durability, repair, reuse, and product redesign to prevent waste generation.

2. **Source separation**: segregating waste at its origin (household, commercial, institutional) into organic, recyclable, hazardous, and other fractions. This improves the purity of recyclable streams and facilitates composting and recycling.

3. **Composting and biological treatment**: turning organic waste into compost or energy (biogas) via anaerobic digestion. This not only reduces landfill burden but also returns nutrients to soil and reduces methane emissions.

4. **Recycling, reuse, and reuse networks**: reclaiming materials such as plastics, metals, paper, glass; promoting reuse and upcycling; integrating informal recyclers.

5. **Extended Producer Responsibility (EPR)**: requiring manufacturers to take responsibility for product end of life, including take back, recycling, and design for recyclability.

6. **Waste to Energy (WTE)**: converting residual waste (after diversion of organics and recyclables) into energy via incineration, anaerobic digestion, gasification, or other technologies, bearing in mind emissions control and cost.

7. **Decentralized and localized processing**: small-scale composting facilities, neighborhood collection points, local recycling centres reduce transport, improve participation, and adapt better to local conditions.

8. **Smart systems & technological innovation**: IoT sensors, GPS routing, automated sorting, real-time monitoring to optimize collection, reduce costs and emissions, and improve operational efficiency.

9. **Inclusion of informal sector**: many cities in developing countries have informal waste collectors, sorters, recyclers; integrating and supporting them through recognition,

training, safe working conditions, and cooperative business models improves reach and equity.

10. **Public awareness, behaviour change, and stakeholder engagement**: education, incentives, regulations, civic campaigns are essential for households and businesses to participate in source separation, recycling, and other sustainable practices.

11. **Policy, legal, and institutional frameworks**: enabling legislation, regulation, financial incentives/disincentives, institutional coordination, financing mechanisms are necessary to support implementation.

4. Case Studies

Examining specific urban areas helps illustrate how the strategies above are implemented, what outcomes have been achieved, and what challenges remain.

4.1 San Francisco, USA

One of the more frequently cited examples, San Francisco passed a Mandatory Recycling and Composting Ordinance (No. 100-09) in 2009, requiring all persons to separate recyclables, compostables, and trash. The program included investment in composting infrastructure, public education, and color coded bins. As a result, city reports show substantial increases in diversion rates; composting volumes grew (e.g. approximately from 400 tons to 600 tons per day of organic material) and recycling/composting rates have reached impressively high levels.

4.2 Pune, India

Pune is noteworthy for adopting a hybrid model that integrates informal waste workers in municipal recycling, and high levels of plastic segregation and resource recovery. Under the “Closing the Loop” initiative, the municipality works with local informal workers and NGOs to track plastic flow and recover materials for local and global recycling industries. The approach is low-cost compared to fully mechanised systems.

4.3 Amsterdam, Netherlands, Flanders, Japan

In comparative studies, Amsterdam (Netherlands), Flanders (Belgium), and Japan’s “Sound Material-Cycle Society” plan is often cited in “enhanced waste management” policies. These include strong governance, public participation, high recycling/diversion targets, material policy, and regulatory instruments. For example, policy tools such as bans, deposit return systems, recycling mandates, and producer responsibility are used.

4.4 Small municipalities: Langebaan (South Africa) and Swakopmund (Namibia)

These municipalities provide insights for smaller urban centers in developing countries. Studies show that much waste still goes to landfill (in one case about 85% of waste), and main challenges include lack of technical capacity, financial resources, regulatory enforcement, private sector involvement. Proposed frameworks include improved regulation, stakeholder involvement, education, and institutional capacity building.

5. Enablers and Barriers

5.1 Enablers

- **Strong policy & legal frameworks**: mandates, regulations, EPR, incentives, penalties.
- **Funding & financial mechanisms**: subsidies, grants, cost recovery models, revenue from tipping fees, or sale of recovered materials.
- **Institutional capacity & governance**: clear responsibilities, coordination among agencies, transparency.
- **Community involvement & awareness**: public education, behaviour-change campaigns, social norms.
- **Technology & innovation**: smart routing, sensors, efficient sorting methods.
- **Informal sector integration**: offering recognition, rights, safe working conditions, fair pay, and integrating informal workers into municipal systems.

5.2 Barriers

- **Infrastructure and technical gaps**: insufficient collection systems, processing plants, composting/biogas facilities.
- **Financial constraints**: high initial investment; low market value for recycled materials; operational costs.
- **Weak enforcement and governance**: regulations may exist but be poorly enforced; corruption or inefficiency.
- **Lack of public participation**: households/businesses not separating waste due to lack of awareness, convenience, or cultural norms.
- **Informal sector marginalization**: informal workers may be excluded, unrecognized, operating in unsafe conditions.
- **Contextual challenges**: in developing countries, rapid urban growth, weak planning, land scarcity, informal settlements, resource constraints.

6. Role of Policy, Regulation, and Institutions

Policies and legal tools are central. Important instruments include:

- **Extended producer responsibility (EPR):** laws or programs that make producers responsible for take back, design for recyclability, packaging, etc.
- **Regulations on landfill use**: restricting open dumping, requiring lining, closure, or transition away from landfills.
- **Regulatory incentives and disincentives**: bans on single-use plastics, deposit-return schemes, subsidies for composting, taxes/fees on landfill or incineration.
- **Standards and guidelines**: for waste segregation, collection, processing, health and safety (especially for informal workers).
- **Public procurement policies**: governments purchasing products with recyclable content, favoring services that minimize waste.
- **Decentralization and devolution**: giving local governments the authority and resources to manage MSW suited to local conditions.

7. Technological Innovations & Smart Systems

Recent innovations are helping to overcome traditional constraints:

- **Smart bins and sensor networks**: monitoring fill levels, optimizing collection routes to reduce cost and emissions.
- **Automated sorting technologies**, robotics, machine learning for waste stream separation.
- **Digital platforms** for coordination between citizens, waste collectors, recyclers.
- **Small scale decentralized composters and biogas plants** for organic waste.
- **Waste-to-energy technologies** with attention to emissions control and integration with municipal energy systems.

8. Sustainable Waste Management & The Circular Economy

The concept of circular economy (CE) is increasingly central to SUWM. CE aims to close loops: reduce, reuse, recycle, recover. Key linkages with waste management include:

- Viewing waste as resource and raw material.
- Designing products for disassembly, repair, reuse.
- Promoting industrial symbiosis: one sector's waste becomes another's input.
- Implementing material-policy (eco-design, resource efficiency).
- Setting targets and metrics for material circularity, waste diversion, recovery.

Research shows that aligning CE with Sustainable Development Goals (SDGs), especially SDG 11 (sustainable cities) and SDG 12 (responsible consumption & production), yields significant environmental, social, and economic benefits.

9. Discussion: Lessons Learned, Scalability, and Contextualization

From the cases and literature:

- **Local adaptation matters**: what works in a highly resourced city (like Amsterdam or San Francisco) may need adaptation in low income or informal settings. For example, in Pune, informal workers' involvement is a key success factor.
- **Cost vs benefit trade-off**: investments in infrastructure or technology may be high initially, but savings (reduced landfill, environmental damages, jobs) and revenue (from recyclables, compost) can offset costs over time.
- **Regulatory consistency and enforcement** matter strongly; uncertainty or lax enforcement undermines trust and investment.
- **Behaviour change is often the limiting factor**: even with infrastructure, lack of participation by households/businesses reduces performance. Education, incentives, convenient design (bin placement, frequency of pickup) are critical.
- **Informal sector is essential in many urban areas**, especially in developing countries, and inclusion leads to significant gains in resource recovery, cost effectiveness, and social inclusion.

10. Recommendations

Based on review and case studies, the following are recommended for urban areas (including those in Nigeria, West Africa, etc.):

1. **Promote and enforce source segregation**: Make it easy and mandatory where possible; provide bins, clear guidance.

2. **Support low-cost composting/biodegradable organic waste systems**: Neighborhood or community composting can reduce volume of organic waste entering landfills.

3. **Formalize and integrate informal waste workers**: Provide training, safety, legal recognition; enable them to participate in collection, sorting, recycling.

4. **Adopt EPR policies** for packaging, electronics, plastics; incentivize product design for recycling.

5. **Invest in decentralized waste treatment** to reduce transport cost and make processing accessible.

6. **Leverage technology**: smart monitoring, routing, automated sorting; but ensure technology choices are affordable and maintainable.

7. **Improve policy, regulatory and institutional frameworks**: clarify responsibility; ensure enforcement; provide financial/investment incentives; ensure cross-department/stakeholder coordination.

8. **Public awareness and behaviour change campaigns**: sustained education; incentives; feedback to communities on recycling/diversion performance.

9. **Monitor, evaluate, and set targets**: Cities should track metrics (e.g. waste diversion %, recycling rates, greenhouse gas emissions); use these to guide policy.

10. **Align with SDGs & international best practices**, adapting lessons from successful cities, while considering local constraints.

10.Conclusion

Urban areas face pressing challenges in managing the increasing volumes of municipal solid waste in a sustainable manner. Traditional strategies centered on landfills and incineration are no longer sufficient due to environmental, social, and economic costs. Sustainable waste management practices grounded in circular economy principles, involving source separation, composting, recycling, EPR, decentralized and smart systems, and inclusive policies offer viable pathways forward. Success depends on a combination of strong regulatory frameworks, public participation, institutional capacity, appropriate infrastructure, financial resources, technological innovation, and inclusion of the informal sector. While many cities around the world provide illustrative case studies, urban areas in less resourced settings must adapt these lessons, accounting for local socioeconomic, cultural, and governance conditions. Future research should focus on long term evaluations of interventions, cost benefit analyses in developing contexts, and exploring scalable models for decentralized and inclusive waste processing. If adequately acted upon, sustainable waste management practices can contribute significantly toward achieving SDG 11 and SDG 12, strengthen urban resilience, reduce environmental harm, and create employment opportunities.

Thanks and Information Note

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Economic Efficiency of the Thai Frog (*Rana tigerina*) Farming in Mekong Delta

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Abstract

Rana tigerina farming has gradually become a potential production model in the Mekong Delta of Vietnam thanks to its advantages such as short farming time, low investment capital, easy utilization of small areas and use of available natural food sources. However, the production efficiency between farming households still has many differences due to differences in technical level, scale and access to technical information. Based on that reality, this paper was carried out to evaluate the level of economic efficiency of frog farming, and identify some factors affecting production efficiency to propose appropriate solutions. This paper was conducted in 2025, through direct survey with 70 frog farming in the Mekong Delta. Data were collected through simple random sampling method. The analysis method used was Stochastic Frontier Analysis (SFA) with the form of Cobb-Douglas function, to estimate economic efficiency. The research results showed that the average economic efficiency was 52.96% in the dry season and 50.02% in the wet season, respectively, indicating that there is still a large room for improving overall efficiency. Economic efficiency were analyzed through the inefficiency error part in the SFA model indicated that some factors such as farming experience, and participation in technical training have a positive impact on production efficiency, while large farming areas can improve economic efficiency, but if not well managed, it can cause economic inefficiency. On that basis, the paper has proposed solutions such as strengthening technical training, supporting farmers to access information and investment capital, as well as promoting sustainable and environmentally friendly farming models.

Keywords: Rana tigerina, cost-benefit, Cobb-Douglas function, SFA.

1. Introduction

The fisheries sector is a key economic sector, with an increasingly large proportion of GDP and a particularly important position in the socio-economic development strategy of Vietnam in general and the Mekong Delta in particular (Ministry of Agriculture and Rural Development, 2024). According to estimates by the Food and Agriculture Organization of the United Nations (FAO), human demand for aquatic and seafood products is high, with an average person consuming about 20.5 kg/year. Global demand for seafood will continue to increase as the world population continues to grow. Given that natural fisheries resources cannot increase unless overexploitation is stopped, aquaculture is the source of supply for the future. Aquaculture can reduce pressure on natural fisheries and contribute to socio-economic development in local communities (Vietnam Marine Aquaculture Association, 2024). The Mekong Delta is one of the important aquaculture regions of Vietnam with an area of 3.9 million hectares, of which freshwater area accounts for more than 600,000 hectares (General Statistics Office, 2023). This is one of the seven major economic regions in the country, with great potential for agriculture, relatively flat terrain, a dense river system and a temperate

climate with two distinct rainy and dry seasons (General Statistics Office, 2023). In the Mekong Delta, there are many valuable aquatic species being raised such as pangasius, perch, snakehead fish, scorpionfish, giant freshwater prawn, etc., of which Thai frog (Rana tigerina) is a subject that is attracting much attention and is developing strongly in some provinces such as Can Tho, Dong Thap, An Giang, Tra Vinh, Tien Giang, etc. (Le Tran Tri Thuc, 2013). Frogs are considered one of the aquatic species with high economic value. Frog meat is not only a food with high nutritional value, but frogs are also used in research in the fields of neurology and physiology (Nguyen Huu Dang, 2004). Vietnam has imported a number of frog species from Cuba, Mexico, Brazil, and Thailand. However, only Thai frogs can adapt to the environmental conditions in the Mekong Delta (Le Tran Tri Thuc, 2013). Frog farming is currently a potential direction in the agricultural and aquatic sectors, due to its many advantages such as: easy to implement, high profits, strong market demand, fast turnaround time, very suitable for farming facilities with little production land. However, there is currently no specific research on the current production status as well as the economic efficiency of the Thai frog meat model in the Can Tho city area. Although frog farming in Can Tho is developing rapidly, there are still many difficulties and challenges that need to be solved, such as price fluctuations, diseases, erratic weather and some issues affecting production efficiency such as farming techniques of people are not guaranteed, the quality of the breed is not uniform, the survival rate is low, etc., thereby affecting the profits of farmers. Based on that reality, the study was conducted to evaluate the economic efficiency of the model, as well as find out the factors affecting production efficiency, thereby proposing solutions to improve farming techniques, contributing to improving productivity, increasing income for farmers, and at the same time promoting sustainable development and replicating the model in the coming time.

2. Research methodology

The primary data of the topic is the data from interviews with frog farmers in Can Tho city in the most recent year. Based on the suitability of the research database, the Cobb-Douglas production function is used to estimate the economic efficiency of the Thai frog farming model. The Cobb-Douglas marginal production function is as follows:

$$ln\pi_i = \beta_0 + \beta_1 ln\, P_G + \beta_2 ln\, P_{TA} + \beta_3 ln\, P_{TS} + \beta_4 ln\, P_{LĐthue} + \beta_5 ln\, P_{LĐnha} + v_i - u_i$$

In which: ln is natural logarithm; βo, β1,…5 are the coefficients that need to be estimated in the model; vi is represented random error; ui is represented error due to inefficiency.

PG is the natural logarithm of the standardized seed price (VND/kg), calculated as the ratio between the purchase price of 1 kg of frog seed and the selling price of 1 kg of frog. This variable reflects the investment cost in the seed compared to the output value, thereby showing the level of influence of seed quality on production efficiency. In many cases, high-priced seeds are often accompanied by better quality, higher growth rate and survival rate. Therefore, this variable is predicted to have a positive (+) impact on standardized profit, consistent with the research of Le Canh Dung et al., (2019); Dang Thi Phuong et al., (2020).

PTA is the natural logarithm of the standardized industrial feed price (VND/kg), calculated as the ratio between the price of 1 kg of industrial feed and the selling price of 1 kg of commercial frog. When PTA is high, that is, the price of industrial feed accounts for a large proportion of revenue, it can reduce economic efficiency. Therefore, this variable is predicted to have a negative impact (−) on standardized profit and is consistent with the study of Le Canh Dung et al., (2019); Dang Thi Phuong et al., (2020). PTS is the natural logarithm of the

standardized drug price (VND/liter), calculated as the ratio between the weighted average price of 1 liter of TS drug and the selling price of 1 kg of frog. The level of investment in drugs can affect product quality and disease prevention and treatment ability, thereby affecting production efficiency. This variable is generally expected to have a positive (+) impact on standardized profits, consistent with the research of Le Canh Dung et al., (2019); Dang Thi Phuong et al., (2020).

PLĐnha is the natural logarithm of the standardized daily labor price (VND/day), estimated by the ratio between the price of 1 daily labor price and the price of 1 kg of frog sold. This variable reflects the opportunity cost of family labor participating in the frog farming process, calculated at the same level as hired labor. Using family labor can help save costs while improving production efficiency. This variable is expected to have a positive (+) impact on standardized profits, consistent with the research of Le Canh Dung et al., (2019).

PLĐthue is the natural logarithm of the standardized hired labor price (VND/day), calculated as the ratio between the price of 1 day of hired labor and the price of 1 kg of frog sold. This variable is predicted to have a negative impact (−) on standardized profit and is consistent with the study of Le Canh Dung et al., (2019).

Independent-Samples T-Test

Independent-Samples T-Test is a method of testing hypotheses about the mean of the population. This test is used to test the hypothesis of the equality of 2 population means based on 2 independent samples drawn from 2 populations.

In the Independent-Samples T-Test, there will be 1 quantitative variable to calculate the mean and 1 qualitative variable used to divide the groups for comparison.

Steps to perform the Independent-Samples T-Test are:

+ Step 1: Set the hypothesis:

Hypothesis H_0: There is no difference between the means of the two populations.

Hypothesis H_1: There is a difference between the means of the two populations.

+ Step 2: Perform the Independent-Samples T-Test

+ Step 3: Check whether the variances are equal or not:

If the Sig. value > 0.1 → the variances are equal.

If Sig. < 0.1 → variances are different.

+ Step 4: Compare the Sig value of the t-test determined in step 3 with the calculated value to decide whether to accept or reject the Ho hypothesis.

If Sig. (2-tailed) < 0.1 → reject H_0 → conclude that there is a statistically significant difference between the two groups.

If Sig. (2-tailed) ≥ 0.1 → do not reject H_0 → conclude that there is no statistically significant difference.

3. Findings and Discussion

Current status of frog farming in the study area

By 2024, the whole city will have about 2,704 frog cages with more than 200 households; of which, the most concentrated are in Can Tho city (Can Tho City Fisheries Department, 2024).

Table 1. Frog farming situation over the years

Indicators	Unit	2022	2023	2024	2023-2022		2024-2023	
					Diff	%	Diff	%
Farming area	Ha	354	381	407	27	7,08	26	6,39
Damaged area	Ha	22	18	13	-3	-16,67	-5	-38,46
Harvested area	Ha	332	363	394	29	8,26	31	7,87
Harvested	Ton	1.378	1.594	1.861	216	13,52	267	14,35

Source: Department of Agriculture and Rural Development of Can Tho city, 2024

Based on the data table, the frog farming industry in Can Tho city has developed significantly from 2022 to 2024, in terms of farming area, harvested area and output. However, there are still some challenges related to damaged area.

In 2023, the farming area was 381 hectares, an increase of 27 hectares, equivalent to 7.08% compared to 2022, which was 354 hectares. By 2024, the farming area continued to expand to 407 hectares, an increase of 26 hectares compared to the previous year, equivalent to 6.39%. This continuous increase shows the growing interest of people and organizations in the frog farming sector, and reflects the great economic potential of this livestock industry.

Total frog production has grown impressively. Specifically, in 2022, the total harvested output was 1,378 tons. In 2023, it increased to 1,594 tons, equivalent to 13.52% compared to the previous year. In 2024, the output still increased sharply to 1,861 tons. The results achieved are not only thanks to the expansion of farming area but also thanks to the improvement in farming process management. Farmers have based on the seasonal calendar to arrange production reasonably, focusing on the issue of selecting breeds, and carefully improving the farming water source before stocking.

In addition, the total area damaged in frog farming tends to decrease from 22 hectares in 2022 to 18 hectares in 2023, equivalent to 16.67%. In particular, in 2024 there was a sharp decrease, only 13 hectares, a further decrease of 5 hectares compared to 2023, equivalent to 38.46%. This is a positive sign, showing the improvement in environmental management, disease prevention, and farming techniques of local people.

However, the damaged area is still quite scattered in many different farming models and in many different localities. The main causes of this damage include the use of poor quality feed, not suitable for each stage of frog development; water pollution along with the outbreak of diseases such as ulcers, red spot disease, edema disease, and fungal diseases.

The amount of excess feed, the accumulation of waste and pathogens in the pond increases the risk of infection and mass death of frogs. These problems have affected the frog farming efficiency of many households, reducing output and quality of final products.

Some characteristics of the main producers

Table 2. Gender of household head (*Source: Survey, 2025*

Gender	Frequencies (households)	Proportion (%)
Male	61	87.14
Female	9	12.86
Total	**70**	**100.00**

According to the results of a survey of 70 Thai frog farming households in Can Tho city, the majority of the main producers are men with 61 households (equivalent to 87.14%) and only 9 interviewed households are women (equivalent to 12.86%). The dominance of men in this field reflects the common characteristics of rural labor, where jobs related to livestock farming, especially aquaculture, are often undertaken by men. This may stem from the nature of the work requiring physical strength, time and technical management experience during the farming process, from pond construction (making cages, building frames, pond renovation, etc.) to care (changing water, feeding, etc.) and harvesting.

Demographic size

The demographic size of a household reflects the level of labor, as well as the ability to support each other in implementing farming methods. The larger the population size, the more advantages the farm household has in increasing productivity, reducing costs, developing markets and income.

Table 3. Statistics on household population size (Unit: No. of households) (*Source: Survey, 2025)*

No. of people in family	Ob.	Proportion (%)
<4 people	15	21.43
from 4 - 6	49	70.00
> 6 people	6	8.57
Total	**70**	**100.0**
Average		4.54
Lowest		2
Highest		8

The proportions of different population size groups show the uneven distribution of population size in frog farming households. The population size group from 4 to 6 people accounts for the highest proportion of 70%. This population size is enough to meet the labor demand for frog production, and also helps households participate in other business activities to increase income. Next is the population size group under 4 people with a proportion of 21.43%. The population size group over 6 people accounts for the lowest proportion of 8.57%.

The average population size of a household is 4.54 people. The lowest recorded population size is 2 people/household, while the highest is 8 people/household, showing a certain difference in the number of members between households in the survey sample. The size of a

farm household's population may also change over time, due to the influence of population policies, education and health programs, migration and settlement opportunities, etc. Therefore, there may be fluctuations in the size of a farm household's population in different periods.

Table 4. Water surface area for frog farming of households (Source: Survey, 2025)

Area (m²)	Frequncies	Proportion (%)
<100	32	45.71
From 100 – 1.000	23	32.86
> 1000	15	21.43
Total	**70**	**100.00**
Mean		1,091
Standard Deviation		3,041
Minimum		20
Maximum		20,000

The survey results show that the majority of frog farming households have a water surface area of less than 100 m², accounting for the highest proportion of 45.71% with 32 households. The group of households with a water surface area for frog farming from 100 to 1,000 m² accounts for 32.86%, corresponding to 23 households. The number of households with a water surface area for frog farming larger than 1,000 m² is the smallest, accounting for 21.43% with 15 households. The average area of the household is 1,091 m². However, the standard deviation is quite large, up to 3,041 m², showing a significant difference in the scale of farming area between households. The smallest frog farming water surface area recorded is 20 m², while the largest area is up to 20,000 m². This shows that the frog farming area in Can Tho has a difference and uneven scale among households. At the same time, the above situation also shows that the frog farming area in the area is still small. Households with small areas mostly do not have enough capital to invest, are afraid of risks, so they do not dare to invest and expand the scale, but it is easy to manage and take care of during the frog farming process. Besides, households with large areas have been involved for many years, have a lot of experience in frog farming or some households have large pond areas, have capital to rent land to raise frogs.

The farming area is quite important, but the stocking density is equally important. Different farming areas lead to different stocking densities. According to research scientists, too high or too low stocking density also affects the development of the breed. If the density of the breed is too low, it can help the breed grow strongly but the yield is not optimal. However, if the density is too high, it will reduce the growth ability of the breed, create conditions for diseases to develop, seriously affecting productivity, and significantly increase the loss rate from breeding to harvest.

Financial performance analysis results:

Selling price: Is a key factor determining the revenue and profit of frog farmers. The higher the selling price, the greater the potential revenue and profit. According to survey data, the average selling price in the dry season is 48.31 thousand VND/kg, ranging from 46 to 51 thousand VND/kg. Meanwhile, the rainy season has a higher average selling price, reaching 51.97 thousand VND/kg, ranging from 50 to 55 thousand VND/kg. It can be seen that the price of frogs in the rainy season is generally higher than that in the dry season. The main reason for this difference is that the farming conditions in the rainy season often encounter many disadvantages such as wet weather, fluctuations in the water environment, and the risk of disease outbreaks, causing a higher loss rate and a decrease in market supply. Meanwhile, consumption demand remains stable, creating a situation where supply is lower than demand, pushing up the selling price. However, although the selling price in the rainy season is higher, farmers do not necessarily get better profits, due to the decrease in output and the increase in costs, especially labor costs and disease prevention costs. This shows that risk control and improving survival rate in the rainy season are key factors to take advantage of the selling price.

Output: Is a factor that directly affects the total revenue and profit of frog farming households. Survey results show that the average output achieved in the dry season is 23.52 kg/m², higher than that of the rainy season at 22.28 kg/m². The highest output in the dry season is up to 43.17 kg/m² and the lowest is 12.27 kg/m²; while the rainy season ranges from 11.78 to 39.1 kg/m². The difference in average yield between the two crops was 1.24 kg/m², and was statistically significant at the 1% level, indicating that the difference was significant. The main reason for the higher yield in the dry season was due to more favorable weather conditions for the growth and development of frogs: stable temperature, easy-to-control pond environment and less disease outbreaks. Meanwhile, the rainy season often encountered unfavorable climatic conditions such as low temperature, high humidity and sudden changes in water environment, increasing the risk of outbreaks of bacteria, parasites and fungi. This significantly increased the loss rate, reducing the harvest yield. Cost: The average total cost for frog farming in the dry season was 1,041.01 thousand VND/m²/crop, while in the rainy season it was 1,117.85 thousand VND/m²/crop. The cost ranged from 489.2 to 1,473.6 thousand VND/m² in the dry season, and from 501.5 to 1,382 thousand VND/m² in the rainy season. The cost difference between the two seasons was about 76.84 thousand VND/m², statistically significant at the 1% level. The main reason for the higher cost in the rainy season was the longer rearing time. Unfavorable weather conditions in the rainy season caused frogs to grow slowly, forcing farmers to extend the rearing time to reach harvest size. This increased costs such as feed, medicine, labor and operating costs, leading to higher total costs compared to the dry season. Revenue: This indicator shows the total value of frogs sold per m² of rearing area. Revenue is calculated by multiplying output by the selling price. In the dry season, revenue ranged from VND655,000 to VND2,115,000/m² with an average of VND1,148,000/m² and a standard deviation of VND216,000. In the wet season, revenue ranged from VND816,000 to VND2,032,000/m² with an average of VND1,165,000/m² and a standard deviation of VND210,000. The high standard deviation indicates a large difference in revenue between households, mainly due to fluctuations in output and the higher the better the selling price. Although the selling price in the wet season is usually higher due to reduced supply, the output is lower, resulting in a significant difference in revenue between the two seasons. Specifically, the average revenue in the dry season is VND16,64,000/m² higher than in the wet season, thanks to high output despite lower selling prices.

Profit: Calculated by subtracting revenue from costs. The average profit in the dry season is 106.96 thousand VND/m²/crop, while the rainy season is only 46.74 thousand VND/m²/crop. The lowest profit in the dry season is (-411.64) thousand VND/m² and the highest is 718.92 thousand VND/m². In the rainy season, the biggest loss is up to (-1,445.37) thousand VND/m² and the highest is 609.81 thousand VND. The difference in average profit between the two seasons is 60.22 thousand VND/m², statistically significant at the 1% level. The reason why some households suffer serious losses in the rainy season is because the farming time is longer, forcing them to spend more family labor to take care of the pond, especially during epidemics or when the water environment needs to be treated. Therefore, when taking into account the opportunity cost, some models have negative profits even though the revenue is not too low.

Income: Is the difference between revenue and production costs, excluding family labor costs. This indicator shows the amount of money each household earns after subtracting family labor costs from profits. According to the data table, household income ranges from 29.9 to 742.92 thousand VND/m² with an average of 220 thousand VND/m² in the dry season, and from 26 to 660.48 thousand VND/m² with an average of 203.43 thousand VND/m² in the rainy season. The income difference between the two seasons is 16.47 thousand VND/m² and is statistically significant at the 1% level. This result shows that raising frogs in the dry season is likely to bring in better income, even though the selling price is not as high as in the rainy season. The main reason is due to higher yields and shorter rearing time, which helps save costs and optimize production efficiency.

The analysis results show that indicators such as yield, revenue, profit and income of frog farming households in the dry season are all higher than the rainy season, with statistical significance at the 1% level. This is evidence that the dry season brings better financial efficiency. On the contrary, the rainy season has many disadvantages such as erratic weather, difficult-to-control pond environment and disease outbreaks, increasing costs and reducing output. Although the selling price is higher, the financial efficiency of the rainy season is still lower due to reduced productivity and increased costs. Therefore, many households choose to focus on frog farming in the dry season to reduce risks and ensure profits. Choosing the right time to raise frogs is a key factor in the farmer's production strategy.

Estimation results of the economic efficiency model

Economic efficiency in production is measured from the stochastic marginal profit function estimated by the maximum likelihood estimation (MLE) method. One-stage estimation results from the simultaneous estimation of the stochastic marginal profit function and the inefficiency function.

Table 5. Estimation results of marginal profit and profit inefficiency functions of Thai frog farming households in Can Tho (Source: Survey, 2025)

	α_i	Z
EE		
Cons	15.266***	2.97
P_G	-1.170***	-9.79

P_{TA}	-0.440***	-2.76
P_{TS}	-0.319***	-4.24
$P_{LĐnha}$	0.228^{ns}	1.52
$P_{LĐthue}$	0.994***	3.41
TIE		
Cons	2.049^{ns}	0.14
Tuoi	-3.668^{ns}	-1.41
Knghiem	0.288^{ns}	0.82
Hocvan	1.515^{ns}	0.65
Taphuan	-0.011^{ns}	-0.00
Vayvon	1.382^{ns}	0.52
Dientich	0.0002^{ns}	-0.35
QuymoLĐGĐ	-4.052*	-1.90
Ob. (n)		70
P-value		0,0000
Log likelihood		14.451
Lambda		6.463
Gamma (γ)		0.98

The results of the random marginal regression show that both models of economic efficiency in frog farming in the dry season and the rainy season are highly statistically significant, with p values (Prob > chi2) equal to 0.0000. This confirms that the variables included are capable of explaining well the variation in economic efficiency in frog farming practice.

The Gamma coefficient in the dry season and the rainy season are 0.98 and 0.61, respectively, at the 1% significance level. The closer the γ value is to 1, the more appropriate the model is and the error is mainly due to profit inefficiency rather than random noise. This means that inefficiency explains up to 98% and 61% of the variation in profit in the dry season and the rainy season. Therefore, the economic inefficiency in production of households is about 98% (sunny season) and 61% (rainy season) due to subjective factors that farmers can control. The rest is due to other uncontrollable random factors (such as weather, pests, market prices). With γ = 0.977 in the sunny season, it can be affirmed that most of the errors in the model are due to inefficiencies from the producer side, and the model has a high explanatory power. This means that there is still a lot of potential to improve profit efficiency through improving management skills, reasonable cost allocation and applying more effective techniques in the sunny season. In contrast, the rainy season has γ = 0.611, which is significantly lower, showing that the proportion of errors coming from inefficiencies is still high, but random noise due to uncertain factors (such as weather, diseases, price fluctuations, etc.) accounts for a larger proportion than in the sunny season. This reflects that in the rainy season, no matter how experienced or technically skilled the farmer is, the profit efficiency is still easily affected by objective factors beyond control. In terms of Log likelihood value, the dry season model has a log likelihood value of 14.451, while the wet season model is (-76.848). The dry season model has a higher and positive log likelihood value, reflecting a better fit to the data

than the wet season model. This shows that in dry weather conditions, the collected data is more homogeneous and less noisy, thereby helping the model estimate economic efficiency more accurately.

4. Conclusion and Recommendations

From the practical difficulties in the process of raising frogs in the locality, the author proposes a number of solutions to support farmers to improve production efficiency and develop a sustainable farming model:

Farmers need to take advantage of the available conditions of their families to raise frogs according to a suitable model. Select and invest in high-quality breeds from reputable hatcheries, ensuring clear origins. Size frog breeds and manage the amount of food well so that the harvested frogs have a more uniform size. Manage the stocking density reasonably (reduce the stocking density that is too high), rearrange the tank/cage area appropriately.

Use additional supplementary foods and biological products to improve production efficiency. Using additional supplements such as garlic yeast, thigh and bone strengthening medicine, calcium milk, etc. helps improve the digestive system, strengthen the immune system, stimulate growth and help frogs adapt better to changing weather conditions. In addition, adding biological products to the farming environment also helps improve water quality, balance the microflora and create more stable farming conditions.

Enhance the exchange of experiences between farmers. Actively participate in sharing activities and learn from each other. Ineffective producers should actively learn from successful farmers in the locality or in areas with similar conditions. The form of exchange can be through meetings, training, and field trips. In addition, households with many years of experience should also proactively share, provide technical guidance and exchange views to improve the overall production level of the community. Join a cooperative or cooperative: Increase access to capital, technical training, and have stable output through production-consumption linkages. In the long term, farmers should expand their production scale to achieve higher technical efficiency. Farmers can borrow capital from policy banks to invest in renting more ponds, buying more food or high-quality frog breeds, thereby expanding the scale as well as improving the quality and output of meat. In addition, farmers can register to participate in pilot models of agricultural projects in the area to access preferential capital sources, no interest, and at the same time be guided to apply advanced techniques in the production process.

There should be a contract binding the input supplier (food) with the farmer to limit the shortage of food sources and fluctuating input prices, between the farmer and the trader to ensure product output and peace of mind in production.

Thanks and Information Note

The article complies with national and international research and publication ethics. All authors contributed equally to the article.

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The Economic Policies on Agriculture of The Republic of Vietnam in South Vietnam (1955-1965)

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Abstract

Following the signing of the 1954 Geneva Accords, Vietnam was partitioned into two zones. North of the 17th parallel was the government of the Democratic Republic of Vietnam (DRV), and south of the 17th parallel was the US-backed regime of President Ngo Dinh Diem (historically referred to as the Republic of Vietnam (RVN) or the Saigon government). Upon taking power in South Vietnam, President Ngo Dinh Diem promulgated numerous economic policies on agriculture to be applied across the region. These policies included: Land Reform, Land Development Centers, Agrovilles, Strategic Hamlets…The objectives of these agricultural economic policies were to consolidate political power in the hands of President Ngo Dinh Diem, to create a "new middle peasant class" to serve as a solid social base for the Saigon regime, and simultaneously to prevent the strong growth of the revolutionary movement in South Vietnam, particularly in rural areas. Initially, these agricultural economic measures demonstrated some effectiveness, but they gradually lost their impact over time. This failure was primarily due to the limited amount of land distributed to the peasants. The forced relocation of farmers away from their homes, fields, and ancestral tombs caused strong resistance, as it went against village traditions and disrupted community structure. Consequently, farmers south of the 17th parallel became increasingly alienated from the Saigon government. The revolutionary movement in South Vietnam developed vigorously in the countryside. The agricultural economic policies of the Saigon government were fundamentally considered a resounding failure. Therefore, the study, "Economic Policies on Agriculture of the Republic of Vietnam in South Vietnam (1955-1965)" will contribute to the field of Vietnamese social science in particular and the history of the modern world economy.

Keywords: economy, agriculture, Republic of Vietnam, revolution, peasant, land.

1. Introduction

Following the signing of the 1954 Geneva Accords, Vietnam was formally divided into two zones at the 17th parallel, ushering in a period of intense historical complexity and confrontation. The North was governed by the Democratic Republic of Vietnam, while the South saw the formation of the government of President Ngo Dinh Diem (commonly known as the Republic of Vietnam or the Saigon regime), which was backed by the United States.

In this context of acute separation and conflict, controlling and consolidating power in the South became the Saigon government's paramount strategic priority. Given that the vast majority of the population resided in rural areas, issues concerning agricultural economics and land were not merely about economic development; they were crucial strategic political tools for winning and maintaining influence.

Consequently, this paper focuses on researching and analyzing the key agricultural economic policies promulgated by President Ngo Dinh Diem, including Land Reform, the Land Development Program, the Agrovilles Program, and the Strategic Hamlet Program. This study not only clarifies the Saigon regime's efforts to create a "new middle peasant class" as a stable

social anchor but also delves into exposing their strategic failure. This failure stemmed from implementing policies that disrupted the traditional village structure and ran contrary to the fundamental interests of the peasantry. This analysis is key to understanding the root cause of the farmers' alienation and was a fundamental factor that undermined the Saigon regime during its initial period in power.

To build a clear argument for this study, we have referenced and relied on a system of academic works and related source materials, including:

On Vietnam's economy through the periods: Southern economy 1955-1975 (Dao Phong, 2004), Vietnam's economy 1955-2000 (Tran Van Tho, 2000), 35 years of Vietnam's economy 1945-1980 (Dao Van Tap, 1980), Vietnam's economic history (Vo Van Sen, 2017), and Vietnam's industrial economy 1955-1975 (Le Dinh Trong, 2020).

On the political and social context of South Vietnam: South Vietnam after Dien Bien Phu (Nguyen Khac Vien, 2008).

The published works have outlined a comprehensive and multi-dimensional picture of the Vietnamese economy in general and the South Vietnamese economy in particular, covering key sectors like agriculture, industry, and commerce. Notably, some studies have also touched upon policies for developing the agricultural economic sector in South Vietnam during the 1955-1965 period.

However, the majority of these materials often focus on a general description of agricultural policies. They have yet to delve into a systematic and specialized analysis of: The implementation and detailed content of agricultural policies, the actual impact (including both successes and failures) of these policies on socio economic life, the causes of failure for certain agricultural policies, and the causal link between that failure and the political goals of the South Vietnamese government during the First Republic. Therefore, this research aims to fill that gap by providing an in-depth analysis of the nexus between agricultural economic policy and the political objectives of the Republic of Vietnam government during the 1955-1965 period.

In parallel with the comprehensive research works, our argument is also reinforced through access to a system of original administrative documents and specialized monographs from the former National Institute of Administration, Saigon, and related agencies. These works provide a detailed look at the operational mechanism of the Republic of Vietnam's agricultural policies, typically:

On Legal Basis and Structure: Land Reform Law (Department of Land and Agrarian Reform, 1960).

On Resettlement and Development Programs: The policy of the Ngo Dinh Diem government in the years 1959-1960 (Nguyen Thi Thanh Huyen, 2014); The policy of the Ngo Dinh Diem government in South Vietnam in the period 1957-1963 (Tran Thi Ha, 2015).

On Security and Rural Development: An outline of the National Policy of Strategic Hamlets and the pacification, construction and development of the Republic of Vietnam (Ta Ngoc Cuong, 1973); The rural situation and the methods of pacification and construction (Huynh Cong Hieu, 1970).

Overall, these works hold high value as primary source material, as the authors had direct access to the documents and data of the Republic of Vietnam government. They are essential sources of information for reconstructing the policy context. However, a limitation on objectivity is that most of these materials were compiled within the contemporary political environment or influenced by the political perspective of the Saigon regime. As such, they often tend to describe or defend the policies, but do not offer a critical or multi-dimensional objective assessment of the actual effectiveness and failure of the agricultural policies.

The other identified limitations in existing works further affirm the urgency of this research. Simultaneously, the current study aims to critically analyze the correlation between agricultural policies and the political objectives of the Republic of Vietnam government (1955–1965) with an objective view of rural development programs in this period. Thereby, it contributes to supplementing historical documentation and advancing post-colonial studies in the social sciences and humanities.

2. Research Methodology

This research employs a combined methodology, primarily based on the Historical Method and the Logical Method, reinforced by the Statistical Method. Specifically:

The Historical Method is used to analyze the relationship between policy implementation and its actual consequences, highlighting the contradiction between the declared political goals and the reality of execution, especially the conflict between the government's political interests (consolidating power, concentrating the population) and the farmers' material and spiritual interests (limited land, forced relocation from homeland and ancestral tombs).

The Logical Method acts as the conceptual bridge, using inductive reasoning to collect and systematize information from source materials on the Saigon government's specific agricultural economic policies (Land Reform, Land Development Centers, Agrovilles, Strategic Hamlets, Civic Life Hamlets, etc.) and to clearly identify the political and social objectives that the Ngo Dinh Diem regime sought to achieve through these policies.

The Statistical Method is the quantitative tool to process and distill important evidence and documents to assess the consequences of this contradiction, which led to the farmers' alienation from the government and the vigorous development of the revolutionary movement in the countryside, thereby leading to the conclusion of the policies' resounding failure.

In addition to the main research methods above, throughout the process of researching this content, we also utilized other methods such as comparison, deduction, induction, and synthesis.

3. Research Content

Objectives of the Agricultural Economic Policies

After the Geneva Accords of 1954, the Republic of Vietnam (RVN) government faced two major challenges: its lack of legitimacy as the successor to the French colonial regime and the direct threat from a growing revolutionary movement in the countryside. In this context, US support was based on a “counterinsurgency” doctrine that emphasized that victory in war was achieved not only by military force but also by “winning the hearts and minds” of the people.

The Ngo Dinh Diem government considered agriculture as a key sector to restructure rural society, thereby strengthening the political and security foundation of the regime. Policies

such as land reform, the land concentration program, the densely populated areas and the strategic hamlets were not only economic goals, but mainly strategic tools to serve the goal of political control. With more than 80% of the population living in rural areas, this area became the central battlefield, where the real power of the Saigon government was determined in the period 1955-1965. But the reality was mainly the period 1955-1963.

Politically, President Ngo Dinh Diem's most urgent goal was to centralize power and eliminate any local power structures that could challenge the regime. The Land Reform Law No. 57/BC was enacted to limit land ownership by landlords and redistribute some of the land to peasants. Although this policy was not as radical as the land reform in the North, in essence, it aimed to break the traditional socio economic power, which had a profound influence in the countryside, and replace it with a peasant class dependent on the central state through administrative and credit mechanisms.

In addition, the land and settlement programs allowed the central government to extend its administrative, military, and political control down to the village and commune levels. The traditional village structure was replaced by a system of officials and cadres loyal to the regime. From then on, all activities from population planning to agricultural production were directly controlled by the central apparatus.

On the social front, the Diem government hoped to form a "new middle peasant class"landowners whose material interests were tied to the political stability of the regime. Theoretically, this class would be a solid social base, conservative in outlook, and resistant to revolutionary movements. However, in reality, the reform program faced many limitations: the scale of land distribution was small, the majority of good land remained in the hands of the regime's close associates, while farmers bore the burden of prolonged installment payments. Bureaucracy, corruption, and tokenism prevented the program from achieving the desired socio-political goals, even leading to increased public dissatisfaction.

The peak of the effort to control the countryside was the Strategic Hamlet policy (1961-1963), a measure with a strong military administrative character. By concentrating the population into fenced and strictly controlled areas, the RVN government hoped to separate the peasants from the influence of the revolutionary forces, cutting off supplies, manpower, and intelligence to the opposing side. However, the coercive nature of the relocation, the destruction of homes, ancestral tombs, and traditional living patterns led to widespread resistance. This policy did not "win the hearts and minds" of the farmers; on the contrary, it pushed them towards the revolution.

The failure of the Strategic Hamlet Program, as well as the entire system of agricultural policies under Ngo Dinh Diem, demonstrated the limits of an imposing, politically driven "counter-insurgency" strategy that was disconnected from Vietnamese social reality. Instead of consolidating legitimacy, these measures eroded the regime's credibility and political base, contributing to the collapse of the First Republic government in 1963.

Key Agricultural Economic Policies

Land reform policy: The US and the Saigon government soon paid attention to and implemented land policies in two phases, namely 1955-1963 and 1967-1975. In the 1955-1963 period, the Ngo Dinh Diem government issued the "land reform" law, and it was carried out in a special historical context. During the war, most of the big and middle landlords fled to Saigon, Cho Lon and other provincial capitals, leaving hundreds of thousands of hectares

of land in the countryside without anyone to take care of them. That land, along with the land of the French colonialists, was temporarily handed over and granted to poor farmers by the resistance government.

By the time peace was restored, “564,547 hectares of land in the South were divided among 527,163 people” (Institute of Economics under the State Science Committee, 1960, p. 305)

Thus, after the Republic of Vietnam government was established, within just two years (1955-1956), the US government sent an advisory delegation led by W. Ladejinsky (Chief Advisor on Land Reform) to South Vietnam to assist the RVN government in drafting land policy. The Cong Luan newspaper (July 7, 1969) reported that from 1955 to 1960, the US provided 12 million USD in aid to the RVN government to implement the land reform policy.

Ngo Dinh Diem sequentially promulgated three ordinances detailing the implementation of the "Land Reform" policy. The main content of these ordinances regulated the relationship between landlords and tenants and set a reasonable limit on the amount of land a landlord could own.

Ordinance No. 2 (January 8, 1955), amending Ordinance No. 20 "Stipulating the Tenant Status" (Ministry of Land and Land Reform, 1960, trang 91-95), largely repeated Ordinance No. 20 signed by puppet Chief of State Bao Dai on June 4, 1953. While Ordinance 20 set the maximum rent (land lease price) and interest rate negotiated between landlords and tenants uniformly at 15% of the land's yield, Ordinance No. 2 revised this: the minimum land rent was 15% and the maximum was 25% of the land's yield. The lease period was set at 5 years.

Ordinance No. 7 (February 5, 1955) "Stipulating conditions for re-exploiting fallow, uncultivated land (replacing the completely repealed Ordinance No. 22)" (Ministry of Land and Land Reform, 1960, trang 91-95), It stipulated that land left fallow during the crop season must be handed over to "tenants for cultivation under conditions of rent exemption for the first year, half rent for the second year, and three quarters rent for the third year." The contract duration was similar to the provisions of Ordinances No. 2 and No. 20, with renewal options. Tenants had the right to return the land with a 6 month prior notice to the landlord. Landlords wanting to reclaim the land (not renew the contract) had to notify the tenant 3 years in advance. Fallow rice fields during the war for independence (without an owner present to claim ownership) were estimated at around 500,000 hectares. A large portion of this land belonged to middle landlords (5 to 10 hectares) and major landlords (50 hectares or more). To contribute to rural agricultural development, the government also allowed former tenants who had followed the revolution to continue cultivating the plots allocated by the revolution during the war. Their tenancy and rent rights were now recognized and guaranteed by the government. Public and communal fallow lands were also to be handed over to tenants for cultivation under the same conditions.

One year after applying the tenancy regulation, President Ngo Dinh Diem promulgated Ordinance No. 57 on October 22, 1956, "Stipulating Land Reform" (Ministry of Land and Land Reform, 1960, trang 91-95). According to this, a landlord could only keep a maximum of 100 mẫu (equivalent to 100 hectares or 247 acres), of which 30 mẫu had to be directly cultivated, and the remaining 70 mẫu had to be rented to tenants under the tenancy regulation. Land exceeding this limit was to be expropriated (by selling it themselves or selling it to the state for redistribution to those who needed it for farming). However, the newspaper Cách Mạng Quốc Gia (October 23, 1959) reported that "by 1959, the total number of expropriated

landlords was only 627, with compensation reaching 267,220,705 South Vietnamese đồng. According to the newspaper France Observateur (July 23, 1959), only 40,000 hectares of expropriated land had been sold (only 5.7% of the land intended for distribution) to 20,000 farmers" ((Institute of Economics under the State Science Committee, 1960, p. 305).

These figures alone are sufficient to expose the hollow and deceptive policy of the so called "expropriation of landlord land" by the Ngo Dinh Diem regime. Also, according to Ordinance No. 57, if landlords had an area exceeding 100 mẫu, the law required them to sell the surplus to the landless. The government established four priority groups to receive land: people who had been tenants for more than two years, former soldiers, northern migrants, and the unemployed. "In addition, they could keep an extra 15ha of ancestral land (ruộng hương quả), and the retained land could be chosen freely" (Tran Phuong, 1968, pp. 245-259). The surplus land would be bought by the government at market price, with 10% paid in cash upfront, and the remainder in bonds over 12 years with an interest rate of 3%/year (Le Dinh Trong, 2020, p. 65). The expropriated land was resold to the land-poor, with a maximum limit of 5 hectares per person, "except for farmers who took advantage of the recent situation to brazenly occupy landlords' land, avoided signing contracts, or did not pay rent or land tax in the past year and refused to pay the arrears before March 31, 1957" as stipulated in Article 11. Buyers had to pay gradually over 6 years, during which the land remained the property of the government. Within 10 years, they were not allowed to lease, mortgage, resell, or seize the land.

As seen above, besides the basic features, the US-Ngo Dinh Diem ordinances included some specific additions and amendments. However, when compared to the French-Bao Dai ordinances, they were neither more advanced nor more complete. The land distributed to farmers was limited; or, as author Dang Phong observed, "the land reform of the Ngo Dinh Diem government brought little political effect, and political effect was the fundamental goal of that reform. Until Ngo Dinh Diem was killed, the land reform still failed to resolve the fundamental issues of the farmer and the countryside" (Dang Phong, 2005, p. 833).

Population Concentration Policies for Control

Land Development Centers: Proposed by President Ngo Dinh Diem during the First Republic, the Land Development Centers (LDCs) aimed at political, military, as well as economic and social objectives:

Economically: The LDCs aimed for a more even distribution of the population, increasing cultivated area to boost production and agricultural expansion, improving the lives of migrants and poor farmers, combating slash-and-burn practices by ethnic minorities that damaged forests and land, and helping them improve their lives through common economic policies.

Politically: Residents would receive land for cultivation and materials, as well as money to build houses. Simultaneously, the government would grant them ownership of the cultivated land. Thus, politically, the government sought to win over the people's hearts by making them align with the nation and oppose the Communists.

Socially: They aimed to solve the housing problem for nearly one million Northern migrants to the South. They also sought to redistribute the population across the country more evenly and rationally to avoid large empty regions that made government control difficult.

Security-wise: The LDC locations were essentially critical strategic points for the Saigon government to resist incursions and attacks by the Communists. As some military strategists argued, "in the attacks on some cities of the Republic of Vietnam, the reason why the Communists could not seize a province or district,... was thanks to the system of fences around the Land Development Centers actively blocking and forming a continuous screen of support for the provincial and district capitals" (Tran Van Dinh, 1974, p. 43).

To establish an LDC, the Ngo Dinh Diem government conducted surveys (this task belonged to the General Commission of Land Development) and selected suitable locations large enough to settle 1,000 people or more. To do this, promotion and mobilization were conducted through media to encourage public participation.

According to Decrees No. 1502 and 1503 TTP/VP dated September 25, 1957, the Saigon government practically established 4 LDCs in South Vietnam: "1 in the Central Highlands and 3 in the Southern region (Dong Thap Muoi LDC area including Kien Tuong and Kien Phong provinces, An Xuyen - Ba Xuyen LDC area, Cai San LDC area including Kien Giang, An Giang)" (Tran Thi Ha, 2015).

The LDCs were new villages established to receive Northern migrants and poor farmers from the Central Coastal plains to settle and make a living. They received full social benefits such as schools, clinics, and dispensaries. They were then given a title deed confirming their ownership of the land. In addition, the government subsidized them with food, farming tools (hoes, hammers, sickles, shovels, chemical fertilizers...), seeds, and livestock (chickens, ducks) free of charge. The National Agricultural Credit Fund provided low interest loans so they had financial means to farm.

In general, the Saigon government's LDC policy not only had economic effects, was practically implemented, stabilized people's lives, and contributed to agricultural development, "improving livelihood," and "turning the proletarian farmer into a property owner," as the Saigon government praised. It also had a strong effect on military strategy, being a type of concentration camp to suppress farmers, exploit labor in preparation for war against the revolution, and a measure for the Saigon government to realize its schemes.

Consequently, the Ngo Dinh Diem government's policy of concentrating the population into LDCs led the Saigon regime into a new political crisis after the "Denounce Communists" campaign. The forced migration destroyed villages, brazenly trampled on the land rights, customs, and traditions of the ethnic people, causing the separation of countless families and stirring up widespread public resentment. Furthermore, the LDC policy was heavily focused on formality to please superiors, neglecting effectiveness, and corruption in the establishment of LDC locations further eroded public trust in the policy. The LDC policy also proved deficient in finding markets for agricultural products, causing farmers to be unable to sell their produce. A typical example was the government's recommendation for people to plant a lot of Kenaf (jute), which then couldn't be sold, further causing people to lose faith in the LDC. These were the causes that ignited the struggles against forced migration and land seizure to establish LDCs in the South.

Agrovilles

After the failure of the "Land Development" program, in 1959, the Ngo Dinh Diem government continued to implement the "Agrovilles" program, primarily targeting farmers in the Mekong Delta. According to Ngo Dinh Diem: "This year, I propose the task of

establishing Agrovilles in the countryside, in places with convenient transportation, good sanitation, and minimal facilities to gather scattered and deprived farmers. These Agrovilles will be economic units that will later play an important role in the nation's economic development" (Tran Van Giau, 1968, p. 16)

The Agrovilles program was piloted starting in May 1959 in several locations in the South such as Vi Thanh (Can Tho), Mo Cay (Ben Tre), and Hac Phong, An Long areas in An Giang. From July 1959, this model was expanded across the entire South Vietnam.

To establish the Agrovilles, the Directorate General of Construction was responsible for drafting the overall design, while the Provincial Land Registry was in charge of surveying and specific planning. Each Agroville was relatively large, having to include at least 200 new houses to be considered a standard for establishment. The entire area was surrounded by a large canal to create a natural boundary and facilitate control. Inside the area, there were many smaller canals dividing the lots, and the excavated earth was used to build roads: large roads as main traffic axes, and small roads for internal travel.

The structure of an Agroville was usually divided into three main areas:

Administrative Area: including village offices and headquarters for specialized units like the post office, information, police, and clinic...

Commercial-Industrial Area: for trade activities, building factories, technical workshops, developing commerce, and small-scale industries associated with local agriculture.

Residential and Farm Area: "where farming families were concentrated to live and raise livestock. Each family was allocated a plot of 4,800 square thước (equivalent to 4800 square meters), or more or less depending on the locality's potential for agricultural development" (Office of the Prime Minister of the Republic of Vietnam, 1960, trang 16). Additionally, the cultivated area could be expanded by reclaiming more fertile land, so that future generations could advance to become landowners.

The US-Diem regime established the Agrovilles for the following purposes:

Political Security: The Ngo Dinh Diem government and its apparatus sought to deceive public opinion by promoting the construction of "Agrovilles" as aiming to "build a new society on the foundation of social justice and fraternity to promote the common progress of all strata of the population, with the limited means of an underdeveloped country that relies only on its own efforts" (Nguyen Thi Thanh Huyen, 2014, pp. 136-137). According to this statement, the goal of the Agroville was for farmers to live together in a safe environment, no longer fearing intimidation from communists and robbers. Residents within the area were tightly organized, with self-defense forces and youth teams protecting the hamlets day and night. The government hoped that when people felt this was a safe place, tied to their families, property, and lives, they would voluntarily side with the government and "actively fight against the communists." The newspaper Quê Hương (Homeland), a communication organ of the Ngo Dinh Diem government, once wrote: "The success of the Agroville is concrete proof of the complete failure of the communist policy of proletarianizing the people. Therefore, the day the Agrovilles are perfected in this free South will be the day the communists will no longer have any means to operate" (Nguyen Thi Thanh Huyen, 2014, pp. 136-137). However, despite the Saigon government's efforts to propagandize and embellish the Agroville program with "beautiful" ideals, the political conspiracy and tactics behind it soon became apparent. In

fact, the deep-seated goal of the government was to separate the revolutionary forces from the people, isolate families connected with or suspected of supporting the resistance, causing the revolutionary cadres to lose their support and liaison base among the masses. Thus, the Agroville was not just under the guise of "building a new countryside," but was essentially a tool for political control and suppression, serving the conspiracy to counter the revolutionary movement in South Vietnam.

Economically: The Ngo Dinh Diem government claimed that the construction of Agrovilles would contribute to the expansion of the Southern agricultural economy through cooperatives and farmers' associations. According to the propaganda, these organizations would give farmers better conditions for production, improving productivity and livelihood. The newspaper Quê Hương praised: "Developing the community, social progress, improving the livelihood of Vietnam... Thanks to the Agroville, people in the countryside can hope to equally enjoy all amenities and progress like city dwellers" (Nguyen Thi Thanh Huyen, 2014, pp. 136-137). However, the reality was entirely contrary to the propaganda. Ngo Dinh Diem himself stated: "Destroying houses, destroying gardens, taking rice land, forcing labor without compensating anyone" (Office of the Prime Minister of the Republic of Vietnam, 1960). In many places, hundreds of fruit gardens and thousands of graves were dug up. The management and suppression policy in the Agrovilles was also incredibly harsh. A contemporary report described: "People in the Agroville are like in a cramped prison. A family occupies a width of less than 4 meters and a length of less than 10 meters (4m x 10m) with no occupation or means of livelihood. They can only live like serfs of the ancient times, dedicating themselves to the American-Diem machine farming owners and contractors" (First Republic of Vietnam background, 1960).

In essence, the Agroville did not bring prosperity as advertised, but disrupted the socio economic life of the Southern countryside. Farmers were forced to leave their homes, lost their land, lost their means of livelihood, and became dependent laborers in the very land of "safe settlement" imposed by the government.

Socio Culturally: The US and the Ngo Dinh Diem government advocated for building "Agrovilles" as a model of a "flourishing market town in the countryside," with the proclaimed goal of both material development and the restoration of mutual assistance, bravery, self-sacrifice, and traditional values of the Vietnamese countryside. However, all of that was just a false image created by the Ngo Dinh Diem government. In reality, the government introduced a depraved and counter-cultural lifestyle through the dissemination of reactionary and decadent books, newspapers, and films, aiming to poison the youth, disrupt ideology, ethics, and traditional lifestyles. Furthermore, they intensified propaganda about the "Republic," the "Personalist Labor Party", and "US strength" with the aim of instilling a sense of fear and dependency, weakening the will for revolutionary struggle, and forming a psychology of complacency and resignation among the people of the South. If people resisted or showed reluctance to relocate, the government would send troops to sweep through, shell with mortars, and drive armored vehicles to bulldoze villages and hamlets. According (Le Dinh Trong, 2020, p. 3): "The people were immensely resentful, so they abandoned the national government and followed the Revolution."

Despite its practical failure, the Saigon government still managed to establish a significant number of Agrovilles in the South during its existence: "In 1960, 19 areas were planned, 17 were established; by 1962, 22 more were established, gathering 6,954 families on an area of

601 samples" (Ta Ngoc Cuong, 1973, p. 16). However, these figures only represent "paper success."

In reality, the Agroville policy was even less successful than the previous "Land Development" program because the implementation was coercive, brutal, and contrary to the people's will. The Agrovilles were scattered, lacked comprehensive control, and destroyed many villages, trampling on the land rights, customs, and traditions of the farmers. Consequently, the government could not gather the necessary strength and support to achieve the goal of "pacifying the countryside."

Thus, the Agroville was essentially a giant concentration camp, a stronghold aimed at undermining the revolutionary movement in all fields: political, economic, military, and cultural. In direct proportion to the government's harshness and deceit was the people's increasingly deep-seated resentment, which ignited the struggles against the Agrovilles and became the fuse for the anti-American-Diem resistance movement across the South.

Strategic Hamlets

Following the failure of the Land Development Centers and Agrovilles policies, the Ngo Dinh Diem regime sought to revolutionize its rural pacification strategy with the national policy of the Strategic Hamlet Program (SHP). The program was propagandized as an effort to transform the rural landscape and win back the hearts of the people, but in essence, it was a political-military measure aimed at controlling the populace and suppressing the revolutionary movement, serving as an escalation of the two preceding policies.

The SHP was implemented under the advisement of British and American consultants, led by R. Thompson, and was regarded as the regime's "long-term strategic solution." A document from the Presidential Palace affirmed: "The Strategic Hamlet national policy is a long-term and momentous strategy... which concretizes the path of eliminating communism, implementing Personalist Republicanism, community, and common progress... aiming to restore security in the countryside and enact democracy" (Palace of the First President of the Republic of Vietnam, 1962).

Unlike the Land Development Centers and Agrovilles, the Strategic Hamlet policy clearly displayed its political-military nature, without disguising itself under the banner of "economic development." After the "Concerted Uprising" movement, the Saigon government had virtually lost control of the countryside. Thus, it adopted the "New Village" model used by the British in Malaya: isolating the population from the revolution and transforming villages and hamlets into anti-communist fortresses.

According to RVN government documents, the Strategic Hamlet training involved two weeks of activities such as "strategic fencing, combat fortifications, communication trenches, mine traps... to isolate the enemy, separate the enemy from the people for military operations and destruction" (The Palace of the First President of the Republic of Vietnam, 1961)

In essence, the Land Development Centers were a form of migrant resettlement to clear fallow land, while the Agrovilles concentrated people in prosperous areas near military bases. Both featured fences, deep moats, and strict surveillance, with all activities tightly controlled. When expanded into the Strategic Hamlet Program, the degree of coercion and surveillance became even more severe. The government had to acknowledge the violent public backlash yet proceeded with deployment across the entire South.

Ngo Dinh Nhu's Directive dated March 19, 1962, asserted: "The Strategic Hamlet differs from the Agroville... because the Agroville concentrates people on a large scale, while the Strategic Hamlet only concentrates a small number of scattered families according to the principle of shortening the range". In practice, Strategic Hamlets were still heavily fenced with barbed wire, densely laid with mines, and strictly guarded. Every household was on a surveillance list, and movement was restricted. The new element was that they were organized right on the residents' original land to minimize reaction while consolidating local control.

The ultimate goal was to turn the Strategic Hamlets into the regime's political and military base, serving as a source of manpower and logistics for the Saigon government. Ngo Dinh Nhu stated: "The content of the Strategic Hamlet includes the strategic line of the constitution, the strategic line of the nation; the content of the hamlet is a strategic, not tactical, content, because tactics are only a phase while strategy is permanent" (Tran Van Tho, 2000, pp. 5-6) The long-term objective here was not merely to control the population and separate them from the revolution a "draining the water to catch the fish" approach to eliminate the revolutionary movement but also to build the South into a new-style colony to serve the long-term goals of colonialism.

This demonstrates that the Strategic Hamlet was not just a military measure but a tool for establishing a new-style colonial regime, serving the global strategy of the United States. On February 3, 1962, Ngo Dinh Diem signed Decree No. 11-TTP establishing the Inter-Ministerial Committee for Strategic Hamlets. On April 19, 1962, the Republic of Vietnam National Assembly passed Resolution No. 1214-CT/LP, "Endorsing the Strategic Hamlet National Policy and fully supporting the Strategic Hamlet strategy of the Ngo Dinh Diem government," thereby rapidly deploying the Strategic Hamlet policies across the entire South and making it a national policy (Palace of the First President of the Republic of Vietnam, 1962).

According to the Saigon government's zoning, the South was divided into three areas: "Zone A occupied by the nation, Zone B where influence is being contested between the nation and the Communists, and Zone C completely controlled by the Viet Cong (secret zones)" (Ta Ngoc Cuong, 1973, p. 16). For the Southwest region, Ngo Dinh Nhu clearly stated: "In the initial phase, we must strive to firmly grasp the provinces of Vinh Binh, Vinh Long, An Giang, and Kien Giang, paying special attention to establishing a strong barrier (using SHP and Special Forces) along the Rach Gia, Long Xuyen route up to the Hau Giang River, while also sweeping Phu Quoc Island" (Nguyen Duc Thuan, 2017, pp. 49-53).

Thus, the Strategic Hamlet Program was both a product of the US-directed "counter-insurgency" strategy and a continuation of the coercive, anti-people policies of the Land Development Centers and Agrovilles. It became one of the direct causes that ignited the widespread movement to dismantle the Strategic Hamlets across the South, particularly in the An Giang region during the years 1961-1963.

Assessment of Effectiveness and Causes of Failure

The agricultural policies of the RVN under Ngo Dinh Diem, which included the Land Reform (cải cách điền địa), Land Development Centers (dinh điền), Agrovilles (khu trù mật), and Strategic Hamlets (ấp chiến lược), in form achieved some short-term results: land distribution to a segment of the peasantry, the establishment of new settlements, and the creation of administrative-security structures in rural areas.

However, in reality, these were political-military tools aimed at controlling the population, isolating the revolutionary forces, and consolidating President Ngo Dinh Diem's power. This very policy deviation failed to establish a solid socio-economic foundation for the farmers and did not achieve the strategic objective of "winning the hearts and minds" of the masses, leading to the comprehensive failure of agricultural policy in South Vietnam during the 1955-1965 period, politically, socially, and economically.

Causes of Failure

The failure first stemmed from the politicized nature of the agricultural programs: Although framed as "reform" or "community development," all agricultural policies under Ngo Dinh Diem served the counter revolutionary strategy and the consolidation of his personalist authoritarian regime. Instead of implementing substantial land reform to eliminate inequality and create opportunities for farmers to own land, the government only carried out token measures aimed at dismantling local power structures and forcing the peasantry into dependency on the central administrative machinery. The Land Reform Ordinance No. 57/BC (1956) therefore did not create an independent landowning peasant class but merely restructured the relationship of dependency from the landlords to the state.

The imposed and culturally insensitive nature of planning and implementation: Policies such as the Agrovilles and Strategic Hamlets were profoundly influenced by the US "counter-insurgency" doctrine and the British "New Village" model in Malaya. When applied to the conditions of Vietnam, the Diem regime failed to consider the socio economic characteristics, cultivation practices, and communal culture of the Southern peasantry. The forced relocation of people, the destruction of homes and ancestral tombs, and the coercive life within areas fenced with barbed wire and guarded by bunkers made the people feel insulted, deprived of their freedom, and stripped of their livelihoods. This "anti-people" and "anti cultural" nature directly pushed the policies into opposition with the interests and sentiments of the farmers the very force the government wished to conquer.

Bureaucratic, corrupt, and incompetent implementation mechanism: The administrative apparatus from central to local levels was both clumsy and inefficient. The abuse of power by local officials, combined with corruption in land allocation, supply distribution, and resident surveillance, caused the masses to lose faith. Furthermore, the lack of financial and technical resources, as well as inadequate infrastructure, meant that agricultural programs remained only superficial. Slogans like "rural development" or "common progress" became empty rhetoric when the people's lives were not improved.

As a result, the failure of agricultural policy is comprehensive in three aspects.

Economically, these policies have failed to generate higher agricultural productivity, improve farmers' incomes, and disrupt traditional production patterns. Forced displacement and loss of productive land have left many farming households impoverished and dependent on aid and relief.

Socially: Programs such as Agrovilles and Strategic Hamlets shattered the structure of the village community the long standing cultural foundation of rural Vietnam. Kinship, neighborhood relations, and religious beliefs were severed; living spaces were transformed into "collective prisons." This not only weakened communal solidarity but also incited strong resentment and resistance among the populace.

Politically and Security wise: Instead of pacification, the Diem regime isolated itself from the people. The “draining the water to catch the fish” policy of concentrating the population to isolate the revolution backfired, causing previously neutral or passive residents to side fully with the revolutionary movement. The widespread movement to dismantle the Strategic Hamlets across the South, particularly in An Giang, Ca Mau, Ben Tre, etc., demonstrated the complete failure of this strategy.

4. Conclusion

The agricultural policies of the Republic of Vietnam government during the period 1955-1963, represented by the land reform programs, plantations, special zones and strategic hamlets, reflected the efforts of the Ngo Dinh Diem regime to control the countryside, which accounted for 80% of the population of the South, in order to consolidate political power and prevent the revolutionary movement. However, these policies, although in the name of economic and social development, were in fact tools serving the counterinsurgency strategy oriented by the United States.

In terms of effectiveness, the above programs achieved some formal results such as limited land distribution, the construction of some concentrated residential areas and the extension of the central government's administrative reach to the countryside. However, these results only existed on paper and were unsustainable, due to their coercive and top down nature. Instead of improving life and creating momentum for development, the policies broke down traditional social structures and eroded farmers' trust in the government.

The reason for the failure stemmed from the fact that the Diem regime placed political goals above socio economic goals. The models were mechanically imported from the US counter-insurgency strategy, which was not suitable for the historical, cultural and customary conditions of the Vietnamese people. The implementation process was coercive, lacking a mechanism for people's participation, while corruption and poor management made the policy unfeasible. Moreover, the government failed to offer real economic solutions to improve farmers' productivity and income, making social support almost non-existent.

As a result, the agricultural policies of the Republic of Vietnam not only failed to control the countryside, but also became one of the direct causes of weakening the social foundation of the regime. Instead of “winning the hearts and minds” of the people, the Diem government pushed them towards the revolutionary forces. That failure showed that any policy that goes against the interests and aspirations of the people cannot be sustainable.

Thanks and Information Note

The article complies with national and international research and publication ethics. All authors contributed equally to the article

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Comprehensive Feasibility Design for Architectural and Structural Integration of Arched Windows in Contemporary Building Practice

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Abstract

This study investigates the feasibility of integrating arched window systems into modern architectural designs through a comprehensive assessment framework encompassing architectural, structural, and sustainability perspectives. The research employs a mixed-methods approach including case study analysis of contemporary buildings featuring arched windows, structural modeling using finite element analysis (FEA) under various load conditions, and environmental impact assessment using life cycle analysis (LCA) methodology. Results indicate that properly engineered arched window systems can achieve structural reliability with a safety index (β) ≥ 4.2 while enhancing building energy performance by 12-18% through optimized daylight penetration. The study identifies critical design parameters including rise-to-span ratios between 0.15-0.35 as optimal for balancing structural efficiency with architectural aesthetics. Furthermore, the research develops a novel assessment matrix for evaluating arched window feasibility across multiple criteria, providing designers with a practical tool for early-stage decision-making. These findings contribute to reviving historical architectural elements through contemporary engineering approaches, establishing a foundation for their viable application in sustainable building design.

Keywords: Arched windows, structural feasibility, architectural design, sustainability assessment, finite element analysis, building integration, historical elements, contemporary architecture.

1. Introduction

Arched windows represent a significant architectural element with rich historical provenance, tracing their origins to Roman and Byzantine architecture where masonry arches enabled innovative spatial and fenestration designs (Anderson, 2020). These elements flourished throughout Gothic cathedral architecture, evolving into complex traceried windows that defined ecclesiastical structures across Europe (Archisoup, 2023) . Despite their historical significance, arched windows experienced a decline during the 20th century with the advent of modernism and rectangular structural systems, leading to a gradual erosion of traditional craftsmanship associated with their construction (ASHRAE, 2022). In contemporary architectural practice, there is a resurgent interest in integrating arched windows, driven by

three primary factors: the aesthetic value of curvilinear forms in breaking the monotony of rectilinear modernism, the potential for enhanced daylight performance through optimized geometry, and the growing appreciation for contextual design in historically sensitive areas (Baker, 2023). The integration of arched windows in modern buildings presents unique challenges that span multiple disciplines. Architecturally, there exists a tension between historical authenticity and contemporary expression, requiring designers to navigate aesthetic appropriateness while meeting modern performance standards (Bullen, 2021). Structurally, the introduction of arched elements in primarily rectilinear building envelopes creates complex load transfer mechanisms, particularly concerning point loads at the springing points and thrust management in masonry-style arches (Chen, 2022). From a construction perspective, the manufacturing and installation of non-standardized window units incur premium costs compared to conventional rectangular windows, while specialized installation requirements further complicate their implementation (Construction Industry Institute, 2023). These challenges necessitate a systematic feasibility assessment framework to guide designers in making informed decisions regarding arched window integration.Current literature reveals significant gaps in comprehensive arched window design guidance. While numerous studies have examined the structural behavior of arches in bridge and large-span structures (Department of Sport and Recreation, 2023), limited research addresses the specific requirements of window-scale applications in building envelopes. Similarly, architectural publications often focus on historical precedents or aesthetic considerations without adequately addressing technical performance aspects (Dubois, 2023). This disciplinary fragmentation has resulted in a knowledge gap regarding the holistic integration of architectural intent, structural performance, and building science principles specific to arched windows (Ellingwood & Maes, 2025).

This study aims to develop a comprehensive feasibility design methodology for arched windows that integrates architectural and structural considerations within a contemporary building context. The specific objectives include: (1) establishing key architectural design parameters for arched windows and their relationship to building typology and context; (2) quantifying structural performance under various loading conditions and material configurations; (3) assessing environmental impacts and energy performance implications; and (4) developing a practical feasibility assessment matrix to support design decision-making. By addressing these objectives, this research provides a evidence-based framework for the successful integration of arched windows in modern construction, bridging the gap between historical architectural elements and contemporary performance requirements

2. Materials and Methods

This research employs an integrated mixed-methods approach to assess the feasibility of arched windows in contemporary architecture, combining quantitative structural analysis, architectural case studies, and environmental impact assessment. The methodology was designed to address the multifaceted nature of arched window integration, recognizing that a comprehensive understanding requires examination across multiple domains and scales.

2.1 Architectural Feasibility Assessment

The architectural feasibility assessment employed a two-tiered approach examining both contextual integration and design parameters. First, a comprehensive review of 45 contemporary projects featuring arched windows was conducted, analyzing their application across various building typologies including residential, commercial, institutional, and

religious structures . This review documented key architectural considerations such as stylistic approach (historical revival vs. contemporary interpretation), scale relationships with building massing, and material palettes. Second, detailed documentation was performed on 12 selected case studies through site visits, photographic surveys, and interviews with design professionals to understand decision-making processes and implementation challenges.

The spatial and aesthetic impact of arched windows was quantitatively assessed through daylight analysis and spatial composition evaluation. Daylight performance was modeled using RADIANCE software across varying arched window geometries (semicircular, segmental, elliptical, and pointed arches) with identical openable areas to establish performance differentials based on shape alone (Gohn, 2024). Spatial perception was evaluated through a survey of 125 architectural professionals using simulated interior environments, assessing subjective responses to arched versus rectangular windows in comparable spatial configurations. Table 1 shows the case study profile distribution

Table 1. Case study profile distribution

Building Typology	Number of Cases	Primary Arch Type	Contextual Setting
Residential	18	Segmental	Urban Infill
Cultural Institutional	12	Semicircular	Historic District
Commercial Mixed-Use	9	Elliptical	Contemporary Urban
Religious	6	Pointed/Gothic	Traditional

2.2 Structural Analysis Methodology

The structural feasibility assessment employed both analytical modeling and finite element analysis (FEA) to evaluate arched window performance under various loading conditions. The study investigated four common arch geometries semicircular (R=0.5W), segmental (R=0.6W, H=0.3W), elliptical (a=0.5W, b=0.25W), and pointed (equilateral) with consistent span width (W) of 2.4m across all configurations to enable comparative analysis (Guindos, 2022).

Material behavior was analyzed for three primary construction approaches: (1) monolithic stone or precast concrete arches, (2) segmented masonry arches with mortar joints, and (3) steel-framed arches with glazing systems. For each material configuration, finite element models were developed using ABAQUS/CAE 2022, incorporating appropriate material properties, boundary conditions, and interface behaviors. The models simulated various loading scenarios including uniform lateral wind pressure (1.5 kPa representing typical design wind load for mid-rise buildings), non-uniform snow accumulation on exterior arch surfaces (0.75 kPa), and seismic accelerations of 0.3g representing high seismic zones.

The structural reliability was evaluated using First-Order Reliability Method (FORM) principles, which have been extensively applied in structural safety assessments . This approach enabled the calculation of reliability indices (β) for different arched window configurations, considering uncertainties in material properties, manufacturing tolerances, and loading conditions. The analysis specifically examined stress concentrations at keystone and springing points, deformation compatibility with surrounding wall systems, and long-term creep effects in masonry and concrete arches.

Table 2. Material Properties for Structural Analysis

Material Type	Elastic Modulus (GPa)	Compressive Strength (MPa)	Tensile Strength (MPa)
Natural Stone	50-60	60-100	5-8
Structural Steel	200	250-400	250-400
Laminated Glass	70	600-1000	30-50
Reinforced Concrete	30-35	30-40	2-5

2.3 Environmental and Sustainability Assessment

The environmental impact assessment employed life cycle assessment (LCA) methodology following ISO 14044 standards, comparing arched window systems with conventional rectangular windows across multiple environmental indicators. The assessment considered cradle-to-grave impacts including material extraction, manufacturing, transportation, installation, use phase, and end-of-life disposal or recycling. Energy performance was specifically evaluated through thermal modeling using EnergyPlus v9.4, analyzing heating and cooling loads associated with different arched window configurations across various climate zones (ASHRAE Zones 2A, 4C, and 6A) (Hammond & Jones, 2019).

Daylighting performance was quantified through dynamic metrics including Useful Daylight Illuminance (UDI) and Annual Sunlight Exposure (ASE), with simulations conducted for spaces with identical window-to-wall ratios but varying window shapes. Additionally, the embodied carbon of arched window systems was calculated using the ICE (Inventory of Carbon & Energy) database v3.0, providing comparative data on carbon emissions associated with different material selections and manufacturing processes.

2.4 Feasibility Assessment Framework Development

Based on the integrated analysis results, a comprehensive feasibility assessment matrix was developed to support design decision-making. The matrix incorporated weighted criteria across architectural, structural, environmental, and economic domains, with weighting factors calibrated through expert surveys of 45 architectural and engineering professionals. The framework was designed to be applied during early design phases, allowing designers to evaluate different arched window configurations against project-specific requirements and constraints.

Validation of the feasibility assessment framework was conducted through three case study applications, where independent design teams implemented the matrix on ongoing projects considering arched windows. The validation process assessed the framework's usability, comprehensiveness, and effectiveness in identifying potential integration challenges before detailed design development. Figure 1 show the proposed window arched. Figure 1 shows the window arched drawing.

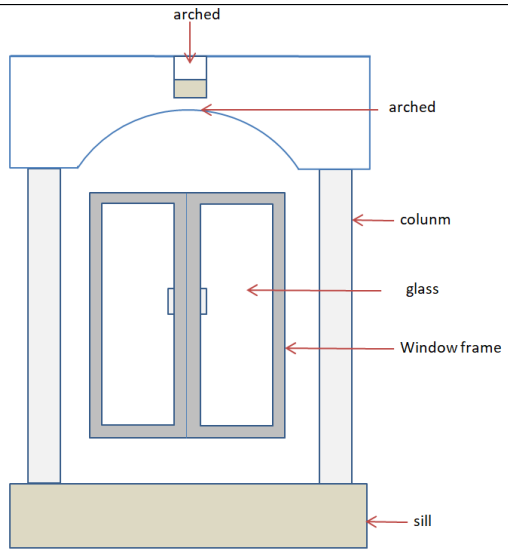


Figure 1. the window arched drawing

3. Findings and Discussion

3.1 Architectural Integration Analysis

The case study analysis revealed distinct patterns in arched window application across different building typologies. In residential projects, segmental arches with low rise-to-span ratios (typically 0.15-0.25) were predominant, valued for their subtle curvature that provides visual interest without overwhelming interior spaces . Cultural and institutional buildings favored more pronounced arch forms, with semicircular and elliptical arches (rise-to-span ratios of 0.3-0.5) creating stronger architectural statements and enhanced spatial experiences. Contemporary interpretations frequently employed material contrasts, such as traditional arched forms executed in modern materials like corten steel or frameless glass, creating a dialogue between historical reference and contemporary expression.

Daylighting analysis demonstrated significant performance variations based on arch geometry. Semicircular arches provided 18% higher useful daylight illuminance in the rear zones of deep spaces (≥6m depth) compared to rectangular windows with identical openable areas, attributable to their ability to capture and redirect light from higher solar altitudes (Heyman, 2020). However, pointed arch configurations showed more uniform light distribution across seasonal variations, particularly in climates with extreme seasonal solar altitude differences. The spatial perception survey revealed a strong preference (78% of respondents) for arched windows in living and gathering spaces, associating them with qualities of "grandeur," "openness," and "architectural character," though respondents noted potential style conflicts in rigorously minimalist interiors.

3.2 Structural Performance Findings

The structural analysis revealed distinct performance characteristics across the different arch geometries and material systems. Semicircular masonry arches demonstrated superior load distribution capabilities under uniform vertical loading, developing primarily compressive stresses with minimal tensile forces when properly proportioned. However, these configurations showed vulnerability under asymmetric loading conditions, with 35-40% higher stress concentrations at the haunches compared to segmental arches under equivalent

wind loads. Segmental arches with rise-to-span ratios between 0.15-0.25 exhibited more balanced performance across loading scenarios, though their flatter profiles resulted in 20-25% higher bending moments under uniform vertical loads.

The finite element analysis identified critical stress concentrations at several key locations: (1) the intrados at the quarter-points under full wind load, (2) the extrados at the keystone under snow loading, and (3) the springing points under seismic lateral forces (Hu, 2024). Steel-framed arched systems demonstrated superior performance under seismic conditions, with 40-50% lower stress concentrations at the supports compared to monolithic stone systems. The structural reliability analysis yielded safety indices (β) ranging from 4.2 to 5.1 for properly designed and constructed arched window systems, meeting or exceeding the target reliability of $\beta \geq 4.0$ for non-structural components in building envelopes. Table 3 shows the structural performance comparison by arch type.

Table 3. Structural performance comparison by arch type

Arch Type	Max Deflection Under Wind Load (mm)	Stress Concentration Factor	Reliability Index (β)
Semicircular	2.8	1.8	4.8
Segmental	3.5	2.2	4.5
Elliptical	4.2	2.5	4.2
Pointed	3.1	2.4	4.6

Material performance analysis revealed significant differences in long-term behavior. Monolithic stone and precast concrete arches exhibited excellent durability but required careful detailing at connections with surrounding wall systems to accommodate differential movement. Segmented masonry arches showed higher initial deformation but favorable long-term creep behavior, with stress redistribution reducing peak stresses by 15-20% over a 5-year period. Steel-framed systems demonstrated superior stiffness and predictable performance but required comprehensive thermal breaks and condensation prevention details in climate zones with significant temperature variations.

3.3 Environmental and Sustainability Performance

The life cycle assessment revealed that material selection constituted the most significant environmental impact factor for arched windows, accounting for 65-80% of total embodied carbon across all configurations (International Energy Agency [IEA], 2023). Stone arches showed the lowest embodied carbon per unit area (85-110 kg CO_2/m^2) when sourced locally, while steel-framed systems ranged from 120-180 kg CO_2/m^2 depending on recycling content. Operable energy performance varied significantly by climate zone, with arched windows in heating-dominated climates showing 12-15% reduction in annual heating loads compared to rectangular windows due to reduced thermal stratification and improved convective flow patterns (Natterer, 2023).

Daylighting optimization potential was highly dependent on arch geometry and orientation. South-facing semicircular arches in northern hemisphere locations provided 25-30% higher daylight autonomy compared to equivalent rectangular windows, reducing artificial lighting energy use by 15-18% in office and institutional settings (National Institute of Building Sciences [NIBS], 2021). However, east and west-facing arched windows required additional

shading devices to prevent glare and solar heat gain, somewhat diminishing their energy advantage. The environmental payback period for the additional material investment in arched windows ranged from 8-15 years based on energy savings, with shorter payback periods in buildings where daylight harvesting strategies were fully implemented.

3.4 Feasibility Assessment Matrix

The integrated feasibility assessment matrix incorporated 22 evaluation criteria across four domains: architectural (40% weighting), structural (30% weighting), environmental (20% weighting), and economic (10% weighting). The architectural domain addressed contextual compatibility, aesthetic intent, spatial quality, and visual connectivity; the structural domain assessed load resistance, durability, movement accommodation, and connection details; the environmental domain evaluated energy performance, daylight availability, material impacts, and end-of-life considerations; while the economic domain addressed first costs, life cycle costs, and maintenance requirements.

Application of the matrix to three validation case studies demonstrated its effectiveness in identifying potential integration challenges early in the design process. In all cases, the matrix highlighted at least two critical considerations that had not been initially addressed by the design teams, including differential movement between arch and curtain wall systems, thermal bridging in steel arch supports, and maintenance access for cleaning and repair. Design teams reported that the systematic assessment approach facilitated more informed decision-making and earlier collaboration between architectural and engineering disciplines.

3.5 Interdependencies between architectural design and Structural performance

The results demonstrate significant interdependencies between architectural design decisions and structural performance in arched window systems. The selection of arch geometry, often driven primarily by aesthetic considerations, directly influences structural behavior, construction complexity, and environmental performance. Semicircular arches, while architecturally prominent and historically resonant, require more substantial supporting elements to resist lateral thrust, potentially compromising interior spatial quality and flexibility. Conversely, segmental arches with lower rise-to-span ratios integrate more readily with conventional building geometries but may require additional reinforcement to resist bending moments under asymmetric loading (National Institute of Building Sciences [NIBS], 2023).

The research identifies an optimal range for rise-to-span ratios between 0.15-0.35 that balances architectural expression with structural efficiency and construction practicality. Within this range, arches provide distinctive character without requiring specialized construction techniques that significantly increase costs or compromise thermal performance. This finding aligns with historical precedents in vernacular architecture, where empirical knowledge often produced arch proportions within similar ranges, though contemporary materials and engineering methods allow for greater flexibility in application (Narayanan, 2024).

3.6 Integration Challenges and Solutions

The integration of arched windows into contemporary building envelopes presents several technical challenges, primarily related to the interface between curved and rectilinear systems. Differential movement between structural materials, particularly in composite construction,

requires careful detailing to prevent cracking or water infiltration (OGScapital, 2025). The research identifies several effective detailing strategies, including: (1) flexible flashings at the arch-perimeter interface, (2) structural isolation joints that accommodate differential movement without compromising weathertightness, and (3) graduated transition elements that mediate between arched windows and rectilinear wall systems.

Thermal bridging represents another significant challenge, particularly in steel-framed arched systems where continuous metal elements can create significant heat transfer paths (Park, 2024). The analysis demonstrates that thermally broken aluminum frames and pultruded fiberglass frames reduce heat transfer by 55-70% compared to unbroken steel sections, with minimal impact on structural performance. In masonry arches, incorporating continuous insulation on the exterior face with appropriate vapor management strategies proved most effective in meeting modern energy standards while maintaining architectural authenticity.

Manufacturing and installation complexities contribute significantly to the cost premium associated with arched windows, typically ranging from 25-60% above equivalent quality rectangular windows. However, standardization of certain arch geometries and the development of modular component systems can reduce this premium to 15-25%, improving economic feasibility without sacrificing design quality. Additionally, the research identifies opportunities for digital fabrication technologies, including CNC stone cutting and robotic welding, to reduce labor costs while improving precision and quality.

3.7 Sustainability Implications

The environmental assessment reveals that the sustainability implications of arched windows extend beyond energy performance to encompass material efficiency, durability, and cultural sustainability. While arched windows typically require more material per unit of opening area compared to rectangular windows (15-30% additional material depending on geometry), their potential for enhanced daylighting and associated energy savings can offset the embodied environmental impacts over the building life cycle(Poirazis, 2022). Additionally, the durability and longevity of well-constructed arched windows, particularly masonry systems, can extend service life significantly, reducing life cycle environmental impacts through reduced replacement frequency.

The cultural sustainability aspect of arched windows deserves particular consideration in the context of sustainable development. As elements that contribute to sense of place, historical continuity, and architectural character, arched windows can enhance cultural sustainability by creating meaningful connections to architectural traditions while employing contemporary performance standards (Reinhart, 2021). This cultural dimension, while difficult to quantify, represents an important consideration in holistic sustainability assessment, particularly in historic districts or contexts where architectural continuity supports community identity.

3.8 Limitations and Future Research

This study has several limitations that suggest directions for future research. The structural analysis focused primarily on static loading conditions, while dynamic effects such as wind-induced vibration and long-term creep require further investigation. Additionally, the research examined individual arched windows rather than combinations of multiple arches, which may exhibit different structural interactions and collective behavior (Straube, 2023). The environmental assessment considered operational energy use but did not fully address the

implications of arched windows on HVAC system sizing and operation, which could amplify or diminish the energy savings identified.

Future research should investigate the performance of innovative material applications in arched windows, including carbon fiber reinforcements, engineered wood products, and high-performance glass composites that may offer improved structural and thermal properties (Traditional Building Conference, 2022). Additionally, research is needed on standardized connection details and prefabricated arched window systems that could reduce costs and improve quality control. The development of digital tools that integrate the feasibility assessment matrix into BIM platforms would enhance practical implementation, allowing designers to evaluate arched window options within integrated design workflows.

4. Conclusion and Recommendations

This research establishes a comprehensive framework for assessing the feasibility of arched windows in contemporary architecture, integrating architectural, structural, environmental, and economic considerations. The key findings demonstrate that arched windows can be successfully integrated into modern buildings when specific design parameters are addressed systematically, including optimal rise-to-span ratios between 0.15-0.35, appropriate material selections based on structural and thermal requirements, and careful detailing of interfaces with surrounding building systems.

The study makes several significant contributions to architectural practice. First, it provides evidence-based guidance on the structural performance of different arch geometries, enabling designers to make informed decisions that balance aesthetic intent with technical requirements. Second, it quantifies the environmental impacts and energy performance implications of arched windows, supporting their consideration in sustainable design strategies. Third, the developed feasibility assessment matrix offers a practical tool for early-stage evaluation of arched window proposals, facilitating collaboration between architectural and engineering disciplines and identifying potential integration challenges before detailed design development.

The successful integration of arched windows in contemporary architecture requires a multidisciplinary approach that acknowledges the interconnectedness of form, structure, and performance. By applying the principles and assessment methods developed in this research, designers can revive the rich architectural tradition of arched windows while meeting contemporary standards for structural safety, energy efficiency, and economic feasibility. This approach demonstrates that historical architectural elements can be successfully adapted for contemporary practice through thoughtful design, appropriate technology, and evidence-based decision-making, enriching the architectural language of modern buildings while maintaining technical and economic viability.

Thanks and Information Note

The article complies with national and international research and publication ethics. All authors contributed equally to the article.

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Feasibility Design for Two-post Car Lift from Locally Available Materials

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Abstract

Car mechanics currently rely on pit bays to access the underside of vehicles. However, these bays are cumbersome, require significant space, limit mobility, and present ergonomic challenges. Moreover, importing foreign car lifts is costly, further complicating the situation. To address these issues, the design of an efficient and cost-effective two-post car lift has been proposed. This innovative machine operates with a single hydraulic cylinder, enabling the lifting of vehicles to a height of 1.8 meters. Powered by a hydraulic power system, the car lift ensures smooth and reliable operation. Vehicles are securely anchored at four points using dampers positioned between the front and rear wheels, enhancing stability and safety during maintenance. The final design parameters demonstrate the lift's efficiency and practicality. With a motor power of 6.1 kW, the car lift can support a maximum load of 4,000 kilograms. It achieves a lifting height of 1.8 meters within 40 seconds, while lowering takes just 30 seconds, ensuring time-efficient operation. Additionally, the lift provides a clearance of 2.794 meters between the two posts, accommodating a variety of vehicle sizes. The successful completion of this design offers a robust, space-saving, and affordable alternative to traditional pit bays and expensive imported lifts. This locally developed two-post car lift enhances accessibility and affordability, making it a significant advancement for car repair facilities.

Keywords: Car lift, design, locally-sourced, structural integrity load capacity**,** material substitution cost-effectiveness, fabrication**,** stress analysis**,** prototyping.

1. Introduction

Car lift is a simple mechanical device for raising object from ground to a certain height with minimum effort (Design and Fabrication of Mechanical Lift for Transportation 2016). In the olden days, mechanics used cramped and dangerous conditions for lifting motor vehicle (Gandhi & Dhulugade 2018). The present day of pit-bay digging, consumes permanent space and gives less access to bottom side of car, and also it is immovable. Research has shown that many car lifting machine are already in existence (Design and Fabrication of Mechanical Lift for Transportation 2016), but the fact is that they are too expensive to buy from abroad. If such a machined can be designed and fabricated here in Nigeria, that can have almost the same performance at low cost, it will be a welcome idea to the car repairer. As to avoid the permanent digging of ground, and have easy access.

1.1 Types of Car Lifts

There are many types of car lifts on the market today. Whether you want to be able to work on your car at home or have an automotive repair shop, there are several options for you. There are platform lifts, post lifts that come in two and four posts, and scissor lifts. You can purchase a heavy duty lift, a low rise lift or a storage lift. They are all car lifts which means

they all get car off the ground making it easier for you to work on it, but they are different in that individually serve a different need.

1.2 How They Work

Most lifts work on a hydraulic system. There will be an on and off switch that you will hit to make the lift go up or down. Hydraulics is a pressure system that requires pressure to go into one chamber and transferring it to another. The first chamber is much smaller and it must travels over a long distance to multiply and create a larger pressure in the second chamber. As the pressure builds in the second chamber it pushes the lift up. When you are finished working on the car, you hit another button that releases the pressure and allows the lift to slowly descend. Some lifts are portable coming with a battery power pack that pneumatically works the hydraulics. Lifts can be as simple as using a pulley system that when activated pulls cables that lifts the bars. The cable is wound up and when you are finished you reverse the system allowing the cable to unwind and bring the bars and car down.

1.3 Features of Car Lifts

i. These lifts come in a variety of lifting capacities. They range from 7,000 lbs. to 12,000 lbs. Any more capacity than that and you are getting into the truck range. Most come with lock features so when the lift is up you can lock it in place and not have to worry about it accidentally coming down on you. You can purchase them with pull outs that extend for the platforms and equalization torsion bars. The two and four post lifts come with height adapter extensions and dual safety latches. Most lifts come in steel and aluminum too. Steel is a much stronger metal therefore much safer, but it is more expensive.

ii. There are many different designs of hydraulic car lifts in use today. The most common designs have two or four posts with arms that extend beneath the car to lift the car by the frame (or at specified jacking points). Another common design, sometimes called a "drive-on" lift, has solid metal tracks for the car to drive onto before being lifted. Other designs sometimes use a center column sunk into the floor beneath the lift. Regardless of the design, all car lifts operate using hydraulic systems.

iii. A car lift operates using the same basic concept as any hydraulic system: when you apply force to a liquid in one place, the pressure is transmitted through the system to exert an effect somewhere else. Car lifts use hydraulic fluid (a petroleum oil with additives), which cannot be compressed no matter how much pressure you exert on it. Instead, the fluid flows through the hydraulic system and moves a cylinder that raises the car off the ground. Some car lifts use an air compressor, while others use an electric motor. Regardless the power source utilized, the basic idea is the same. The lift exerts force on the hydraulic fluid, which in turn moves a cylinder to raise the car. Trading force for distance is a common idea in mechanical systems. In the case of a car lift, this means connecting a narrow cylinder to a wide one via hydraulic lines. Oil compressed through the narrow cylinder travels a great distance. When that force is transferred into the wide cylinder, it moves a shorter distance, but with much greater force.

iv. The same theory is used to operate the brakes on your car: when you press down on the brake pedal, the force is transferred through the fluid in the brake lines to the master cylinder, which transmits force equally to the calipers at all four wheels.

Because the brake fluid cannot be compressed, you can push down harder on the pedal to exert more pressure on the brakes. (This is why it's crucial to eliminate any air bubbles from your brake system by "bleeding" the brake cylinders. Air, unlike hydraulic fluid, can be compressed. So if air bubbles are present inside your brake lines, the force you apply to the brake pedal is used in part to compress the air bubbles instead of pushing on the calipers, which reduces the efficiency of your brake system) (Qingdao Hydro Park Machinery Co. n.d.).

The aim of this research is to design a car lifting machine that can lift a car of average weight 4000kg to height of 1800mm.

2. Materials and Methods

2.1 Performance specification

i. The machine should lift a car of average 4000kg to the height of 1.8m, and take it back on to ground safely, without damaging the car body.

ii. The car should be very stable when lifted as to carry out any task on it.

iii. The machine should be easily mountable, and can easily be moved from one place to another when there is such need.

2.2 Ideation and Invention

Design 1 Hydraulic machine can be used to provide the lifting force. Here the input effort is needed only during lifting the car. The weight of the car is used to bring the car down. Hence energy is saving. The only problem here is linking.

Design 2 A screw jack principle can also be used. Here in both the lifting up and down, input effort is needed. Energy is consumed to overcome friction in the trade in both.

Design 3 pulleys, metal rope and hydraulic system can also be employed. Here the input effort is needed only during lifting the car. The weight of the car is used to bring the car down, hence energy is saving. The problem of space and complication may be encountered

2.3 Selection

The appropriate design is selected using decision matrix as follows as shown in Table 1:

Table 1. Decision matrix

	Functionality	Performance	Safety	Manufacturability	Maintenance	Cost	Rank
Weighing factor	0.2	0.1	0.3	0.05	0.05	0.3	1.0
Design 1	9 / 1.8	6 / 0.6	5 / 1.5	3 / 0.15	2 / 0.1	2 / 0.4	4.5 / 5
Design 2	7 / 2.1	6 / 0.6	5 / 1.5	1 / 0.05	1 / 0.05	9 / 0.4	4.7
Design 3	9 / 1.8	4 / 0.4	4 / 1.2	4 / 0.2	1 / 0.05	5 / 1.5	5.15 / 3

After considering all other, we choose 5.95 that is design 3 (Denarit 216AD)

2.4 Analysis

The design is possible looking at the fact that other lifting machines are already in existence. Figure 1 shows the working system of the two post car lift.

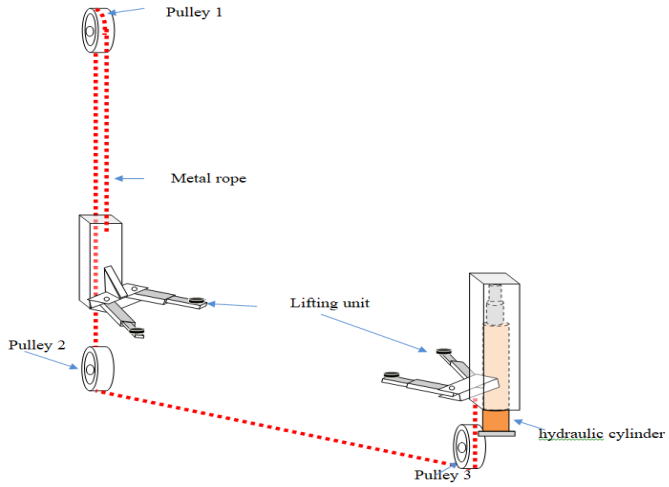


Figure 1. the working system

To calculate degree of freedom, the number of units contains in the system are: Each lifting unit has four deep grooved rolling bearing rolling on the frame, Table 2 present the number of unit involve the in selected design.

Table 2. Number of unit

Unit	Joint
Number of units to the lifting unit	= 2 unit
Number of units on the metal rope	= 1unit
Number of units on the pulley = 3+3	= 6 unit
Number of units on sliding hydraulic shaft	= 2 unit
Number of units on frame	= 1unit
Total	= 12 unit

Table 3 shows the number of joint contains in the system.

Table 3. The number of joints contains in the system

Unit	Joint
Number of joints on the lifting unit	= 2 joints
Number of joints on metal rope	= 2
Number of joints on pulley = 2x3	= 6 joints
Number of joints on hydraulic shaft	= 2 joint
Number of joint on the frame	= 1 unit
Total	13 units

Using the Grübler's equation

$$F = 3(n-1)2j,$$

Where n = number of unit, j = number of joints

Hence,

$$F = 3(12-1) - 2(13) = 7,$$

Therefore the kinematic chain is movable since $F \geq 1$

2.5 Detailed Design

The hydraulic car lift design includes the following:

i. Frame
ii. Lifting unit
iii. Hydraulic system
iv. Metal rope
v. Pulley

2.6 Design of frame

The material used for the design is plain carbon steel AISI standard 1020 channel iron of (C180x0.215); flat steel bar (thickness = 12.7), tensile strength: 450Mpa. The parts are jointed together using electric arc welding as shown (Speiegel and Lmbrunner 2003). Figure 2 shows the frame of the two post car lift.

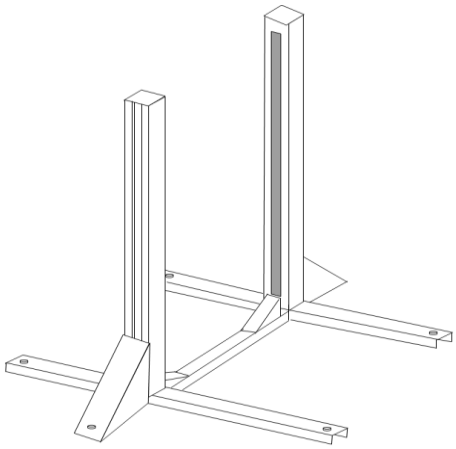


Figure 2. Frame for car lift

Figure 3 shows the front view of two post car lift.

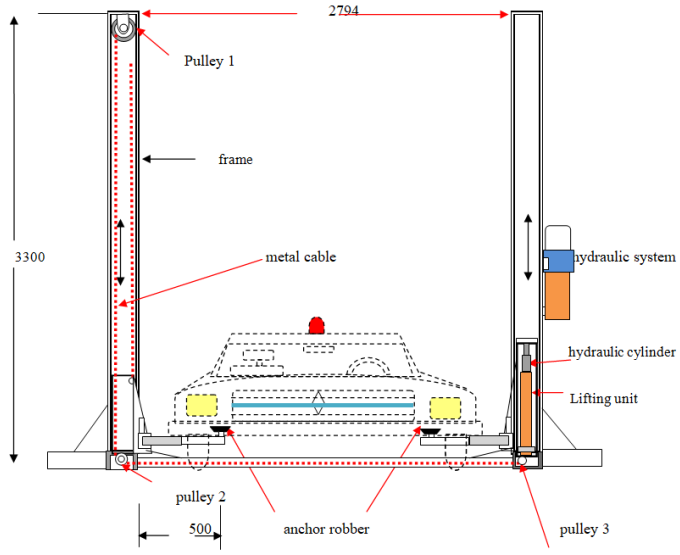


Figure 3. Front view of two post car lift

Figure 4 shows the side view of left post

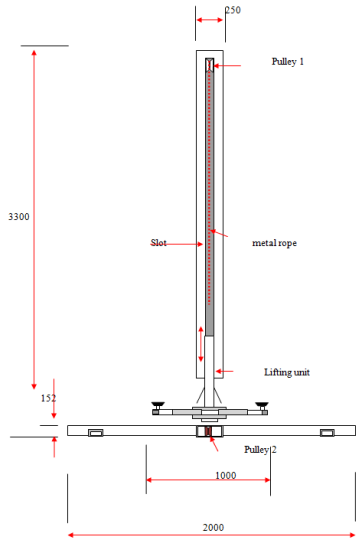


Figure 4. side view of left post

Figure 5 shows the plan view of two-post car lift

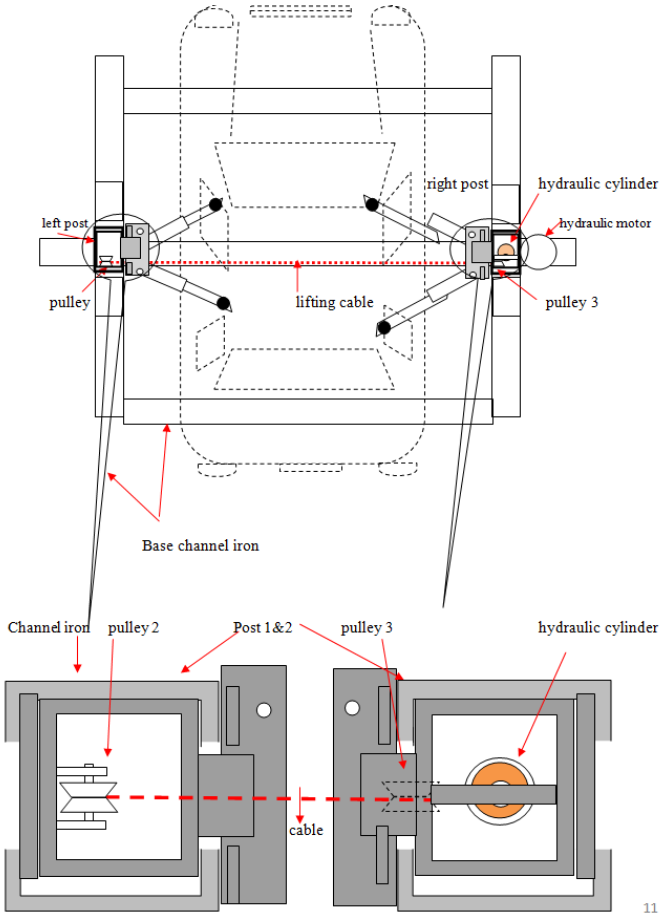


Figure 5. the plan view of car lift

Figure 6 shows the Isometric view of lifting unit arm

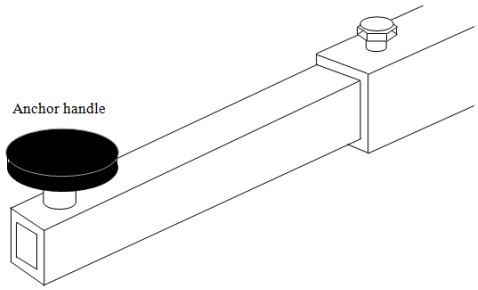


Figure 6. Isometric view of lifting unit arm

Table 4 shows the size of the pipe used.

Table 4. Pipe use of carbon steel

Pipe	Cross sectional Area (in^2)	Wall thickness (in)	Distribution (wt/ft)
A	3.000x3.000	0.375	12.16
B	2.000x2.000	0.313	8.430

Figure 7 shows the angle adjuster.

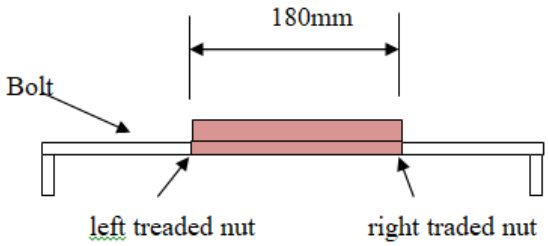


Figure 7. Angle adjuster

Figure 8 shows the lifting arm.

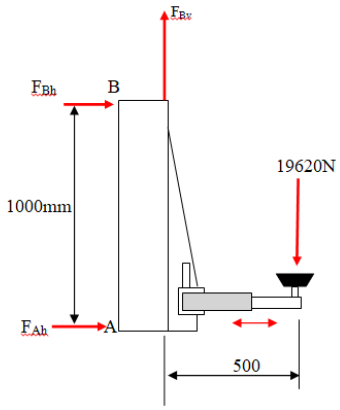


Figure 8. lifting arm

From the law of equilibrium,

$$\sum M_n = 0$$

$$19620N(500 \times 10^{-3}) - F_{Ah}(1000 \times 10^{-3}) = 0$$

$$F_A = +9810N$$

Also,

$$\sum M_h = 0$$

$$9810 + F_{Bh} = 0$$

$$F_{Bh} = -981N$$

$$\sum M_y = 0$$

$$F_{By} = -19620 = 0$$

$$F_{By} = 19620N$$

2.7 Anchor robber

Anchor robber is selected from market with following dimension. The shaft is made up of steel iron. Figure 9 shows the anchor rubber.

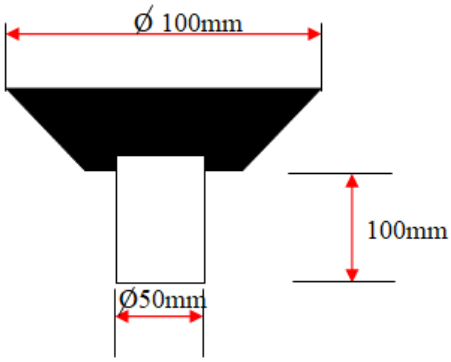


Figure 9. Anchor rubber

2.8 Design of Hydraulic cylinder

Multi- stage hydraulic system is used and AISI40 cast iron of tensile strength 410 Mpa. Figure 10 shows the two-stage hydraulic cylinder.

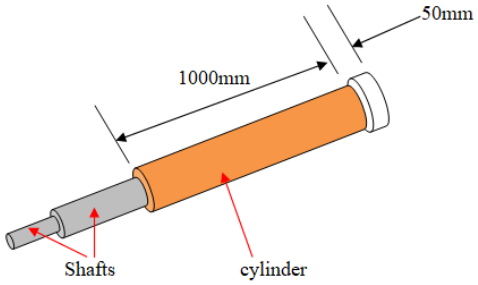


Figure 10. Two stage hydraulic cylinder

To determine the diameter of the cast iron cylinder and its thickness to produce the operating force F = 40,000N.

Assuming,

i. an allowable of 10% of the force F for friction in the cylinder and packing
ii. Pressure of pump = 5N/mm^2
iii. a pressure drop of 0.2 N/mm^2 between the tank and cylinder.
iv. Taking Safe stress for cast iron = 30 Mpa
v. Time require for the working stroke is 40s
vi. The efficiency for hydraulic = 80% and for pump = 60%
vii. Working cycle repeats after 30s
viii. Diameter of tank = 200mm
ix. Efficiency = 100%
x. Allowable tensile stress = 50 Mpa

1- The Thickness of the pressure tank (Budynas−Nisbett 2006)

$$t = \frac{P.d}{2\sigma_{t1}.\eta} = \frac{5\times200}{2\times50\times1} = 10mm \text{(Budynas−Nisbett 2006)}$$

2- Diameter and thickness of the cylinder (Budynas−Nisbett 2006)

The total force provided including fiction F_1= 1.1 x 4000 = 44000N

Therefore the pressure P_1= 5- 0.2 = 4.8 N/mm^2

$$F_1 = \frac{Л}{4} \times D^2 \times P_1$$

$$D = \sqrt{\frac{4F_1}{ЛP_1}} = \sqrt{\frac{4 \times 44000}{Л48}} = 10.8\text{mm}$$

$$t = \frac{P_1 \times D}{2\sigma_{t1}} = \frac{108 \times 4.8}{2 \times 30} = 8.64mm$$

3- Out power of the cylinder (Budynas−Nisbett 2006)

Distance move per second = 2/40 = 0.05m/s

Work done per second = F x distance move per second

= 44000 x 0.05 = 2200Nm

Hence, power output of the cylinder = 2200W = 2.2 KW

4- Power of the motor (Budynas−Nisbett 2006)

$$\frac{power\ of\ cylinder\ \times 40}{\eta_p\eta_m \times 30} = \frac{2.2 \times 40}{0.8 \times 0.6 \times 30} = 6.1KW$$

Hence let select an electric motor of 6.5kW (Khurmi and Edition 2005).

2.9 Design of Metal rope (Budynas−Nisbett 2006)

The material used is AISI 160 steel, tensile strength 1600Mpa

i. The load (weigh of car) = 4000kg x9.81 = 39240N, height = 1.8m, t= 40s
ii. speed v = 1.8/40 = 0.045 , acceleration = v/t = 0.045/40 =1.3x10^{-3}m/s^2
iii. From table 20.6 wire rope 6x19 is chosen.
iv. From table 20.11 the factor of safety 2x 3.5 = 7 is taken, Therefore, the Design load for the wire is rope = 7 x 39240N = 274680N

v. From table 20.6 , the tensile strength of 6x19 rope made of wire with tensile strength of 1800MPa is $595d^2$ (N)
Hence $595d^2 = 274680N$

$$d = \sqrt{\frac{247680}{595}} = 21.5mm$$

vi. From table 2010 for 6x 19 rope, diameter of wire $d_w = 0.063d = 0.063x\ 21.5 = 1.4mm$
Hence area of wire $A = 0.38d^2 = 0.38(21.5)^2 = 175.7mm^2$

vii. From table 20.6, the weight of the rope,
$w = 0.0363d^2 = 0.0363(21.5)^2 = 16.8N/m$
Hence the total weight = 16.8 x 16.3 = 273.8N (*assuming the total length= 16.3m)*

viii. From table 2012, the diameter of sheave (D) may be taken as 60-100 times the the diameter of the rope (d) . i.e. D = 20(d) = 20x21.5 = 430 mm
Therefore the bending stress = $\sigma_b = \frac{E_r \times d_w}{D} = \frac{84\times10^3\times1.4}{430}$ =273.5N/m (taking E_r =$85x10^3$)

ix. The equivalent bending load on the rope, $w_b = \sigma_b$ x Area = 273.5x175.7 = 48051.9N

x. Additional load due to acceleration,

$$w_a = \frac{W+w}{g} \times a = \frac{39240+16.8}{9.81} \times 1.3 \times 10^{-3} = 5.2N$$

xi. The impact load during starring (when there is no slackness in the rope),
$W_{st} = 2(W + w) = 2(39240 + 16.8) = 78513.6N$

xii. The effective load on the rope during normal working (*i.e.* during uniform lifting or lowering) = $W + w + w_b = 39240 + 16.8+ 48051.9 = 87308.7N$
Therefore the actual factor of safety during normal working
$F.S_{actual}$ = 274680 /87308 = 3.1

13- Effective load on the rope during staring = $W_{st} + W_b = 78513.6 + 48051.9 = 126565.5N$

Actual factor of safety during starting = 274680/126565.5 = 2.2

xiii. Effective load on the rope during acceleration of the load (*i.e.I during first 10 second after starting)* = $W + w + W_b + W_a$
= 39240 + 16.8 +48051.9 + 5.2 = 87313.9N

xiv. Actual factor of safety during acceleration of the load = 274680/877313.9 = 0.3
Since the actual factor of safety as calculated above are safe, therefore a wire of diameter 31.5mm and 6x19 is satisfactory (Khurmi and Edition 2005).

2.10 Design of pulley (Budynas−Nisbett 2006)

The material used is cast iron AISI 5, tensile strength 620Mpa. The pulley diameter is taken = 100mm and mounted on fixed axles on antifriction bearing. The diameter of pulley shaft is 100m.

Hence, the standard rim of a rope sheave is calculated as follows:

$r = 0.53d = 0.53x21.5 = 11.4mm$

$r_1 = 1.1d = 1.1x\ 21.5 = 23.7mm$

$a = 2.7d = 2.7\ x\ 21.5 = 58.05mm$

b = 2.1d = 2.1x 21.5 = 45.15mm

c = 0.4d = 0.4 x 21.5 = 8.6mm

l = 0.75d = 0.75 x 21.5 = 16.125mm (Khurmi and Edition 2005)

3. Findings and Discussion

3.1 Final Analysis

A hydraulic car lift is designed with following specification. Table 5 shows the specification of the device

Table 5. Technical data for two post car lift

Loads lifting capacity	4000kg
Hydraulic cylinder	x1
Power	6.1KW
Lifting time	40s
Lifting height	1.8m
Electric motor	x 1
Hydraulic pump	x 1
Post Height	3300mm
Clearance between posts:	2.794 m
Lowering Time	30s
Voltage	110V/220V/380V/415V, 1ph/3ph

3.2 Final assembly

The final assembly of two-post car lift is shown in Figure 10.

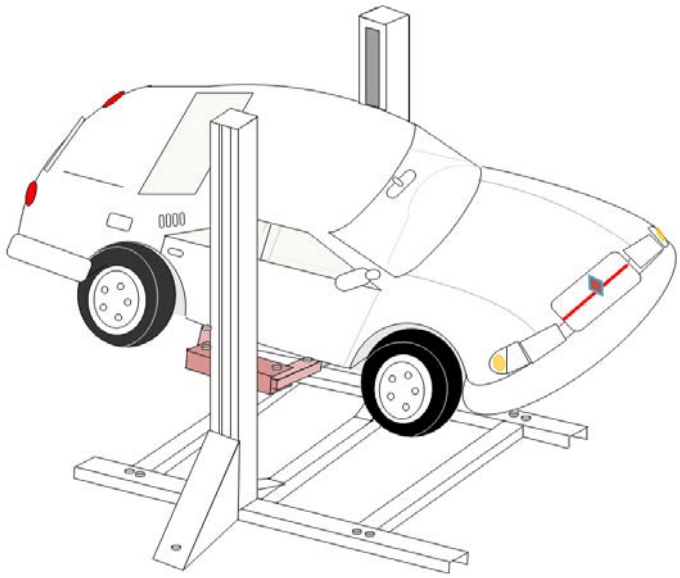


Figure 10. Angle adjuster

4. Conclusion and Recommendations

As it can be seen that car lift is very essential at this current situation due to the increase of auto vehicles and with current high cost for purchasing foreign car-lifting machines, designing and constructing such car-lifting machine with our local capacity will be a good welcome ideas. And finally the design for two-post car lift is successfully done with the final parameters as: motor power 6.1Kwatt, load lifting capacity 4000 kg, lifting time 40 s, lowering time 30 s, lifting height 1.8 m, clearance between the two post 2.794 m.

Thanks and Information Note

The article complies with national and international research and publication ethics. Ethics Committee approval was not required for the study. All authors contributed equally to the article.

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Modeling of 1D SMA spring Under Thermal and Mechanical Loadings Using Comsol Multi Physics

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Abstract

In this conference paper, a comprehensive thermo-mechanical model simulation of Shape Memory Alloy (SMA) wires is presented, developed based on the fundamental principles of energy and momentum conservation using COMSOL Multiphysics. The study adopts the Landau phenomenological model to describe the complex dynamics of SMA phase transformation between the martensitic and austenitic phases under varying thermal and mechanical loading conditions. The constitutive relations are formulated to capture the nonlinear coupling between temperature, strain, and stress, which are key to understanding the unique behavior of SMAs. The model is further extended and adapted to investigate the response of SMA springs, taking into account the geometric nonlinearity and the influence of temperature-dependent material parameters. The Landau free energy density function, expressed as a function of the stretch ratio, is analytically derived and plotted at different temperatures to illustrate the phase transition process. Numerical simulations are conducted using COMSOL Multiphysics to evaluate the thermomechanical behavior, energy dissipation, and transformation kinetics. The results provide valuable insights into the actuation characteristics, hysteresis behavior, and stability of SMA-based components, offering a robust modeling framework for the design and optimization of smart materials and adaptive structures.

Keywords: Martensitic transformation, shape memory alloy, pseudoelasticity, comsol mulit-physics.

1. Introduction

SMA is a smart material that can trained and modified as to memorized different shapes (Machado et al. 2003; Nagendra, Tamilselvan, & Sadhasivam 2018; Sittner 2019), though when it is deformed, it can readily regain its original shape (Halahla et al. 2019; Shiva et al. 2019) when temperature increases, through this it converting thermal energy to mechanical (Melnik Roderick et al. 2003; Wang & Melnik 2007; Zhu et al. 2001). This behavior of plastic deformation and full recovery is known as shape memory effect (SMEs) (Alexandrakis, Manuel, & Pérez-checa 2020; Churchill & Shaw 2011; LECCE & Antonio 2015). The history of this wonderful material started since in the year 1800s, as William Buehler and his coworker uncovered its behavior of this shape memory effect capability(Fritsch, Izadi, & Ghafoori 2019). After this the name NINOL is given to the material with Ni stands for nickel and NOL stands for the Naval Ordinate Laboratory where the incident happened (Huang, Yao, & Su 2019). The material produces a loud strange sound at cold stage, which is different from when it is at hot stage (LECCE & Antonio 2015).

The researchers' attention was dawned to the material over a decade for various engineering application (Fei et al. 2019; Honarmandi, Johnson, & Arroyave 2020). After a serious

investigation, it was resolved that the material has a unique property (Adarsh & Sampath 2019), that made it differs from other materials , therefore it was renamed as NITINOL. This material can recover energy up to 10^6 J/m^3, with transformation temperature of about 363 K (Cho, Takeda, & Sakuma 2017).

SMAs has a low-frequency respond with reversible hysteresis properties under a cycle mechanical loading(Ashwin, A. R., & J. N. 2015) thus make them a special material in material applications, like vibration isolation, sensor, impact absorption, actuations etc. (Pirbhulal et al. 2016). With exception of medical field, like wearable devices and teleheathcare, the material has not been commercialized owing to the lack of a defined model describing its behaviors. There are many models proposed for SMA around, but due to the SMA complex characteristics, no exact and simple model is being able to develop (Finney 2008; Ma et al. 2016).

2. Materials and Methods

For the SMA spring thermo-mechanical coupling dynamics, the equation can also be achieved by modifying the model for SMA wire by replacing the strain with stretch ratio of SMA spring and the axial stress σ with shear stress τ. Therefore the model of SMA spring is presented as

$$\left.\begin{aligned} & v=\frac{\partial u}{\partial t};\lambda=\frac{\partial u}{\partial x};g=\frac{\partial^2\lambda}{\partial x^2}, \\ & c_v\frac{\partial T}{\partial t}=k_4\frac{\partial^2 T}{\partial x^2}+A_1T\lambda\frac{\partial\lambda}{\partial t}+Z, \\ & \rho\frac{\partial v}{\partial t}=\frac{\partial}{\partial x}\left(\tau+\Upsilon\frac{\partial v}{\partial x}-k_g\frac{\partial g}{\partial x}\right)+Fr \end{aligned}\right\}, \quad (1)$$

And,

$$\tau=A_1\left(\frac{T-T_1}{T_1}\right)\lambda+A_2\lambda^3+A_3\lambda^5 .$$

This model is for 1D non-linear dynamics of SMA spring, and it is for single crystalline structure. The Landau free energy density $F_l(T,\lambda)$ related to the stretch ratio in Eq. 1 is formulated as:

$$F_l(T,\lambda)=\frac{A_1}{2}\left(\frac{T-T_1}{T_1}\right)\lambda^2-\frac{A_2}{4}\lambda^4+\frac{A_3}{6}\lambda^6 . \quad (2)$$

3. Findings and Discussion

By using the SMA spring parameters, the $F_l(T,\lambda)$ is plotted as a function of stretch ratio in Figure 1:

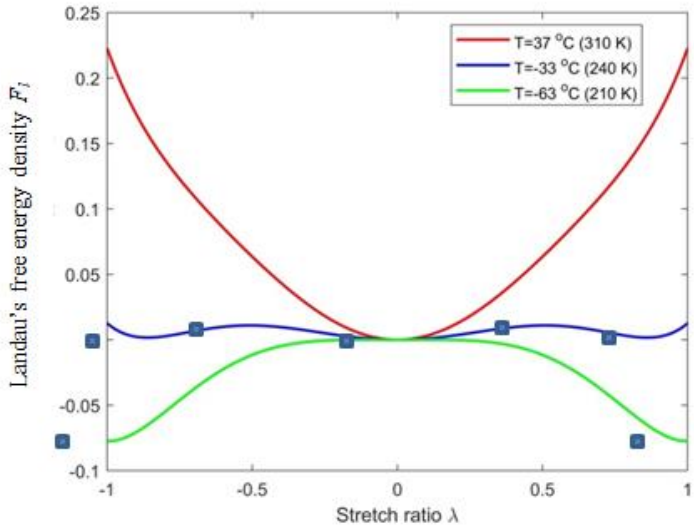


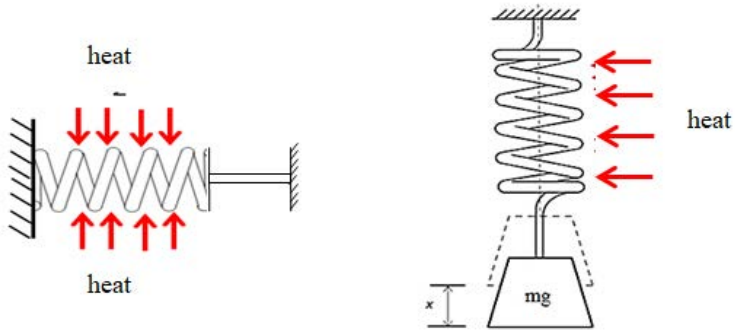
Figure 1. Landau free energy density at different temperatures

2 Numerical Methodology

The numerical simulation and modeling is obtained using COMSOL multiphysics 5.6.

2.1 1D SMA spring modeling under mechanical and thermal loading

Figure 2 shows SMA spring under mechanical and thermal loading, Figure 2(a) has a fixed boundary and subjected to thermal loading only. And Figure 2(b) with one end has free boundary. Both cases are sujected to thermal and mechanical loadings. Hence Eqt. 1 will be modified to suit each of the two cases.



(a) (b)

Figure 2. Model comparison and experimental data at 90°C

For the first case, Eq. 1 is reduced to:

$$\left.\begin{aligned} &v=\frac{\partial u}{\partial t};\lambda=\frac{\partial u}{\partial x};g=\frac{\partial^2\lambda}{\partial x^2},\\ &c_v\frac{\partial T}{\partial t}=k_4\frac{\partial^2 T}{\partial x^2}+k_1T\lambda\frac{\partial\lambda}{\partial t}+Z,\\ &\rho\frac{\partial v}{\partial t}=\frac{\partial}{\partial x}\left(\tau+\Upsilon\frac{\partial v}{\partial x}-k_g\frac{\partial g}{\partial x}\right),\\ &\tau=A_1\left(\frac{T-T_1}{T_1}\right)\lambda+A_2\lambda^3+A_3\lambda^5. \end{aligned}\right\} \quad (3)$$

The initial condition is $T=T_a$; the boundary conditions for this case are:

$$u(0,t)=0,\quad u(L)=0;\ g(0,t)=0,\quad g(L,t)=0;\ T_x(0,t)=0,\quad T_x(L,t)=0,$$

For second case, both thermal and mechanical loadings are involved, and the governing equation is presented as:

$$v=\frac{\partial u}{\partial t};\lambda=\frac{\partial u}{\partial x};g=\frac{\partial^2\lambda}{\partial x^2},$$

$$c_v\frac{\partial T}{\partial t}=k_4\frac{\partial^2 T}{\partial x^2}+A_1T\lambda\frac{\partial\lambda}{\partial t}+Z,$$

$$\rho\frac{\partial v}{\partial t}=\frac{\partial}{\partial x}\left(\tau+\Upsilon\frac{\partial v}{\partial x}-k_g\frac{\partial g}{\partial x}\right)+Fr,$$

$$\tau=A_1\left(\frac{T-T_1}{T_1}\right)\lambda+A_2\lambda^3+A_3\lambda^5.$$

Because one end is free, there will be displacement at the unfixed end. The initial conditions are as $T=T_a$. and the boundary conditions will be as:

$$u(0,t)=0,\quad u(L)=u;\ g(0,t)=0,\quad g(L,t)=0\ T_x(0,t)=0,\quad T_x(L,t)=0,$$

2.2 Numerical experiment

Numerical experiments are performed here using estimated parameters obtained. These are: A_1=0.65 kg/(s^{2}m^{o}C), A_2=-56.5 kg/(ms^{2}m^{o}C), A_3=31.7 kg/(ms^{2}m^{o}C), T_1= -49.4^{o}C, ρ=11100 kg/m^3, C_v = 1.1454x10^3 kg/s^2m^{o}C, k = 0.6960mkg/s^3 ^{o}C, k_g = 1.5x10^6 kg/s^2, r =1.6/2 x 10^{-3} m. T_a =15 ^{o}C.

For case I, the loadings are thermal only

` $F=0$,

$$Z = 4000\text{kg}/\left(\text{s}^3\text{m}\right)$$

Figure 3a shows the velocity of the SMA spring with two ends fixed. The grap generated a sinusoidal pattern. Figure 3b shows the temperature graph, and it has a hyperbolic curve with nonlinearity behavior, which is about 60% of SMA spring. Figure 3c shows a stretch ratio graph. It presents a strong non-linear thermo-mechanical coupling, just like temperature graph. When the external loading is zero, the stretch ration assumes the initial value, showing that SMA spring has become a martensitic phase again. This simulation indicates a clear pseudoelastic effect. The stress-strain relationship presents a non-linear, and then a hysteresis loop will be achieved when the stress varies because AC is unstable, and the stretch ratio will jump from A to B or C to D, as indicated in Figure 3d.

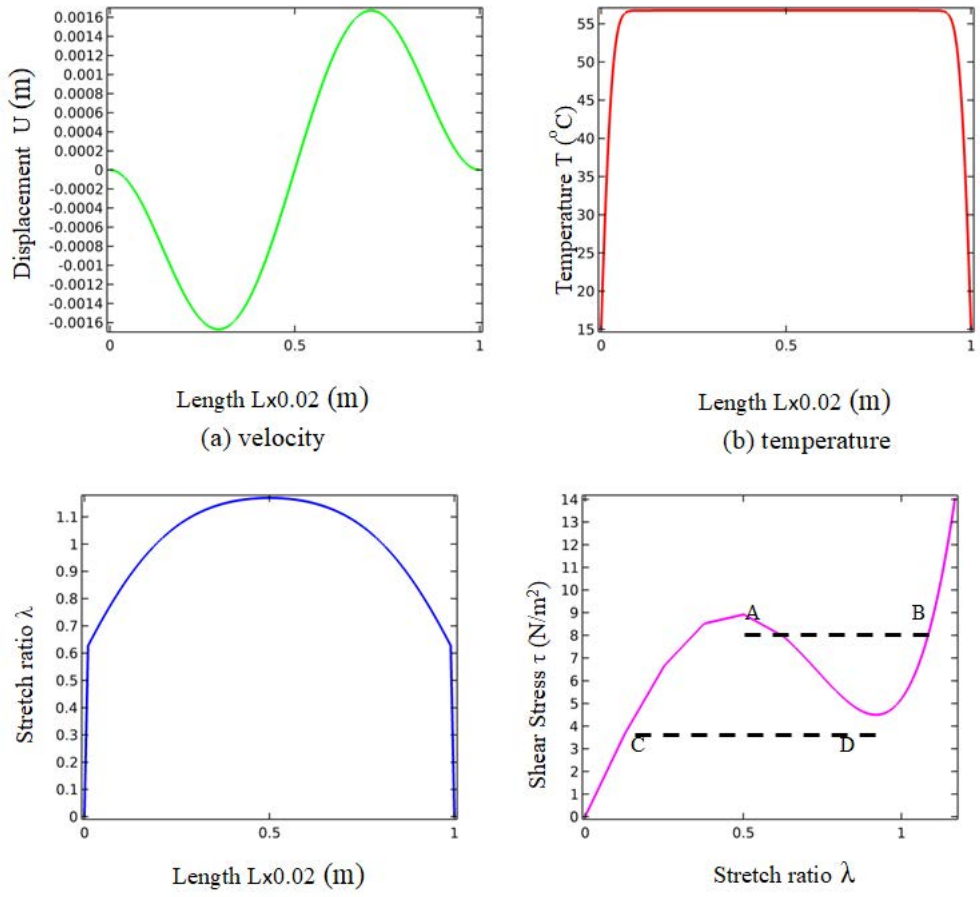


Figure 3. Simulation results of SMA spring under thermal loading only

For the case II, the experiments are done using different loadings. The first simulation is done using only thermal loading.

$$F = 0\,,$$

$$Z = 4000\text{kg}/\left(\text{s}^3\text{m}\right).$$

Figure 4a presents the displacement graph of SMA spring. The graph produced a parabolic curve with strong non-linear thermo-mechanical coupling. Figure 4b presents the temperature graph. It is similar to 3b. Figure 4c shows a stretch ratio graph. It indicates a strong non-

linear thermo-mechanical coupling just like temperature graph. When the external loading returns to zero, the stretch ratio reassumed the initial value, showing that the SMA spring has martensited again. This numerical simulation indicates the pseudoelastic behavior in the SMA spring. The stress-strain relationship indicates a strong non-linear with a hysteresis loop form when the stress varies , because AC is unstable, and the stretch ratio jumps from A to B, or B to D as indicated in Figure 4d.

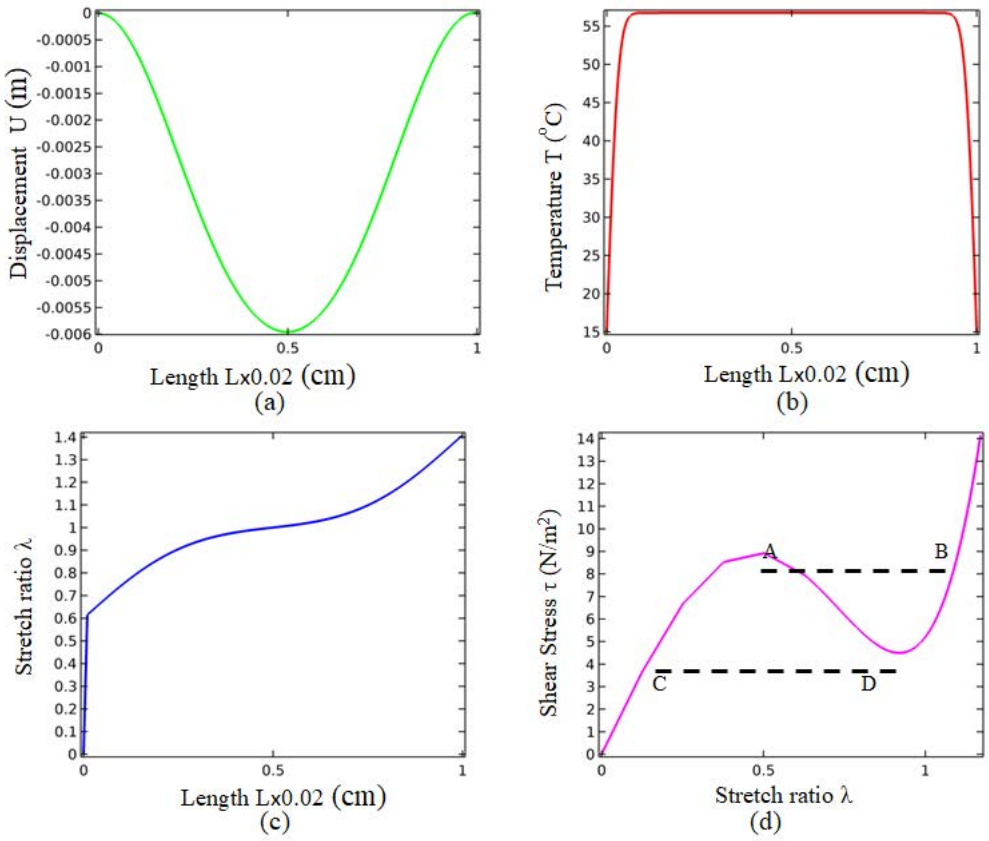


Figure 4. Simulation results of SMA spring under thermal loading only

Simulations are also carried out using mechanical loading only as follows:

$$F = 4000\,\mathrm{N},$$
$$Z = 0\,.$$

Under the influence of mechanical loading, the SMA spring switches between matensite to austenite phases. Figure 5a presents the displacement curve, and the graph produces a strong non-linear curve. Figure 5b shows a temperature evolution graph. It produces a combination of linear and non-linear thermo-mechanical coupling. Figure 5c is for stretch ratio graph. It also has this combination of linear and non-linear sinusoidal graph. The stress-stretch ratio

relationship is also a non-linear curve with a tendency of forming a hysteresis loop.

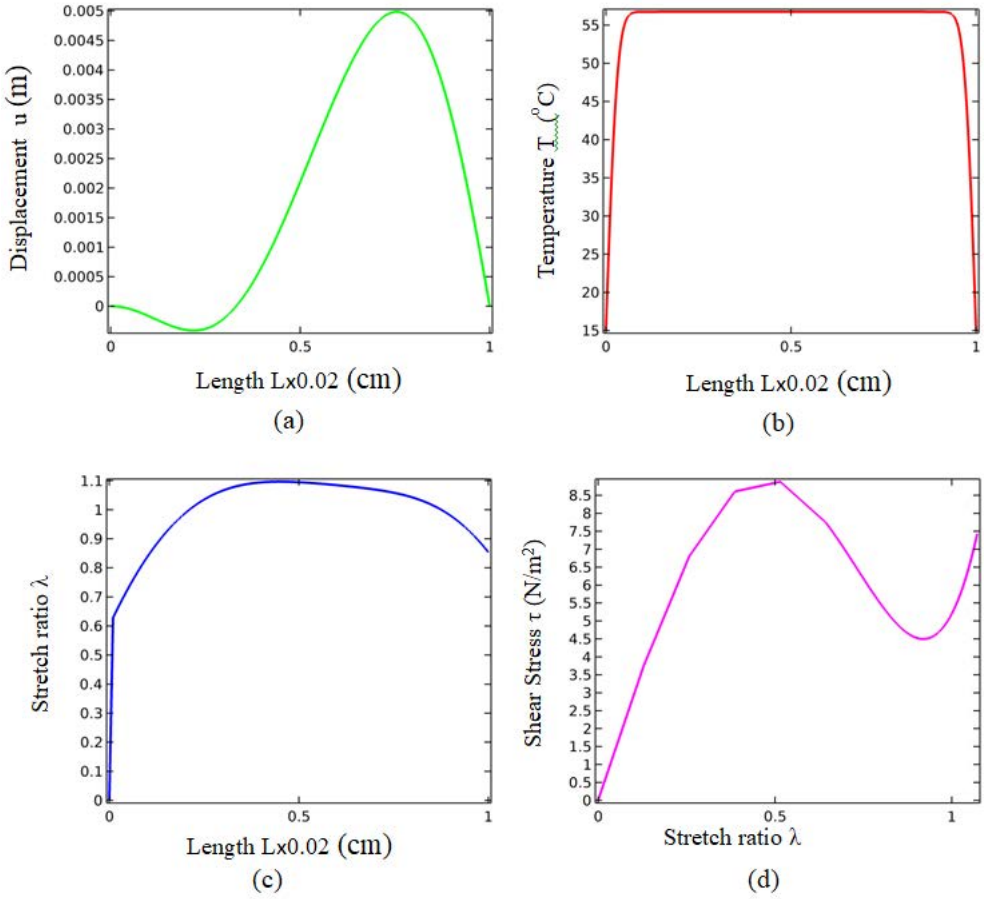


Figure 5. Simulation results of SMA spring under mechanical loading only

Third simulation is performed using both mechanical and thermal loading applied to the system:

$$Z = 4000\text{kg}/\left(\text{s}^3\text{m}\right),$$

$$F = 4000\,\text{N}.$$

The SMA spring switches between austenite and martensite variants under the influence of mechanical and thermal loadings. Figure 6a indicated the SMA spring displacement curves. And the temperature graph is shown in Figure 6b. It is similar to Figure 5b. Stretch ratio graph is shown in Figure 6c. It has a combination of linear and sinusoidal curves. The stress-stretch ratio relationship is presented in Figure 6d. It has a strong nonlinear curve forming a hysteresis loop, and the stretch will jump from A to B or C to D

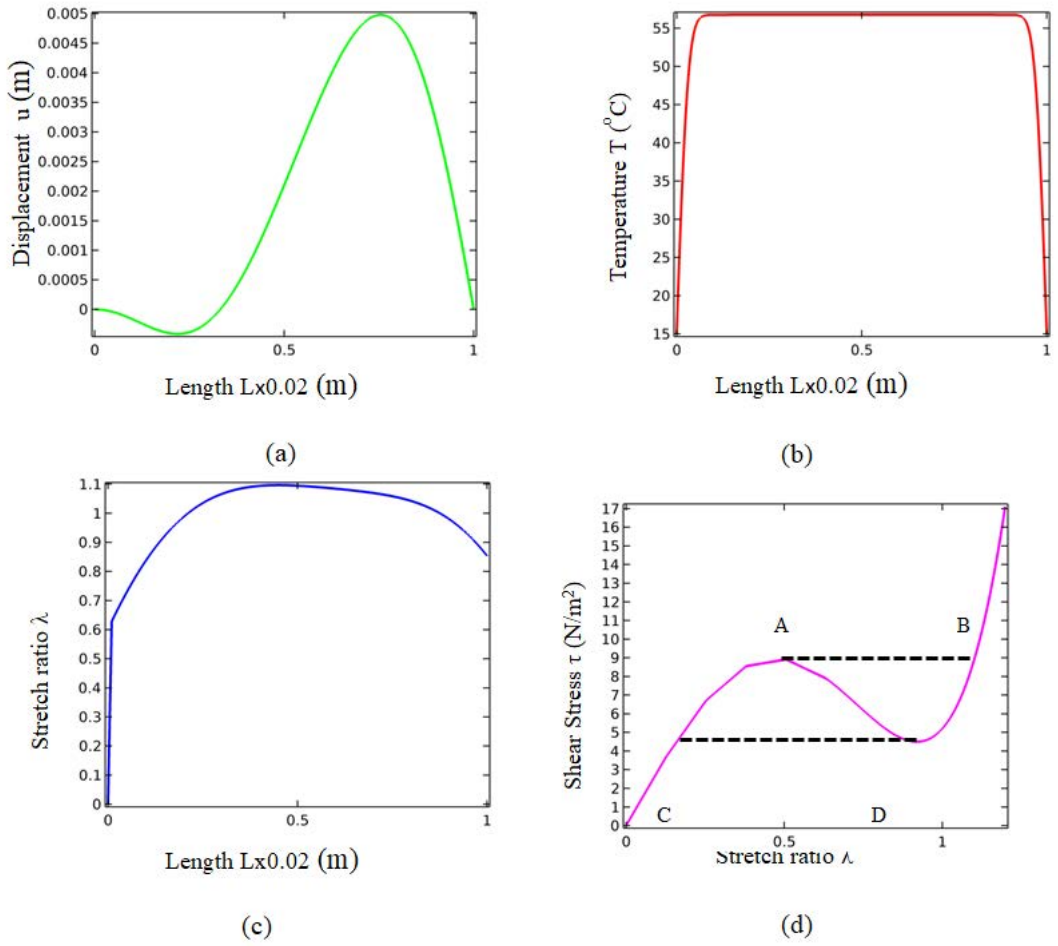


Figure 6. Simulation results of SMA spring under thermal and mechanical loadings

4. Conclusion and Recommendations

Modeling and simulation of SMA spring are carried out using comsol multiphysics. Estimated SMA spring parameters are gotten and used. Modeling and simulation of SMA spring thermo-mechanical coupling equations was carried out using, and the simulation results are presented. The simulated stress-stretch ratio precisely captured the hysteresis loop.

Thanks and Information Note

The article complies with national and international research and publication ethics. All authors contributed equally to the article.

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Students and the Protection of the Environment: An Ecofeminist Discourse Analysis of a Text from a Secondary School Textbook

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Abstract

This article holds the view that there is a dialectical relationship between woman, nature, and development. It also takes the view that no battle against the destruction of the environment can be successful unless it involves women's active commitment. Anchored on ecofeminism (Mason, 2011; Natty, 2017), discourse analytical framework (van Dijk, 1993/1998), positive discourse analysis (Martin, 2004), and the mixed research method, it investigates an academic text culled from Go for English 2nde, a textbook used to teach English in some West African Francophone countries (Benin, Ivory Coast, Niger, etc.). The study aims to explore how textbooks serve as a central tool in engaging students in the safeguarding of their environment. A careful analysis of the text at stake exudes many significant insights. Textually, the excerpt revolves around three main macrostructures or topics: (i) the constant cutting down of trees in Kanyariri (Kenya) begets serious hardships to the womenfolk, (ii) women take bold actions to curb their sufferings through planting trees, (iii) life becomes more agreeable through planting trees. At a semantic level, it is noticed a purposeful lexicalisation based on lexical field, and taxonomic lexical relations (co-hyponomy, contrast, similarity). On the pragmatic ground, the text is a narrative communicative event in which the first-person and third-person perspective is preferentially deployed for persuasive, emotive and authoritative reasons. As for rhetorical features, such devices as appositive, metaphor, alliteration, assonance, consonance, rhythm, parallelism and hyperbole are exemplified. It is concluded that the text is intentionally designed to arouse students' awareness on the fact that while deforestation is harmful to the environment, reforestation protects the ecosystem and ensures a sustainable development.

Key words: Ecofeminism, environment, sustainable development, discourse analysis.

1. Introduction

The role of environmental preservation in development cannot be overemphasised. In point of fact, development, and precisely sustainable development, goes hand-in-hand with the protection of the environment. This implies the observance of some required behaviour to make one's vicinity a better place to live in. In that perspective, one of the principal outcomes of Rio+20 was the call to develop a set of universally applicable sustainable development goals (SDGs) that carefully balance the environmental, social and economic dimensions of sustainable development (United Nations Environment Programme, 2013, p. 2). These SDGs, it is highlighted, have the dual purpose of increasing human wellbeing through development

while protecting and strengthening the ecosystem services that underpin this wellbeing (ibid., p. 14).

As a matter of fact, the excessive desire of human beings to satisfy their material needs leads them to pay less attention to nature. In other words, for some decades now, there has been a growing rate of environmental damages caused by some anthropological factors. That state of affairs, as a result of Man's increasing pursuit of wealth and economic development, is posing serious threats to humanity. Confronted with such a planetary crisis, nations all over the world are taking urgent actions to curb the drawbacks of the phenomenon. Hence, the *anthropocentric* tradition which maintains that Man has the right to subjugate nature is more and more giving place to the *bicentric* view which promotes the idea of 'right livelihood'. Despite the actions taken to minimise the effects of environmental destruction, some people realistically believe that the future of the environment lies in the continuous acquisition of knowledge.

In that sense, the accelerating environmental crisis brings school curriculum designers to discover that textbooks are not only tools of instruction, but also active mediations of ecological survival. With regard to such challenges as climate change, species extinction, and environmental injustice, there is no doubt that ecological devastation should be incorporated in students' learning process. And the best way to ascertain that teachers actually draw learners' awareness to those facts is through learning materials, viz., textbooks. As a matter of fact, textbooks are a pivotal tool to mould learners' minds on important notions and knowledge such as shared school beliefs (social cognitions), teachers' personal beliefs (personal cognitions), and some factors set by the government and the school management (social cognitions). Hence, in deciding to include the issue of environmental protection in the textbooks of the fifth level students in some West African Francophone countries (Benin, Ivory Coast, Niger, etc.), the curriculum designers aim to preserve nature from decay. The present study carries out a discourse analysis on a text drawn from *Go for English 2nde*. It particularly takes an ecofeminist perspective (Mason, 2011; Natty, 2017). In that regard, it draws on discourse analytical framework (van Dijk, 1993/1998), positive discourse analysis (Martin, 2004), and the qualitative research method. Before delving into the analysis proper, it is deemed necessary to outline the different theories which underpin the research work, and the methodology adopted.

2. Theoretical Orientation

As earlier stated, three main theories underpin this study. These are ecofeminism, discourse analysis, and positive discourse analysis.

2.1. Ecofeminism

Morphologically, the term "ecofeminism" is made up of two words: ecology and feminism. Coined in 1974 in her book entitled *Le Féminisme ou la mort* (*Feminism or death*) by the feminist writer and activist Françoise d'Eaubonne, ecofeminism designates two different but related things. First, it is a tool to analyse the connection between environmental justice and gender justice (Mason, 2011). Besides, ecofeminism is a school of thought based on the relationship between the exploitation of the environment by human beings and the oppression of women by men (Natty, 2017). It ensues to reason that ecofeminists advocate women's

rights to the preservation of the environment. Their fight is predicated on the idea that women should regain their connection with nature.

In actual fact, rising temperature, intensifying storms, and collapsing ecosystems have revealed that the environmental crisis is inseparable from social inequality and cultural anxiety (Dhivya, Sudha & Arun Da, 2025). Indeed, environmental harms harshly impact marginalised people -especially women- confronted with both natural disasters and systemic social neglect. Under such conditions, the female gender cannot stand enduring in silence all the time.

Likening metaphorically woman to nature, the female author Carolyn Merchant asserts that the earth can be seen as a nurturing mother who bears life in her breast. She then adds that, with this positive image, "one cannot stab one's own mother, one does not pierce her entrails to extract gold, one does not mutilate her body" (Merchant, 1996, p. 78). These statements suggest that in preserving the earth from being endangered, human beings opt for protecting the life of their life-giver (viz. mother), and by extension, their own life. In that regard, women are called on to get united through solidarity and justice to challenge dominant patriarchal modes with concrete actions. *Practical ecofeminism* comes into being to ensure "resistance grounded in material realities and institutional engagement, rather than mere symbolism" (Chukwu & Gbenoba, 2025, p. 303). This implies a collective action by women to protest as a strategy to claim eco-justice. In that sense, the female gender is presupposed to invert the patriarchal view that equates women with vulnerability into a symbol of power, authority and respect.

2.2. Discourse Analysis

Discourse analysis is an ambiguous concept. It could be used to designate the discipline that studies text and talk, or language use from all possible perspectives. It could also be used to refer to a theoretical and methodological approach to language and language use. In that sense, it is also defined by the object of analysis, namely discourses, texts, messages, talks, dialogues, or conversations (van Dijk, 1998, p. 24).

Discourse analysis is an approach to the analysis of language that looks at patterns of language across texts as well as the social and cultural contexts in which the texts occur (Paltridge, 2012, p. 1). In line with the preceding definition, van Dijk (1993, p. 96; 1998, p. 25) posits that discourse analysis has a double aim: a systematic theoretical and descriptive account of (a) the structures and strategies, at various levels, of written and spoken discourse, seen both as textual "object" and as a form of sociocultural practice and interaction, and (b) the relationships of these properties of text and talk with the relevant structures of their cognitive, social, cultural, and historical "context". In sum, discourse analysis studies "text in context". In other words, the two dimensions of discourse analysis are textual and contextual. While the textual dimension accounts for the structures of discourse at various levels of description, the contextual one relates these structural descriptions to various properties of the context (cognitive processes, sociocultural factors, etc).

Drawing on this, Fairclough (1989, 2001) postulates that discourse is manifest at two levels, namely: macro and micro. At the macro level of discourse are social concepts like social order, power, dominance and inequality. These social realities are abstract and they find

expression at the micro level of discourse which deals with linguistic concepts like grammar, speech acts, style and rhetoric (van Dijk, 2001; cited in Mbui & Ireri, 2019, p. 103). Hence, the discourse analyst is concerned with disclosing how discourse structures reproduce, perpetuate, resist or challenge social realities.

2.3. Positive Discourse Analysis

Proponents of critical discourse analysis (Fairclough, 1989; van Dijk, 2008, Wodak, 2001; Widdowson, 2004) argue that the underlying assumptions behind certain selections of discourse are never value-free or innocent. Rather, they are ideologically-driven and motivated. In their attempt to decipher ideologies by demystifying discourse, these scholars create awareness, enlightenment and emancipation in the 'underprivileged' in society, by revealing how discourse enacts, produces, reproduces and resists dominance, power abuse and social inequality.

However, some discourse analysts view their approaches as deconstructive and suggest an alternative. For Kress (1996), "if critical language projects were to develop apt, plausible theories of their domain, they would be able to move from critical reading, from analysis, *from deconstructive activity, to productive activity*" (pp.15-16, emphasis added). In that perspective, Martin and Rose (2003, p. 264, cited in El-Wakil, 2018, p. 358) argue for a complementary perspective to 'de-demonize' power that focuses on "how people get together and make room for themselves in the world in ways that redistribute power without necessarily struggling against it."

For Martin (2004, cited in El-Wakil, ibid), Positive Discourse Analysis (hereafter, PDA) is a constructive process against the prevailing "apparently pathological disjunction" of CDA that steadily disheartens the study of social and interpersonal attempts of solidarity and integration. Viewed as "a complementary perspective, on language and semiosis, which functions to make the world a better place" (Martin, 2004, p. 179), PDA is "a search for new ways of using language that tell us very different stories from those of the current industrial civilization – stories that encourage us to *protect the ecosystem that life depends on* and build *more socially just societies*" (Stibbe, 2017; cited in Abbamonte, 2022, p. 170, emphasis not ours). It stands then to reason that PDA aims to indulge in the potential of discourse analysis to bring about change through cooperative transforming practices. And this is the goal ecofeminists also commit themselves to reaching!

3. Methodology

The passage under scrutiny is an academic text drawn from the textbook of the fifth level students' book entitled *Go for English 2nde* used to teach English in some West African Francophone countries (Benin, Ivory Coast, Niger, etc.). The text is a reading passage whose title is "Pushing back the desert". It is part of Unit 2 named "The Environment" in the book. Basically narrative, the excerpt at stake is structured into five paragraphs thematically related, forming a cohesive whole.

The sentences of/in the paragraphs are coded numerically, to help index easily the different linguistic patterns or meanings encoded therein. The sentences in question are the linguistic units of analysis as far as syntactic, semantic/meaning relations, stylistic investigations are concerned. As for the study of speech acts, the utterances are considered as units of analysis.

In addition, a quantitative analysis is undertaken on the speech acts recorded in the text, while the other types of analysis are basically qualitative. Given that the text at stake is not too long (not more than 26 sentences in all), it is appended to the paper to help the reader clearly follow and make out, at each stage, the textual analysis and subsequent discussion.

4.Findings and Discussion

Textual Analysis and Discussion

The analysis, as intended here, revolves around syntactic, lexical style and meaning, actions, interaction, and speech acts, as well as style/rhetoric descriptions. It later evolves by subsuming the macro-level where the overall macrostructure is delved into.

4.1 Discourse Structures

Discourse structures are often informally divided into surface structures and *deep* or *underlying* structures (van Dijk, 1993). Discourse structures are usually associated with the form of language use one can see or hear, and the order of words in a sentence. In order to have a clear view of the complexity of sentences and how words are associated to build syntactically comprehensive sentences in the text at stake, we conceive of Table 1 below.

Table 1. Sentence Types in the Text

Simple sentences	Compound sentences	Complex sentences	Compound complex sentences	Minor sentences	Ranking sentences
4, 5, 6, 10, 11, 14, 16, 17, 18, 22	7, 12, 15	1, 2, 3, 8, 9, 13, 19, 20, 21, 23, 24, 26	25	-	
10	3	12	1	0	26

It is obvious from above that there is a total number of 26 ranking sentences in the text under study. They are split into 10 simple sentences, 3 compound sentences, 12 complex sentences, and 1 compound complex sentence. The high proportion of complex sentences (12/26, i.e. 46.15%) immediately followed by simple sentences (10/26, i.e. 38.46%) is revelatory of a blend of spoken and written modes in the text. The ratio of simple sentences over the other sentence types is 5/8, this corroborates the two concomitantly deployed modes. For instance, while sentence (8) below indicates a reported speech by Esther Wairimu, sentence (4) is a statement by the narrator to show her involvement in the communicative event.

(8) ‘They said if I planted my own trees, I would not have to spend all time looking for firewood.’

(4) No small tree was safe.

Complex sentences are employed to set hypotactic relations between clauses within the same sentence (Eggins, 2004). They are introduced by such conjunctions of subordination or relative pronouns as ‘before’ in (1), ‘for’ in (2), ‘which’ in (3, 21), ‘if’ in (8), ‘when’ in (9, 20, 21), ‘that’ in (13, 20, 24), ‘who’ in (19), ‘because’ in (23, 25). The following two examples illustrate how those linguistic items are deployed to relate clauses in a systematic, cohesive and thematic way.

(1) *Before* conservation came to Kanyariri, Esther Wairimu was a tree killer.

(20) '*When* I visited the village where I was born, I saw *that* whole forests had been cleared in order to remove the timber and grow crops'

The low rates of compound (3/26, i.e. 11.54%) and compound complex (1/26, i.e. 3.85%) sentences denote that the writer has less preference for paratactic clause complexes. However, when those structures are employed in compound sentences, this is meant to coordinate, via the conjunction 'and', two processes dealing with reforestation. Below are the three identified occurrences:

(7) 'My neighbours joined the Green Belt *and* began to argue with me.'

(12) There is shade for Wairimu's tin-roofed house, fodder for her goats and cows, better soil for her crops *and* there are branches for firewood.

(15) This was founded in 1977 *and* has been responsible for the planting of nearly five million trees.

As regard the only one compound complex sentence registered in the text, the same coordinator 'and', as can be noticed underneath, serves to link the two main clauses that it incorporates.

(26) People were eating less of the nutritious, traditional foods, like beans and maize, *and* were choosing refined foods like rice because they require less cooking.

With regard to simple sentences, they are made up of eight categories of word order- or sentence patterns- of the type: SVC, AASVA, SVCA, ASVC, SVA, SVO, SAVO, SV, with S=Subject, V=Verb, O=Object, A=Adjunct. The table beneath sums up those sentence patterns.

Table 2. Summary of Sentence Patterns in the Text

Sentence pattern	**SVC**	**AASVA**	**SVCA**	**ASVC**	**SVA**	**SVO**	**SAVO**	**SV**
Ranking sentence	4, 11, 14	5	6	10	16	17	18	22

For the purpose of saving space, a few illustrative instances are evinced below.

SVC: (4) No small tree was safe.

SVCA: (6) This was the result of a campaign by a new conservation project called Green Belt Movement.

SVO: (17) More than 500 communities have their own tree nurseries.

SV: (22) Springs were drying out.

As it is obvious from Table 2 above, the most predominant pattern from the eight sentence patterns is SVC, subsuming three ranking sentences while each of the seven others comprises just one. This suggests that though the narrator opts for a range of word orders for sentence building, she majorly resorts to a conventional type. In addition, most simple sentences (4, 11, 14, 6, 10, 17, 18) are made up of two arguments: subject and complement/object. It follows thus to infer that nearly all the simple sentences are in active voice, meaning that the narrator foregrounds agency.

On the other hand, it is noticed that apart from the simple sentence (5), passive voice is deployed in the other sentence types (especially compound, and complex sentences) to connote conscious agent obfuscation (15, 20), agent backgrounding (19), or agent deletion (23, 24).

4.2 Lexical Style and Meaning

Although surface structures are the most "visible" part of discourse, language users are mainly oriented toward meaning (van Dijk, 1993). The first analytical choice to adopt here is a study of local meanings, such as the meaning of words, a study which could also be termed lexical meanings depending on one's perspective. Local meanings are the result of the selections made by speakers or writers in their mental models of events or their more general, socially shared beliefs (van Dijk, 2001). Concerning the text under study, a great number of lexical items are intentionally deployed to refer to the lexical field 'Environment'. These are: 'conservation', 'tree', 'bundle of branches', 'firewood', 'water', 'crops', 'farm', 'converted', 'tree killer', 'tree planter', 'conservation project', 'Green Belt Movement', 'planted', maize, 'beans', 'woodland', 'mango-trees', 'blue gums', 'casuarinas', 'podocarpus', 'belt of greenery', 'fields', 'shade', 'soil', 'branches', 'forests', 'grounds', 'tree nurseries', 'biologist', 'damage', 'destruction', 'cleared', 'timber', 'hillsides', riverbeds', 'land', 'cultivated', 'drying up', ' coffee growing area', 'fuel', 'foods', 'beans', 'maize', 'grow crops', 'cooking', 'rural population', 'to grow', 'plant trees', 'push back', 'desert'. Notice that from this plethora of lexical terms pertaining to the same concept, we can have some subdivisions. They could be epitomised as follows: 'Tree', 'Deforestation' and 'Reforestation'. Notice also that collocations are referred to in view to conveying a specific meaning. They are of the types of Noun-Noun (conservation project, mango-tree), Adjective-Nouns (blue gums, rural population), Noun-Verb (coffee growing), Verb-Noun (grow crops, plant trees), Verb-Adverb (push back), Adjective-Noun-Noun (Green Belt Movement).

Another striking semantic property in the text is perspective. Glossed as "the point of view from which events are seen, or more generally the social or political 'position' of the speaker" (van Dijk, 1993, p. 108), perspective is expressed in the text through lexical items and sentence structures. As a matter of fact, events are narrated from the angle of the protection of the environment through some lexical choices such as 'conservation', 'converted', 'tree planter', 'conservation project', 'Green Belt Movement', 'plant', 'belt of greenery', 'shade', 'crops', 'conversion', 'forests', 'tree nurseries', 'grow crops', 'plant trees'. It should, however, be recalled that the meaning of discourse is not limited to the meaning of its words. The events described in the text are narrated from a psychological point of view. According to Simpson (1993), "Psychological point of view refers to the ways in which narrative events are mediated through the consciousness of the 'teller' of the story" (p. 10). While the narrator is projected in the text as someone who knows 'the facts', that is, a *figure of authority* (Fairclough, 1995, p. 4), the reader is projected as *receptive*, viz., waiting to be told, waiting to know (ibid.). It is also important to highlight that in the first four paragraphs the events are narrated in a linear chronological order, also called 'diegesis' (Simpson, 1993, p. 28). They are respectively concerned with Wairimu's hardships, her conversion from a tree killer into a tree planter, her witness as regards the benefits of trees, and the successes of the GBM in Kenyariri. However, the fifth and last paragraph (the longest indeed) is a flashback. It goes back to the foundation of GBM by Wangari Maathai, and sets the rationale behind such a

foundation. As a whole, the text is characterised by both first-person and third-person narration or point of view.

4.3 Action, Interaction, and Speech Acts

Discourse is not only units of expression and meaning, but it is also, and most fundamentally, a form of social practice (Fairclough and Wodak, 1997, p. 258), action, or interaction (van Dijk, 1997, p.2). In less technical terms, discourse is what language users "do", "engage in", or indeed "participate in", most clearly so in spoken dialogue, but also in written communication such as letters, news reports, textbooks, and e-mail messages (van Dijk, 1993). Indeed, a cursory reading of the text under study reveals, as mentioned earlier, that it is a narrative in which situations related to environmental devastation actions and reforestation attitudes (through sensitisation) in Kanyariri are amply described. And to make the text not sound like a mere recount of events, some dialogic moves are, from time to time, embedded therein. For instance, in sentences (7) and (8) the main character Wairimu reports some conversations she has had with some members of the Green Belt Movement (GBM), the women association dedicated to making the environment green. She says: (7) 'My neighbours joined the Green Belt and began to argue with me'. Then, she plainly informs the reader about the gist of their talk: (8) They said if I planted my own trees, I would not have to spend all my time looking for firewood. It follows from the foregoing statements that Wairimu's neighbours who joined the GBM initiated a face-to-face interaction to act, through discursive events, on her mental models or her personal cognitions. The reader later discovers that that verbal exchange actually ultimately influences the woman's perception, attitude and behaviour as she effectively gets converted from a tree killer into a tree planter. To sum up the incommensurable benefits she gets from that conversion, she quips: (13) I have learned that a tree, in another way altogether, is life'. It should be signalled that another type of interaction is also set up between the narrator and the reader. In point of fact, the former appears as the one who knows the events narrated, whereas the latter is someone who wants to discover those events.

As is inferable from the reading, the whole text subsumes a range of speech acts, that is, "the actions performed in saying something" (Austin, 1962; cited in Cutting & Fordyee, 2021, p.15). In a bid to get a clearer picture of the speech acts deployed in the excerpt at stake, we proceed to a cautious speech act identification through a close text reading. The results of the analysis are summarised in Table 3 below.

Table 3. Distribution of Speech Acts in the Text

Speech Acts	Representative	Directive	Commissive	Expressive	Declaration	Total
Utterances	(1), (2), (3), (5), (6), (7), (9), (10), (11), (12), (14), (15), (16), (17), (18), (19), (21), (22), (26)	(8)	-	(4), (13), (20), (23), (24), (25)	-	
Total	19	1	0	6	0	26

The above table exhibits the deployment of three types of speech act out of the five typified by Searle (1976). These are representative, directive and expressive speech acts. In other words, commissive and declaration are absent from the text. Of the three employed categories, representatives top with a lion share (19/26, i.e. 73.08%). It is followed by

expressives which occur 6 times, yielding a percentage of 23.08%. As for directive, only one instance is registered, which represents a rate of 3.84%.

The high proportion of representatives, as exuded in the table, suggests that the speech is designed to describe some state of affairs or to state some facts (Amoussou & Allagbe, 2023). In actual fact, the illocutionary acts of representative are employed to *state* events or actions (1, 2, 3, 5, 6, 7, 9, 10, 11, 12, 14, 15, 16, 17, 18, 19, 20, 26) related to Wairimu's life from a tree killer to a tree planter, and to *describe* actions (21, 22) dealing with the behaviour of the rural population of Kanyariri or the impact of such behaviour on their life. For example, the heroine is introduced to the reader as a Kenyan woman who has had to "trudg[e] along the red paths of her village with bundles of branches tied to her back, searching the hillsides for firewood" (2). Then, her daily hardship of "cooking over an open fire" (3) is put forth as the main reason of her killing of trees. In the next paragraph (viz. paragraph 2), the story of her conversion from a tree killer to a tree planter is narrated: her sensitisation by the GBM (6, 7), her 'joining' of the organisation and her planting of trees -in addition to her rows of maize and beans-(9, 10). Furthermore, a range of achievements by the GBM of which Wairimu's case is just an epitome, are enumerated (springing up of small forests on school and church grounds, tree nurseries owned by more than 500 communities, the possession of thriving piece of woodland by 25, 000 households) (16, 17, 18).

Though expressives (23.8%) are not so profuse in the text, they play a very significant role in conveying psychological states. As a matter of fact, expressive speech acts are subtly incorporated in the communicative event to state what the speaker or the narrator feels as regards either the awesome devastation of forests, or the regeneration of greenery. Thus, to vent up her amazement concerning the high rhythm of extinction of trees (no matter their age), the story teller simply avers: (4) No small tree was safe. Likewise, in uttering (20) the GBM founder openly vows her surprise about the destruction rate of forests, once she goes back to her natal countryside: 'When I visited the village where I was born, I saw that whole forests had been cleared in order to remove the timber and grow crops'(20). On the other hand, after getting converted from a tree killer into a tree planter, Wairimu gladly, and in a satisfactorily way, contends in the following terms that a tree equals life: (13) 'I have learned that a tree, in another way altogether, is life'. Notice, however, the recourse to what systemicists (Halliday & Mathiessen, 2004; Eggins, 2004, etc.) call *mental processes* of the types 'I was shocked' and 'I was amazed' to denote a great surprise in utterances (23) and (24) respectively:

(23): I was shocked to find children suffering from kwashiorkor, because my community was supposed to be a rich, coffee-growing area.

(24): I was amazed to learn that malnutrition was linked with lack of fuel.

As is evident, the above statements definitely exude some appalling consequences of cutting down trees, specially health-related problems. Accordingly, urgent actions need be taken to curb the situation and save lives. And there lies the vital role of the only directive speech act resorted to in the text. At the surface level, the counterfactual presupposition in (8) below seems to be a representative, but, in fact, it is not at all.

(8): They said if I planted my own trees, I would not have to spend all time looking for firewood.

In point of fact, while the conditional clause above ostensibly appears as the report -or verbiage- of the speech of Wairimu's neighbours, it is an invitation to make her act on her own behalf: she must plant her own trees to avoid wasting time for firewood. In other words, the function of the aforementioned declarative clause is to give Wairimu an indirect order for the purpose of behaviour change. This type of illocutionary act, in pragmaticians' jargon, is known as an *indirect speech act* (Yule, 1996, p.54; Cutting, 2002, p. 19; Cutting & Fordyce, 20121, p. 18; Paltridge, 2012, p. 41; Levinson, 1983, p. 263), and it denotes politeness. On the contrary, the utterance would be: 'plant your own trees, and you will not have to spend all time looking for firewood. The next subsection is devoted to the way language is used to convey the meanings thus far unearthed from the excerpt.

4.4 Style and Rhetoric

Style and rhetoric are two other dimensions of the text at hand that deserve a cautious analysis too. Unlike the other properties so far discussed, style is not merely a distinct level, but a dimension that cuts through various levels (van Dijk, 1988). Simply glossed as 'a way of writing' or 'a mode of expression (Leech & Short, 2007, p. 13), style is the result of the choices made by the speaker among optional variations in discourse forms that may be used to express more or less the same meaning (van Dijk, ibid.). Style is indexical of the role of context in the understanding of discourse. Likewise, rhetoric is concerned with both form and context. Regarded in its traditional sense as 'the 'art or skill of effective communication (Leech & Short, 2007, p. 169), rhetoric is the broader art of persuasion which is achieved through stylistic choices.

Rhetorical language is deployed in the text under study through such stylistic features as repetition, assonance, alliteration, consonance, co-hyponomy, synonymy, contrast, parallelism, apposition, simile, hyperbole, metaphor. As a striking stylistic device in the excerpt, repetition is identified both within and across sentences. They subsume such lexemes as 'tree' [in 1, 4, 5 (twice), 14 (twice), and 17], 'trees' (in 8, 9, 11, and 15), 'firewood' (in 2, 3, 12, and 26), 'crops' in (3 and 20), 'woodland' in (10 and 18), 'forests' (in 16 and 20), 'grow' (in 20, and 26), 'planted' (in 8, and 9), 'plant' (in 9, and 26), 'branches' (in 2 and 12), 'maize' (in 9, and 25), 'beans' (in 9 and 25), 'foods' (twice in 25), 'hillsides' (in 2 and 21). However, a careful scrutiny of the preceding list amazingly unveils that all those repeated lexical items -except hillsides- refer to greenery, the focal *theme* or *topic* (to use van Dijk (1997)'s terms) backed up by the narrator in the text. It follows, then, to argue that repetition is amply employed in the text for a cohesive purpose to stress the necessity to opt for green vegetation, cultivation or verdure.

Another remarkable stylistic figure is assonance. Diversely resorted to in the text, it contributes to creating internal rhymes within the sentences, no matter their types. To demonstrate this, let us just consider the following sentence.

(2): For two days **ea**ch w**ee**k the Kenyan w**o**man trudged along the red d**ir**t p**a**ths of h**er** v**i**llage w**i**th bundles of br**a**nches t**ie**d to her b**a**ck, s**ear**ching the h**i**llsides for f**i**rew**oo**d.

In the above, is obvious the repetition of the vowel sounds:

- /i:/ in **ea**ch and w**ee**k;
- /ɪ/ in v**i**llage, w**i**th, and h**i**llsides;
- /ɜ:/ in d**ir**t, h**er**, and s**ear**ching;
- /æ/ in p**a**ths, br**a**nches, and b**a**ck;

- /aɪ/ in t**ie**d and f**i**rewood;
- /ʊ/ in w**o**man and firew**oo**d.

In addition to assonance, alliteration and consonance also convey sentential internal rhythm, enhancing thus the musical dimension of the passage. Sentences (1), (16) and (25) below are, in that order, illustrative of the deployment of those figures of speech.

(1) Before **c**onservation **c**ame to **K**anyariri, Esther Wairimu was a tree **k**iller.

(16): **S**mall forests have **s**prung up on **s**chool and church grounds.

(25): People were eating less of the nutritious traditional food**s**, like bean**s** and mai**z**e, and were choo**s**ing refined food**s** like rice becau**s**e they require less cooking.

It is important to signal that while alliteration is expressed in (1) by the voiceless velar stop /k/, it is introduced in (16) by the voiceless alveolar fricative /s/. It is equally important to stress that the phoneme /s/ in (16) is a hissing sound. It is also known as a sibilant. As for consonance, it is expressed by the sound /z/ in the last syllable of nearby words.

Taxonomic lexical relations are also observable in the text in the form of co-hyponymy as 'gums', 'casuarinas' and 'podocarpus' in (11) and 'beans' and 'maize' in (9 and 25). While the first set can be grouped under the superordinate 'tree', the second set is made of instances of 'foods'. Likewise, synonymy and contrast are two further lexical relations distinctly used in the text to hang sentences together as a whole. Some examples are displayed below.

Synonymy

- 'look for' (8) ≈ 'fetch' (3);
- 'damage' (9) ≈ 'destruction' (9);
- 'tree' (1, 4, 5) ≈ 'timber' (20);
- 'woodland' (10, 18) ≈ 'greenery' (11)

Contrast

- 'Tree killer' (1, 5, 14) # 'tree planter' (5, 14)
- 'traditional' (25) # 'refined' (25)
- 'forests' (16 and 20) # 'desert' (26)
- 'grow' (20, 26) # 'clea[r]' (20)

Parallelism is rather a syntactic rhetorical device designed to produce rhythmic effects through structural repetitions as showcased beneath.

(3) As well as her other jobs of fetching water, looking after crops on her husband's two-hectare farm and cleaning the house, …

(11) There are mango trees,

(12) There is shade …. and there are branches….

Parallelism in (3) is patterned on BV_1 +ing +NP, BV_2 + ing + NP, BV_3 + ing + NP, with BV=base verb and NP=noun phrase. As for the parallelism discovered in (11) and (12), it is made of existential processes, and is framed as 'There + Be + NP'. In each case, it is employed to state the existence of a noun phrase expressing curiously an idea of verdure (mango trees, shade, branches).

Other no less important stylistic figures of speech recorded in the text include apposition, simile, hyperbole, and metaphor. The following examples disclose each of those features respectively.

(19) The Green Belt Movement was founded by Wangari Maathai, a Kenyan biologist …

(18) 25,000 households like Esther Wairimu's now have their own thriving piece of woodland.

(4) No small tree was safe.

(13) I have learned that a tree, in another way altogether, is life.

Apposition in sentence (19) is clearly manifest in the nominal phrase 'a Kenyan biologist' which stands for nothing else than the preceding proper noun 'Wangari Maathai' representing the founder of GBM. As for simile, it is indicated in (18) by the word 'like' to compare the situation of thousands of households to Esther Wairimu's in terms of possessing their own 'thriving piece of woodland'. A close analysis of sentence (4) reveals that the narrator exaggerates the rhythm at which Wairimu is cutting down trees: 'How can she use all types of tree (no matter their age) to make fire? Can the smallest growing trees also serve as firewood to help a woman cook food?' At last, like (18), (13) exudes comparison between two entities. However, the comparison in (13) is between two things of unlike nature: 'a tree' and 'life'. Notice here, though, that despite the different characters of those entities, one implies the other. In point of fact, a tree is dependent upon life and owes its existence to it. As a result, it can be likened to life. Hence, the metaphoric construction. In the next section, the main ideology which underpins the current text (viz., ecofeminism) is unearthed and accounted for, as well as how it contributes to reaching the objective pursued by the text-writer.

From Ecofeminist Stance to the Shaping of Students' Mental Models

From a cautious exploration of the text undertaken in the preceding part, the ecofeminist view adopted in this endeavour becomes plainly justifiable. As a matter of fact, there are many cues in the text that prove women's reclaiming of their rights for the purpose of connecting with nature. To begin with, the narrative starts by making the reader aware of the innumerable household chores the Kenyan woman (and, by extension, the African woman, in general) is submitted to in a patriarchal society. Among other domestic activities, she has to 'fetc[h] water, loo[k] after crops … and clea[n] the house'. Given that she also has to cook for over an open fire for ten children, looking for a lot of firewood becomes a daily headache. Thus,

> (2) for two days each week the Kenyan woman trudged along the red dirt paths of her village with bundles of branches tied to her back.

It should be stressed here that besides her daily chores, walking over kilometres, as it is unveiled in the foregoing sentence, is a very tiring and exhausting task. Moreover, her health is at risk on 'the red paths of her village' that she is obliged to take. As Dhivya *et al.* (2025) concede, "environmental harm disproportionately impacts marginalized communities" (p. 1).

It becomes obvious thus that the womenfolk cannot stand the gloomy conditions assigned to them by the shackles of patriarchy. Rather, they "must fight for [their] space no matter the patriarchal constraints or inhibitions laid on [them]" (Amoussou & Djimet, 2020, p. 37). Solely or collectively, the African woman must find ways and means to vent her pent-up feelings and take actions. As Fairclough (2004) rightly puts it, "being socially constrained

does not preclude being creative" (p. 24). In that respect, the Kenyan biologist, Wangari Maathai founds the GBM in view to relieving woman's pains and suffering, and redeeming the environment. Convinced about the pertinence of the initiative, the women who join the association get organised into groups to sensitise their fellows. Through that sisterhood or bonding, they demonstrate that social relationships should be based on mutual respect and solidarity. The deployment of indirect speech act -connoting negative politeness strategy- to invite their female neighbours to plant trees, is an evidence. And the success of their philosophy, their conviction and their determination ultimately climaxes with 'the planting of nearly five million trees'.

By informing learners about the realities they are familiar with like Wairimu's, the text implicitly attempts to act upon their context models and event models. "Context models and event models", van Dijk (2001, p. 112) explains, "are mental representations in episodic memory, that is, the part of long-term memory in which people store their knowledge and opinions about episodes they experience or read/ hear about". While Wairimu's case is a depiction of the sad reality the African woman has to face, it is also the description of how, through their anthropic actions, human beings contribute to the devastation of their environment. The syntactic and thematic organisation of the text, added to the semantic, meaning-making and stylistic choices, is designed to cause *ideological effects* in students' minds. According to Fairclough (2003), ideological effects are "the effects of texts in inculcating and sustaining or changing ideologies" (p. 9). Ideology, need it be recalled, is simply "the *foundation* of the social representations shared by a social group" (van Dijk, 2004, emphasis in the original). From the underlying or deep meanings exuded through the investigation of the text at stake, it can be inferred that the causal effects are meant to bring about change. More particularly, the text intends to get learners to:

(i) be aware of the domestic frustrations of the womenfolk;
(ii) discover that no equilibrium is possible in society unless social injustice is banned;
(iii) infer that ecological devastation is synonymous with life destruction;
(iv) figure out that eco-justice is the solution for the preservation of the environment, hence of life;
(v) decide to impact their communities through tangible actions aiming at eradicating social/gender injustice, and advocating reforestation (viz., fighting against all sorts of social discrimination or dominance, promoting gender equality, planting trees to make their living area an attractive and eco-friendly place to live in).

In a nutshell, the text seeks to bring about change in students' knowledge, their ideologies, beliefs, attitudes, values and so forth, by acting upon their mental models. van Dijk (2001) plainly submits to that contention when he states that "…it is through mental models of everyday discourse such as conversations, news reports and textbooks that we acquire our knowledge of the world, our socially shared attitudes and finally our ideologies and fundamental norms and values" (p. 114).

5. Conclusion

This paper has hypothesised that there is a dialectical relationship between woman, nature, and development. It has also taken the view that any battle against the destruction of the environment should involve women's active commitment in order to be successful. Anchored on ecofeminism, discourse analytical framework, positive discourse analysis, and the mixed research method, it has examined how textbooks serve as a central tool in engaging students

in the safeguarding of their environment. In that regard, it has investigated an academic text culled from *Go for English 2nde*. A cautious investigation of the aforementioned text proffers significant insights into the meanings embedded therein. For instance, the analysis of discourse structures unveils a high proportion of complex sentences (12/26, i.e. 46.15) immediately followed by simple sentences (10/26, i.e. 38.46%), which is suggestive of a blend of spoken and written modes in the text. As for lexical style and meaning, it is discovered that a great number of lexical items are intentionally deployed to refer to the lexical field 'Environment'. Meanwhile, the text refers to both first person and third person narration or point of view. Concerning actions, interaction and speech acts, a relationship of figure of authority and receiver is set between the narrator and the reader, while representative speech acts predominate over the other types of illocutionary act. At last, rhetorical language is employed in the text at stake through such stylistic figures as repetition, assonance, alliteration, consonance, co-hyponomy, synonymy, contrast, parallelism, apposition, simile, hyperbole, metaphor. All those findings denote substantial change in terms of the social perception of the relationship of people -and more particularly students- and their environment.

It is commonly agreed that "we are living in a period of intense social change" (Fairclough, 1992, p.3) where "language awareness has been widely advocated as an important part of language education" (ibid, p. 1). It implies that while training learners to acquire language skills, language education should also include a critical impetus in the learning/teaching process. As the scholar rightly puts it, "People cannot be effective citizens in a democratic society if their education cuts them off from critical consciousness of key elements within their physical or social environment" (Fairclough, 1992, p. 6). This implicitly suggests that (critical) consciousness is a precondition for the development of new practices and conventions that will ultimately lead to emancipatory discourse practices and social emancipation. In other words, and in the light of the current research's aim, "climate consciousness must account for who suffers most, foregrounding that environmental destruction compounds pre-existing injustices" (Dhivya *et al.*, 2025, p. 2).

Thanks and Information Note

The article complies with national and international research and publication ethics. All authors contributed equally to the article.

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APPENDIX

Text: Pushing back the desert

1. Before conservation came to Kanyariri, Esther Wairimu was a tree killer. 2. For two days each week the Kenyan woman trudged along the red dirt paths of her village with bundles of branches tied to her back, searching the hillsides for firewood. 3. As well as her other jobs of fetching water, looking after crops on her husband's two-hectare farm and cleaning the house, Wairimu had ten children to cook for over an open fire, which needed a lot of firewood. 4. No small tree was safe.

5. Then in 1982 Wairimu was converted from a tree killer to a tree planter. 6. This was the result of a campaign by a new conservation project called the Green Belt Movement. 7. 'My neighbours joined the Green Belt and began to argue with me,' Wairimu remembers. 8. 'They said if I planted my own trees, I would not have to spend all my time looking for firewood.' 9. And so when the time came for Wairimu to plant her rows of maize and beans, she planted trees as well. 10. Now, five years later, her farm is a young woodland.

11. There are mango trees, blue gums, nitrogen-fixing casuarinas and straight-trunked podocarpus which form a belt of greenery around her fields. 12. There is shade for Wairimu's tin-roofed house, fodder for her goats and cows, better soil for her crops and there are branches for firewood. 13. 'I have learned that a tree, in another way altogether, is life,' she says.

14. Esther Wairimu's conversion from tree killer to tree planter is one of the many successes of the Green Belt Movement. 15. This was founded in 1977 and has been responsible for the planting of nearly five million trees. 16. Small forests have sprung up on school and church grounds. 17. More than 500 communities have their own tree nurseries. 18. 25,000 households like Esther Wairimu's now have their own thriving piece of woodland.

19. The Green Belt Movement was founded by Wangari Maathai, a Kenyan biologist, who saw the damage done by the destruction of the forests. 20. 'When I visited the village where I was born, I saw that whole forests had been cleared in order to remove the timber and grow crops,' she says. 21. 'People were moving on to hillsides, riverbeds and poor quality land which was not cultivated when I was a child. 22. Springs were drying up. 23. I was shocked to find children suffering from kwashiorkor, because my community was supposed to be in a rich, coffee-growing area. 24. I was amazed to learn that malnutrition was linked with lack of fuel. 25. People were eating less of the nutritious, traditional foods, like beans and maize, and were choosing refined foods like rice because they require less cooking.' 26. So Wangari Maathai founded the Green Belt Movement to plant trees, to enable the rural population to grow enough firewood for themselves and to push back the desert.

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Electricity Production from Nature (Aloe Vera)

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Abstract

Energy production and conversion is one of the most important and challenging fields of science and technology in today's world. With the expansion of energy needs and the increasing world population, the development of new and sustainable methods of energy conversion is a matter of environmental protection and energy security. Among the advanced ones in this field are energy conversion systems based on biochemical and bioelectric principles that, by utilizing functions and mechanisms derived from biological structures and organisms, enable the production and conversion of energy into clean and sustainable forms. Biochemical energy conversion systems are designed to use biological methods to produce energy, including light-sensitive solar cells and biological fuel cells. These systems, by simulating and utilizing biological methods such as energy production from chemical compounds in living cells, become usable energy sources. On the other hand, bioelectrical systems are able to generate electrical energy by utilizing biological electrochemical interactions between chemicals and biological components. One of the challenges associated with designing biochemical and bioelectrical energy conversion systems is providing methods to increase efficiency and reduce the costs of production and use of these systems.This article presents the results of a research on the energy conversion process using plant to generate electricity for the Iranian climate.

Keywords: Electricity production, nature power, green energy.

Introduction

Electrode potential is defined as the potential of a cell containing an electrode acting as the cathode and a standard hydrogen electrode as the anode. Reduction always occurs at the cathode and oxidation at the anode. Electrode potential (Heusler, 1986) can be related to an electrochemical cell, in which two dissimilar metals conduct an electric current and are treated as they tend to release electrons. For example, when zinc metal is placed with copper metal in their respective electrolytes (Hill, 2007), zinc begins to lose electrons through an external wire connection.

Materials and Methods

The materials required for the experiment are given in this PLAN. In the entire plan, an aloe vera pot and several sets of cables for the anode and cathode were used. The materials used include:

A - Pot soil substrate

B - Pot or cultivation container

C - Aloe vera plant under test

D - Ammeter (amperage measuring instrument)

E - Copper metal and copper rod

F - Zinc metal and zinc metal strip

Findings and Discussion

In this design, two materials, tin and copper, have been used in the sample pot, so that copper metal and copper rod have been used in the soil and tin metal has been used on the leaves of the aloe vera plant.

From both metals, a coated wire cable has been stretched to terminals 1 and 2, and in order to minimize manual intervention and human error, the terminal has been used in all these designs. In the photos, this item is marked with the label PLAN A.

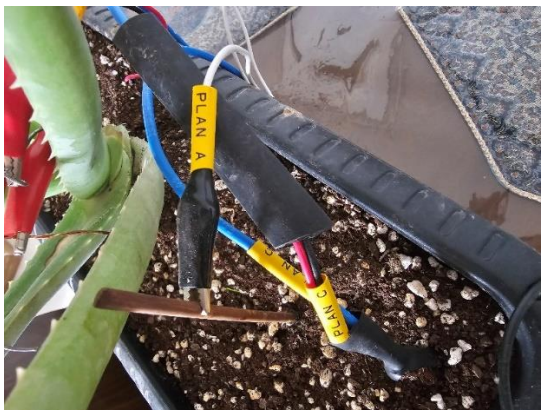




Figure1. Copper material in the soil and tin material on the leaf

4th Day			3rd Day			2nd Day			1st Day			Material on the leaf	Material inside the soil
mV			mV			mV			mV				
C	B	A	C	B	A	C	B	A	C	B	A		
66.8	66.8	66.9	39.7	39.7	39.8	22.7	23.0	24.3	48.7	51.7	54.9		Copper
												Tin	
8th Day			7th Day			6th Day			5th Day			Material on the leaf	Material inside the soil
mV			mV			mV			mV				
C	B	A	C	B	A	C	B	A	C	B	A		
66.8	66.8	66.9	58.4	59.9	61.5	47.9	48.1	47.5	55.4	53.6	62.3		Copper
												Tin	
12th Day			11th Day			10th Day			9th Day			Material on the leaf	Material inside the soil
mV			mV			mV			mV				
C	B	A	C	B	A	C	B	A	C	B	A		
76.0	76.8	76.7	86.0	86.3	86.2	76.9	76.9	76.8	71.8	71.8	72.0		Copper
												Tin	

Table 1. Test result and voltage measurement in millivolts

After obtaining the results of the experiments and tests, the following graph was obtained. Also, the statistical results of the experiments performed are in accordance with the table below. (Table 2). The graphs and charts obtained from the results are also in accordance with Figure 2, which we will examine in the next section (Figure 2).

Standard Error	SSD	Standard Deviation	P-Variance	Variance	Mean	Number	leaf Material on the	Material inside the soil
2.88	17.26	17.02	297.84	297.84	60.39	36.00	**Tin**	**Copper**

Table 2. Statistical results obtained from sampling

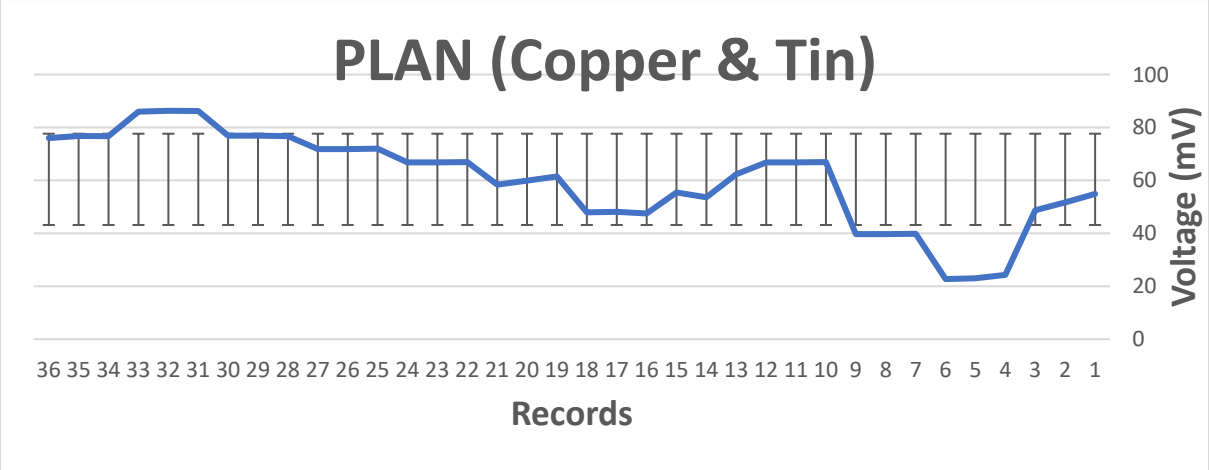


Figure 2. Graph of the results obtained from the experiment

Conclusion and Recommendations

Based on the results obtained, I suggest that by connecting plants in series and wiring them, the voltage obtained will be strengthened, and ion exchange can also be increased by replacing the soil substrate with marsh substrates. I also suggest that by using soil drainage and creating metal rods and grids in the soil, ion exchange can be increased, which will increase ion exchange and voltage, and by using this clean and useful energy, lighting can be provided at minimal cost.

Thanks and Information Note

Many thanks to Dr. Jafar Masah, Director of the Department of Agricultural Engineering, University of Tehran, who provided me with her unwavering and friendly guidance in the development and implementation of this project.

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Patterns and Socioeconomic Drivers of Fuelwood Dependency in Households Adjacent to Rema-Kalenga Wildlife Sanctuary, Habiganj, Bangladesh

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Abstract

Bangladesh, a developing country, relies heavily on biomass fuel, mainly fuelwood, as a major renewable energy source. The study, carried out from December'23 to January'24 to investigate the patterns and socioeconomic drivers influencing fuelwood dependency among households around RKWS. A total of 69 households (n=69) were randomly selected and categorized into high-, moderate-, and low-income groups based on their monthly income. With a daily average consumption of 2.57 kg/capita, consumption varied significantly across income groups. Due to their constrained access to alternatives, the lower-income group consumed the most fuelwood (3.01 kg/capita/day), primarily relying on easily accessible and low-cost fuelwood. Forest was identified as main source of fuelwood, mostly consumed by low-income group. A group characterized by moderate income showed a balanced use of all available sources. Men were found as the primary gatherers of fuelwood from forests. The most often used species were Swietenia macrophylla, Acacia auriculiformis, Syzygium grande, Mangifera indica. A significant negative correlation between household income and consumption ($r = -0.61$; $p < 0.001$), indicating that dependency on fuelwood decreases with income. The findings highlight that unsustainable extraction and excessive dependence on forest-derived fuelwood, especially among low-income households, poses serious threats to forest cover, biodiversity, and overall ecosystem health in RKWS.

Keywords: Fuelwood, socioeconomic status, forest resources, RKWS.

1. Introduction

Fuelwood is the predominant source of fuel in both rural and urban areas of the developing world (Arnold & Jongma, 2006; FAO, 2001). Wood that is burned for energy, is usually used for cooking, heating, or generating power is called fuelwood (United Nations, 2019). Fuelwood is highly favored for its flexibility, renewability, accessibility, cost-effectiveness, and compatibility with cooking practices (Njenga et al., 2023). According to the World Bank (2015) and the International Energy Agency (2010), around 3 billion people living in rural areas worldwide lack adequate energy for basic needs and over 2.7 billion of them still depend on traditional energy supplies to meet their basic energy needs. Generally, rural dwellers exhibit lower socioeconomic status and rely heavily on the natural surroundings to fulfill their necessities. According to the World Health Organization (2006), around 70% of households in poor to developing countries use organic fuels such as wood, branches, leaves, animal dung, and crops waste for cooking purposes. As a consequence, fuelwood makes up around 54% of the total yearly global wood harvest (Osei, 1993). In many tropical regions, fuelwood extraction from forest reserves and biodiversity hotspots is a major threat to

remaining habitat (Asik & Masakazu, 2017; Chowdhury et al., 2013). For example, numerous studies link fuelwood harvest to declines in tropical forest cover (Specht et al., 2015). Conservationists warn that as long as rural communities depend on decreasing forests for cooking fuel, biodiversity and carbon loss will continue unchecked (Asik & Masakazu, 2017; Chowdhury et al., 2013).

Bangladesh is a highly populated developing country, covering an area of 1,47,570 sq. km., where forests occupy only about 12.8% of Bangladesh's land area (Henry et al., 2021). Bangladesh's forests (≈2.52 million hectares) provide most of the nation's fuelwood, but they are already under severe pressure. National surveys confirm that fuelwood is perceived as scarce: roughly 70% of surveyed rural households report that firewood (fuelwood) is becoming scarce due to degradation of homestead and village forests. Rising demand makes this scarcity acute – the government's Forest Master Plan projected a gap of several million cm^3 of fuelwood in the near future (Hassan et al., 2013). Meanwhile, Bangladesh's population (now over 180 million) remains largely rural (60–70%) where access to electricity and LPG is limited (Biswas et al., 2023). As a result, nearly 92% of rural households still cook with biomass, especially fuelwood (BBS, 2022). In short, the energy used for cooking in Bangladesh is heavily weighted toward traditional fuels, and its depleted forests struggle to meet human needs.

Rural households typically burn a mixture of biomass fuels, but wood (fuelwood) predominates (Biswas et al., 2023; Nandi & Nusrat, 2020). Field surveys in Bangladesh find that most families use firewood (fuelwood) as their primary cooking fuel, supplemented by other biomass (branches, leaves, rice straw, animal dung, etc.) when wood is scarce. For example, Hassan et al. (2013) reported that villagers most commonly gather wood branches, tree leaves, cow dung and agricultural residues, but that the preferred fuel due to higher heat output remains wood. The extraction and use of biomass fuel vary throughout villages, regions, and nations, and are shaped by the socioeconomic and demographic attributes of households (Biswas et al., 2023). Income levels, Household size, Education level, Energy alternatives, Cultural preferences and practices significantly influenced the dependency. In Khulna District, Biswas et al. (2023) found that middle-income households actually used more biomass fuel than either poor or rich households. This pattern reflects the "energy stacking" phenomenon, where poorer households rely on freely collected or inexpensive biomass, while wealthier households gradually adopt cleaner fuels such as gas or electricity, often still using traditional fuels for some purposes. (Shankar et al., 2020).

In protected-area settings e.g., Rema-Kalenga Wildlife Sanctuary (RKWS), additional drivers emerged, villagers adjacent to forests often have limited livelihood options beyond natural resources. In case of Rema-Kalenga's, (Shaheed et al., 2013) explicitly observed that high forest dependency of local households may be due to the lack of alternative non-forest income sources. Across Bangladesh's PAs, poverty and population pressure are chronic issues: Buck et al. (2007) note that communities in and around protected areas are typically income-poor and experiencing above-average population growth, creating intense resource pressure (Roy & DeCosse, 2006). Under such circumstances, fuelwood collection becomes a default coping strategy, especially for landless or marginalized groups. Despite recognition that RKWS communities depend heavily on fuelwood, quantitative studies on consumption patterns and drivers remain scarce. A number of researchers have extensively analyzed various aspects of biomass fuel in Bangladesh. (Bari et al., 1998) conducted a study on the

supply and use of biomass energy in the villages of Mymensingh and Kishoreganj districts using three different methods. Miah et al. (2003) assessed the use of biomass fuel among rural households in the Chittagong area. Jashimuddin et al. (2006) conducted a study on the use of biomass fuel and decision-making processes in the overlooked villages of Sawndip and Noakhali Sadar upazila. Alam et. al., (2019) examined the use trends of biomass fuel in households located in the northern region of Bangladesh. Much of the literature on RKWS focuses on conservation management (e.g., ecotourism, co-management, and participatory forestry), but few have studied how much wood local households use or why. As Asik and Masakazu (2017) point out for Bangladesh in general, "There is a lack of research regarding the impact of fuelwood harvesting on deforestation". A thorough review of the relevant scientific literature revealed that there are just a few studies on the use of fuelwood and the drivers that shape that consumption.

The present study aims to fill this gap by (a) analyzing the consumption amount and patterns of fuelwood among households adjacent to the sanctuary (e.g., per-capita use, sources & types of fuelwoods), and (b) finding out the socioeconomic drivers that explain why some households use more wood than others (e.g., monthly income, education, family size, age).

2. Materials and Methods

2.1 Study Area

The study conducted in villages in and around the Rema-Kalenga Wildlife Sanctuary (RKWS), located within the Gazipur and Ranigaon unions of Chunarughat upazila in Habiganj district. RKWS is an evergreen hill forest covering about 1,795 hectares, positioned between 24°06′–24°14′N and 91°36′–91°39′E (BCAS 1997). The sanctuary is bordered by India's Tripura State on the south and east, the Kalenga Forest Range on the north and west, and tea estates toward the southwest. The area is classified as part of the Sylhet Hills zones and is specifically located inside the Tarap Hill Reserve Forest. Initially, 1095 hectares of this forest were declared as a wildlife sanctuary in 1982. Later, in 1996, the sanctuary was enlarged to include a total area of 1995 hectares, in accordance with the Bangladesh Wildlife (Preservation) Order 1973 (Wikipedia, 2023). The sanctuary is divided into three beats, which are tiny administrative entities of the Bangladesh Forest Department. These beats are named Rema, Chanbari, and Kalenga (Chowdhury et al., 2013). The climate of the research site is mostly tropical and humid, while the soils are described as ranging from clay to sandy loam (Mollah et al. 2003, Rana et al., 2010). The sanctuary supports a wide variety of flora and fauna, with 634 plant species and a total of 229 recorded animal species, including 167 birds, 7 amphibians, 18 reptiles, and 37 mammals (Uddin & Roy, 2007). Das (2015) reported that nearly three-quarters of households in RKWS depended on collecting non-timber forest products. The surrounding villages are home to Muslim and Hindu communities, along with ethnic groups such as Tripura, Shantal, Urang, Kharia, Kurmi, Goala, Munda, and Bunargi. Most residents rely on farming, and literacy levels in these communities remain relatively low (Chowdhury et al., 2013; Rahman & Miah, 2017).

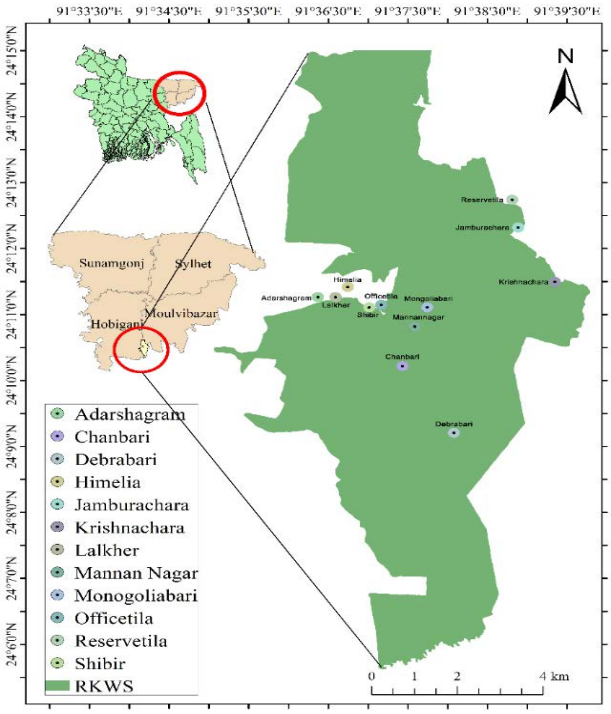


Figure 1. Map of the study area

2.2 Data Collection and Analysis

A random purposive sampling approach was used, with villages (n=12) serving as the final sampling units and households as the primary units of analysis. Villages named Adarshanagar, Chanbari, Debrabari, Himelia, Krisnachara, Jamburachara, Lalkher, Mannannagar, Officetilla, Reservetilla, Monogoliabari, and Shibir were randomly selected to represent both tribal (Tribal) and non-tribal (Muslim and Hindu) communities. Data were collected through a semi-structured questionnaire. Based on monthly household income, households' were categorized as low-income (≤10,000 BDT), moderate-income (≥10,000–15,000 BDT), or high-income (>15,000 BDT). In total, 69 households were randomly chosen for study. Daily fuelwood collection and consumption were recorded in local units and later converted to kilograms (kg). A field survey was carried out at Rema-Kalenga Wildlife Sanctuary (RKWS) over a 10–12 days period between December'23 and January'24. Following household interviews, a paired-ranking exercise was carried out to determine respondents' preferred fuelwood species. Approximately one-third of respondents were women, while men accounted for about 65%. In each village, a group discussion was held to verify and validate the collected data.

Data preparation and analysis was performed using Microsoft Excel (2024) and R (4.2.2). Descriptive statistics (mean, standard deviation, and percentage distribution) were used to summarize household characteristics. The Shapiro–Wilk test was applied to check the normality of continuous data, and since the data didn't follow a normal distribution, nonparametric methods were used for subsequent analyses. Spearman's rank correlation examined relationships between fuelwood consumption and predictor variables. Differences in fuelwood consumption among income groups were assessed using the Kruskal–Wallis test, followed by post-hoc pairwise comparisons with Bonferroni method. Multiple linear

regression analysis was conducted to see the combined effect of socioeconomic and source-related variables , incorporating household income, size, education level, and percentage contributions of sources. All statistical tests were conducted at a 5% significance level ($p < 0.05$), and the results were presented through tables and figures for clarity.

3. Findings and Discussion

3.1 Fuelwood Consumption Quantity

All 69 surveyed households showed a strong dependence on fuelwood as their primary source of domestic energy. The average daily per capita fuelwood consumption varied significantly ($p < 0.001$) across income groups, showing a clear decreasing trend with increasing household income (Table 1; Figure 2). The low-income group consumed the highest mean consumption of 3.01 ± 0.28 kg capita^{-1} day^{-1}, followed by 2.71 ± 0.54 kg capita^{-1} day^{-1} among moderate-income group, and 2.00 ± 0.49 kg capita^{-1} day^{-1} among high-income group. The overall mean consumption across all income group was 2.57 ± 0.61 kg capita^{-1} day^{-1}. The overall mean consumption of 2.57 kg capita^{-1} day^{-1} observed in this study is higher than several comparable findings, such as 2.03 kg capita^{-1} day^{-1} in rural Karnataka (Ranganathan et al., 1993) and approximately 2.10 kg capita^{-1} day^{-1} in rural northern Bangladesh (Ador et al., 2020). The highest daily fuelwood usage on the Teknaf peninsula was 4.20 kg (Ullah, 2017). Because fuelwood moisture content wasn't always taken into account, this study's finding is only an approximation and might not be correct in all cases.

Table 1. Average consumption quantity by the households'

Income Group	Monthly Income (BDT) Average	Fuelwood Quantity Used Average	Fuelwood Quantity Used Average
Low	8748 (±619)	3.01 (±0.28)	
Moderate	12339 (±996)	2.71 (±0.54)	2.57 (±0.61)
High	16604 (±811)	2.00 (±0.49)	

The Kruskal–Wallis test confirmed a statistically significant difference in fuelwood consumption among the income groups ($\chi^2 = 33.35$, df = 2, $p < 0.001$). Pairwise Wilcoxon comparisons with Bonferroni correction indicated that high-income group consumed significantly less fuelwood than both moderate- ($p < 0.001$) and low-income group ($p < 0.001$), while the difference between low- and moderate-income group was not statistically significant ($p = 0.061$). As illustrated in Figure 2, low-income households displayed the highest median and narrow variation, indicating a consistent reliance on fuelwood across families within this group. In contrast, the moderate-income group showed a slightly wider spread, suggesting a gradual shift toward mixed energy use, while the high-income group exhibited the lowest consumption and the widest variation, reflecting greater access to modern fuels such as LPG and electricity. Similar methodological approaches were adopted by Akther et al. (2010), Hassan et al. (2012), and Alam et al. (2019), confirming that household income is a dominant determinant of fuelwood consumption.

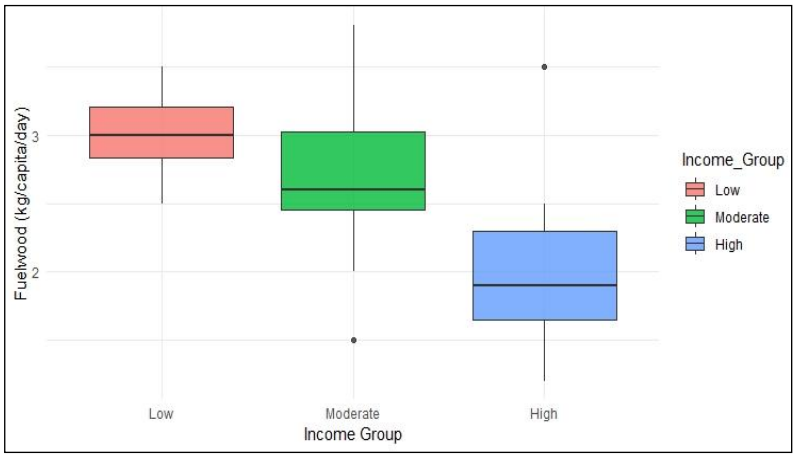


Figure 2. Fuelwood consumption across income groups

3.2 Types of fuelwoods used

Respondents reported the use of various biomass materials, mainly tree stems and branches, for household energy needs, which was also reported by Jashimuddin et al. (2006), Asaduzzaman et al. (2010), and Miah et al. (2010). Income level strongly influenced the type of fuelwood consumed. Low-income group primarily relied on branches (69.92 ± 1.33%) rather than stems (30.08 ± 1.33%), while high-income households used a greater proportion of stems (70.41 ± 1.37%) compared to branches (29.59 ± 1.37%) (Table 2). Moderate-income group showed a balanced pattern, with stems (49.13 ± 1.02%) and branches (50.87 ± 1.02%) contributing almost equally to total fuelwood use (Table 2). The current study's findings differ somewhat from those of Miah et al. (2003), which found that low-income households ingested just 2% of stems while high-income households consumed 78%.

A strong positive relationship was observed between monthly household income and the proportion of stems used ($R^2 = 0.84$) (Figure 3), while a negative relationship was found for branches ($R^2 = 0.84$) (Figure 4). This indicates that households with higher income tend to use a greater share of stemwood, reflecting their better access to purchased or higher-quality fuelwood sources. Kruskal–Wallis tests indicated significant differences among income groups for both stem ($\chi^2 = 59.89$, df = 2, $p < 0.001$) and branch use ($\chi^2 = 59.89$, df = 2, $p < 0.001$) (Table 2). Pairwise comparisons revealed that all income groups differed significantly ($p < 0.001$), implying that as income rises, households shift from lower-quality, easily accessible branches to stems.

These findings align with those of Jashimuddin et al. (2006), Asaduzzaman et al. (2010), and Miah et al. (2003), who noted that wealthier households tend to use stemwood due to affordability and access to purchased fuelwood, while poorer households depend mainly on branchwood collected from nearby forests and homesteads. Stems are denser and provide higher energy per unit, making them more efficient, but their collection is often restricted, compelling low-income households to rely on smaller branches or residues (Chowdhury et al., 2013). The mixed use of stems and branches among moderate-income households reflects both market access and resource availability.

Table 2. Percentage contribution (mean ± SE) of different fuelwood types (Stems and Branches) across income groups and Kruskal–Wallis test results

Variable	Income Group	Mean ± SE (%)	χ^2	p-value
Stems	Low	30.08 ± 1.33	59.89	<0.001*
	Moderate	49.13 ± 1.02		
	High	70.41 ± 1.37		
Branches	Low	69.92 ± 1.33	59.89	<0.001*
	Moderate	50.87 ± 1.02		
	High	29.59 ± 1.37		

Note: Values are presented as mean ± standard error. Significant differences ($p < 0.05$) were found among all income groups (Bonferroni-adjusted Wilcoxon test).

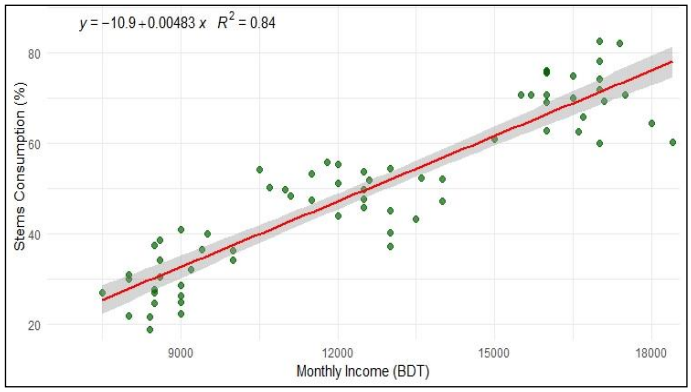


Figure 3. Relationship between monthly income and stems consumption



Figure 4. Relationship between monthly income and branches consumption

3.3 Sources of fuelwood

Fuelwood was obtained mainly from three sources: forests, markets, and homesteads. The relative contribution of sources varied significantly with household income. Kruskal–Wallis tests confirmed significant differences among income groups for all sources of fuelwood (forest: $\chi^2 = 60.46$, $df = 2$, $p < 0.001$; market: $\chi^2 = 60.12$, $df = 2$, $p < 0.001$; homestead: $\chi^2 = 44.79$, $df = 2$, $p < 0.001$) (Table 4). Pairwise Wilcoxon tests showed that forest and market dependency varied significantly across all income categories, while homestead sourcing differed mainly between low- and high-income households. Low-income households relied predominantly on forest sources (71.8 ± 3.88 %), with limited dependence

on markets (11.5 ± 2.87 %) and homesteads (16.6 ± 3.66 %). Moderate-income households collected 39.2 ± 3.55 % from forests, 33.4 ± 3.77 % from markets, and 27.6 ± 3.67 % from homesteads. High-income households sourced the least from forests (23.1 ± 3.46 %) but relied more heavily on markets (47.0 ± 3.54 %) and homesteads (29.9 ± 3.48 %) (Table 4). The boxplot (Figure X) visually supports these statistical results, with distinct letter groupings indicating significant differences among income categories.

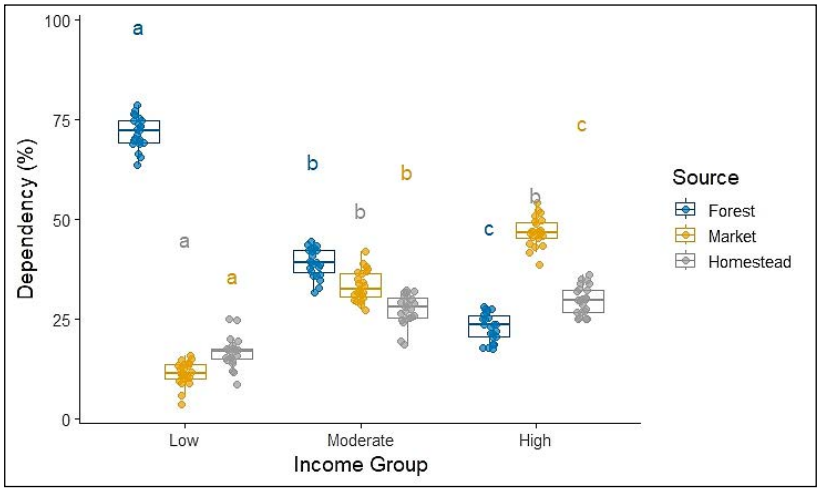


Figure 5. Fuelwood Source Composition by income group

The overall pattern of forest (44.7%), market (30.5%), and homestead (24.8%) (Calculated from Table 3) contributions resembles the findings of Ador et al. (2020) from northern Bangladesh, indicating a progressive shift from direct forest extraction toward purchased fuelwood as income increases. The decline in forest dependency among higher-income households may reflect both improved purchasing power and compliance with forest-use restrictions. The growing reliance on market-purchased wood suggests an emerging informal trade in fuelwood within local communities. This pattern indicates a clear shift from forest dependency toward market and homestead sources as household income increases, reflecting changes in accessibility and purchasing power.

Table 3. Sources (%) of fuelwood used by the households

Variable	Income Group	Mean ± SE	χ^2	df	p-value	Significance
Forest source (%)	Low	71.8 ± 3.88	60.46	2	<0.001	***
	Moderate	39.2 ± 3.55				
	High	23.1 ± 3.46				
Market source (%)	Low	11.5 ± 2.87	60.12	2	<0.001	***
	Moderate	33.4 ± 3.77				
	High	47.0 ± 3.54				
Homestead source (%)	Low	16.6 ± 3.66	44.79	2	<0.001	***
	Moderate	27.6 ± 3.67				
	High	29.9 ± 3.48				

Note: Results are based on Kruskal–Wallis rank sum tests (non-parametric). ***p < 0.001 indicates highly significant differences among income groups.

3.4 Fuel Collectors

Men represented 56% of the total fuelwood collectors, followed by women (32%) and children (12%) (Figure 6). The gendered pattern of collection observed here is consistent with findings from Miah et al. (2003) and Alam et al. (2019). The physically demanding and time-intensive nature of forest collection makes it a male-dominated task, while homestead collection and processing of smaller branches are typically handled by women and children. Men primarily collected fuelwood from forests and markets, while women and children collected smaller quantities from homestead areas and nearby surroundings. Distance to collection sites was also considered an indicator of resource availability in the study area. This division of labor highlights the socio-cultural dynamics of household energy acquisition in rural Bangladesh.

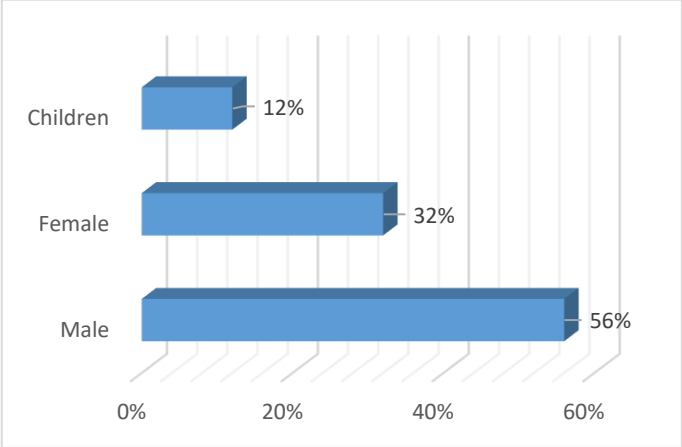


Figure 6. Collectors of the fuelwood

3.5 Drivers of the fuelwood consumption pattern

The relationship between household characteristics and per capita fuelwood consumption was examined using both bivariate and multivariate analyses. Fuelwood consumption showed a strong negative correlation with monthly income ($\rho = -0.61$) and a positive correlation with household size ($\rho = 0.54$) (Figure 7)**.** The strong negative relationship with income and positive association with household size are consistent with Miah et al. (2003) and Alam et al. (2019). Similarly, fuelwood consumption was positively associated with forest dependency ($\rho = 0.67$) and negatively associated with market dependency ($\rho = -0.67$)**,** suggesting that low-income households with larger families relied more on forest sources for meeting their energy needs.

The Kruskal–Wallis test confirmed a significant difference in fuelwood consumption among income groups ($\chi^2 = 33.35$, $df = 2$, $p < 0.001$). Pairwise Wilcoxon comparisons showed that low-income households consumed significantly more fuelwood than both moderate ($p = 0.00015$) and high-income groups ($p < 0.001$), while the difference between moderate and high groups was less pronounced ($p = 0.0609$).

Education level also had a significant effect on fuelwood consumption ($\chi^2 = 16.20$, $df = 3$, $p = 0.001$). Post-hoc analysis showed that households with no formal education consumed more fuelwood than those with primary education ($p = 0.00044$), whereas higher education levels

did not differ significantly from the secondary or primary groups. These findings indicate that education contributes to awareness and adoption of alternative energy sources.

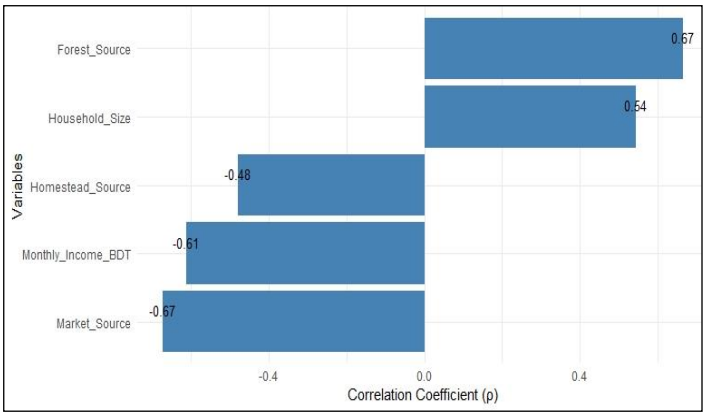


Figure 7. Spearman correlation of fulwood consumption with key variables

A multiple linear regression model was constructed to assess the combined effects of socioeconomic and source-related variables on per capita fuelwood consumption. The model explained approximately 72% of the total variation in consumption ($R^2 = 0.72$, Adjusted $R^2 = 0.67$, $p < 0.001$) (Table 4). Among the predictors, household size ($\beta = 0.183$, $p < 0.001$), income group ($\beta = 0.95–2.00$, $p < 0.05$), and to some extent forest, market, and homestead sources ($p \approx 0.08–0.10$) had notable influences. Households with larger family sizes and lower incomes tended to consume higher amounts of fuelwood. Education level, monthly income alone, and age of household head were not statistically significant in the model, suggesting that consumption behavior is shaped more by access to energy sources and family size rather than individual education or income alone.

In sum, these results indicate that socioeconomic status and household composition play dominant roles in determining fuelwood dependency, while access to different sources (forest, market, homestead) further shapes consumption patterns.

Table 4. Drivers affecting household fuelwood consumption

Predictor	Estimate (β)	Std. Error	t value	Significance
(Intercept)	-24.52	13.98	-1.75	0.084
Monthly Income (BDT)	0.000070	0.000055	1.28	0.206
Household Size	0.183	0.044	4.21	<0.001 ***
Income Group (Low)	2.000	0.831	2.41	0.019 *
Income Group (Moderate)	0.950	0.356	2.67	0.010 **
Education Level (None)	-0.071	0.143	-0.50	0.620
Education Level (Primary)	0.291	0.152	1.92	0.060
Education Level (Secondary)	0.149	0.160	0.93	0.356
Forest Source (%)	0.235	0.141	1.67	0.100
Market Source (%)	0.248	0.140	1.77	0.082
Homestead Source (%)	0.249	0.139	1.80	0.078

3.6 Species preferences for fuelwood

A total of 19 tree species were identified as commonly used for fuelwood in the study area. Species preference scores ranged from 1 - 10, where higher values indicated greater preference (scores near 9). The most preferred species included Acacia auriculiformis, Albizia saman, Swietenia macrophylla, and Syzygium spp. Native species accounted for approximately 78% of total use, while exotic plantation species comprised about 22%, mainly from degraded areas restored by the Forest Department.

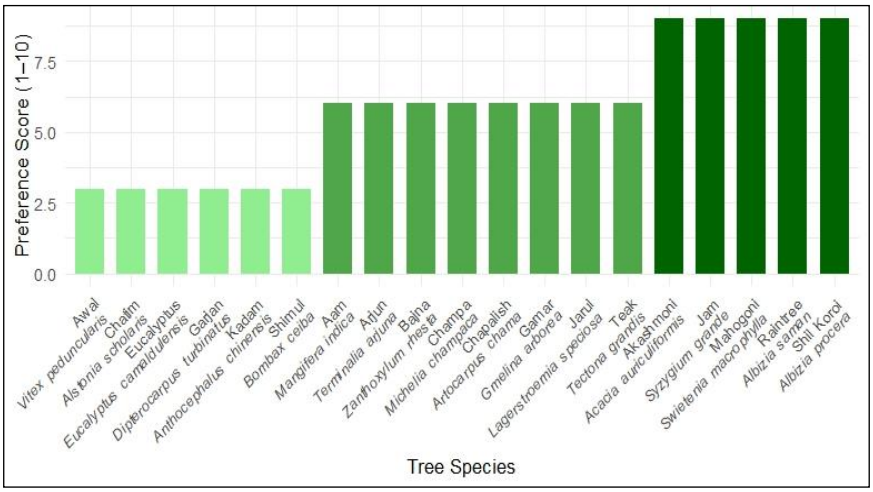


Figure 8. Preference level of tree species for fuelwood

The preference for specific species can be attributed to factors such as burning efficiency, ease of splitting, low smoke production, and local availability. Species such as Acacia auriculiformis and Albizia saman are fast-growing and widely planted by both households and the Forest Department, ensuring consistent supply. Similar preferences were reported by Chowdhury et al. (2013) and Alam et al. (2019) in nearby forest areas, reflecting local adaptation and continuity in species selection.

4. Conclusion

Finally, this study makes one thing clear: households' living around Rema-Kalenga Wildlife Sanctuary (RKWS) still rely heavily on fuelwood, and their economic status shapes almost every part of that dependency. Every household uses fuelwood more or less, but in different pattern. Low-income households use the most, depend largely on forest branches, and have very few realistic alternatives. As income rises, households' go for less fuelwood and shift toward purchased stemwood from local markets or from homestead sources. The pattern forms a steady gradient; those with the least money lean most on the forest because it's the only feasible option they can afford. The statistical results back this up. Fuelwood use falls as income increases and rises with household size. Forest dependency strongly predicts higher consumption. Species choices also reflect a mix of practicality and availability, with fast-growing species like *Acacia auriculiformis*, *Albizia saman*, and *Swietenia macrophylla* topping the list.

In together, the findings show that the pressure on RKWS is driven less by preference and more by necessity. If conservation goals are going to hold, the communities who rely on

these forests need alternative energy options and better support. Expanding access to affordable clean fuels, encouraging small-scale woodlot planting, and effective community-based management could ease the pressure on the forest while improving households' well-being.

Thanks and Information Note

This research complies with all national and international standards for research and publication ethics. Ethics Committee approval was not required, as the study did not involve human or animal experiments.

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Conflict of Interest: The authors declare no conflict of interest.

Authors Contribution: Shahruk Khan Himu (SKH) and Md. Saifuzzaman Bhuiyan (MSB) conceptualized and designed the study. SKH did formal analysis and wrote orginal draft. MSB supervised the study through contributing comments, reviews and edits on the manuscript.

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Monumental Religious Buildings from an Environmental Impact Perspective: The case of Anatolian Seljuk Mosques in Konya

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Abstract

Creating an inventory of monumental mosques, valuable elements of religious and cultural architectural heritage, is crucial for the preservation of cultural heritage. Understanding the design principles and environmental impacts of monumental mosques is also important for designers. In this context, this study investigates the life cycle environmental impacts of monumental mosques constructed in Konya during the Anatolian Seljuk period. Monumental religious buildings are systematically examined within the framework of life cycle assessment, an environmental management tool. The study area is Konya, which has hosted numerous civilizations throughout its history. The architectural design properties of the mosques are documented, and the relationship between their design properties and their life cycle environmental impact is evaluated. The findings demonstrate that monumental mosques, with their traditional construction techniques and design features, are of great importance in terms of environmental impact.

Keywords: *Monumental mosques, environmental impact, life cycle assessment, Anatolian Seljuk Period.*

1. Introduction

Monumental mosques have great importance in terms of religious and cultural architectural heritage. Creating an inventory of these buildings is important for the protection of cultural heritage. At the same time, understanding the design principles of monumental mosques and their environmental impacts throughout their life cycles is inspiring for designers today. In this respect, this study investigates the environmental impact of monumental mosques built in Konya during the Anatolian Seljuk period. Monumental religious buildings are examined in terms of their environmental impacts through life cycle assessment, a tool for environmental management. Life cycle assessment is a powerful environmental management tool that can be used to analyze the impacts of buildings on the environment in an integrated and systematic manner (Fay & Treolar, 2003; Cabeza et al., 2014; Simonen et al., 2017; Su et al., 2017; Zuo et al., 2017; Azari & Abbasabadi, 2018).

Mosque architecture is a significant factor in determining the overall experience of worshippers in a mosque. Studies emphasize the importance of considering both the technical and sustainability aspects of mosque architecture (Abed Yahya & Samad, 2015; Azmi & Kandar, 2019; Mat Sobri et al., 2021). It is important to provide interior comfort in mosques using sustainable methods and to evaluate architectural design properties in light of environmental sustainability. In this context, the design of a sustainable mosque should carefully examine environmental strategies that ensure optimal resource utilization.

Konya has been one of the most important centers of Turkish-Islamic culture and art in Anatolia throughout its history. The city has preserved its importance for many years as the capital of the Anatolian Seljuk Civilization and as it is one of the important state centers of the Ottoman Empire. In this respect, in this study, monumental mosques built in the Anatolian Seljuk Period in Konya are handled. Architectural design properties of monumental and historical mosques are evaluated within the framework of the life cycle assessment.

2. Materials and Methods

In the study, firstly, Life Cycle Assessment systematics is defined, and the relationship between LCA systematics and monumental historical buildings is explained. In the study, data from the Scientific Research Project (BAP) titled "Research on the Comfort Parameters and Energy Efficiency of the Monumental Architectural Heritage, Seljuk-Ottoman Period" was completed at Mimar Sinan Fine Arts University. Architectural design properties of the Monumental Mosques of the Anatolian Seljuk Period are systematically explained in light of the data within the scope of the scientific research project. The architectural design properties of monumental mosques are systematically explained. Anatolian Seljuk Mosques are analyzed in line with life cycle environmental impact parameters, and evaluations are explained

3. Findings and Discussion

Life Cycle Assessment Principles and System Boundaries defined in EN 15978:2011 (European Committee for Standardization, 2011) are shown in Table 1.

Table 1. Life Cycle Assessment Principles and System Boundaries in EN 15978:2011 (European Committee for Standardization, 2011)

Production Stage	Construction Stage	Use Stage	End-of-Life Stage	Benefits and Loads Beyond the System
A1: Raw Materials Supply	A4: Construction-installation	B1: Use	C1: Deconstruction, demolition	Reuse
A2: Transport	A5: Transport	B2: Manufacturing	C2: Transport	Recovery
A3: Manufacturing		B3: Repair	C3: Waste process for reuse	Recycling Potential
		B4: Replacement	C4: Disposal	
		B5: Refurbishment		
		B6: Operational energy use		
		B7: Operational water use		

The Şems Tebrizi Mosque, built in Konya during the Anatolian Seljuk Period, is included in the scope of the study. The Şems Tebrizi Mosque is located in the central Karatay district of Konya. The building, which dates back to the 13th century, was built using the masonry technique. Images of the Şems Tebrizi Mosque are shown in Figure 1, and the architectural design properties of the mosque are systematically explained in Table 2.

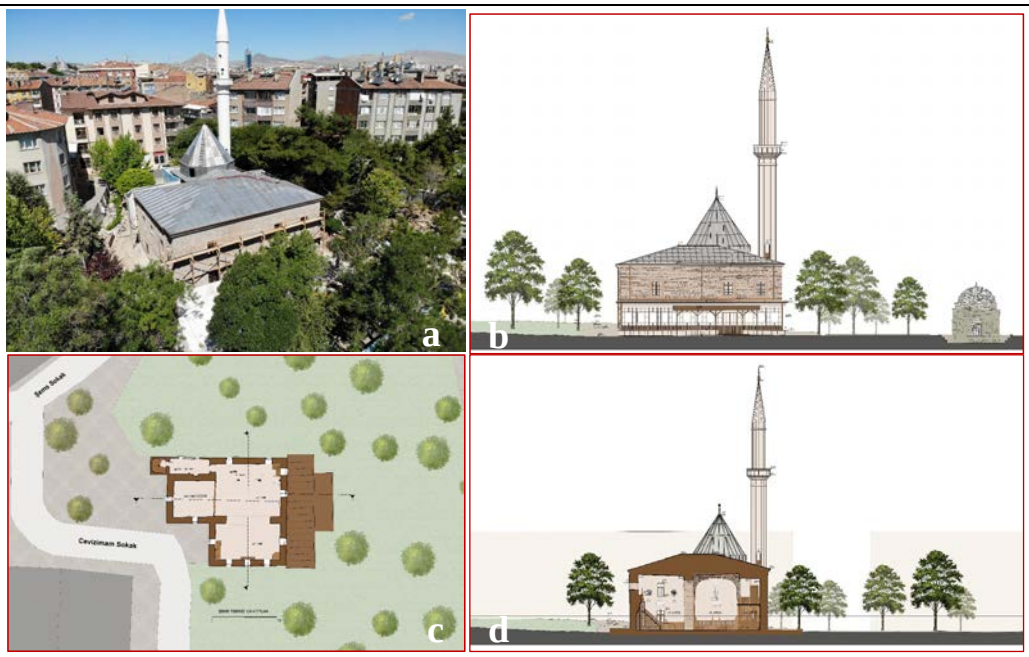


Figure 1. a) Şems Tebrizi Mosque, b) The Mosque's Elevation, c) The Mosque's Plan, d) The Mosque's Section (Created by the authors, 2019)

Table 2. Şems Tebrizi Mosque Architectural Design Properties

Period			13th Century, Seljuk Period
Top Cover	Rectangle		
Plan Organization	Three Spaces		
Top Cover	Pitched Roof		
Building Order	Detached Order		
Total Area of Mosque m^2	271 m^2		
Masjid height (h)	12.30 m		
Wall	Bond Technique		Masonry Wall
	Material		Stone
	Openings		Windows ratios are 1/2.
	Wall Thickness		100 cm
	Window-Wall Ratio (%)	South	6.07
		North	4.05
		East	5.43

	West	4.06
Flooring	Material	Wood flooring
Top Cover	Bond Technique	Wooden construction, pitched roof
	Material	Plumbing
	Openings	There are no openings.
	Size (Diameter/Thickness)	*
Minaret	Bond Technique	Masonry
	Material	Cut-stone

In this study, the Şems Tebrizi Mosque is evaluated in terms of operational and embodied loads. Operational loads include operational energy and carbon emissions. The mosque's plan typology and top cover properties are suitable for Konya, which is located in a moderate-dry climate zone. Its detached order is important for operational loads, as it benefits from or protects against solar radiation gain and wind effects. Regarding building materials, the wall material and thickness have thermal mass properties. This property positively affects the building's heating and cooling performance and total energy load. Directional opening ratios are also important factors in terms of energy load.

Embodied loads include the embodied energy and carbon emissions associated with material production, construction, maintenance and repair, and end-of-life phases. The use of local materials in material production is crucial for its lifecycle environmental performance. This mosque building, which has stood for centuries and has not yet reached its end-of-life phase, offers significant environmental advantages in terms of material production, construction modules, and maintenance and repair factors. Furthermore, based on data obtained as part of the scientific research project, it can be clearly stated that monumental Konya mosques are energy-efficient buildings in terms of operational energy values.

As a result, historic and monumental mosques, valuable elements of cultural and architectural heritage, are of great importance in terms of their lifecycle environmental performance. They are environmentally friendly buildings with traditional architectural design properties and serve as inspiration for today's designers. Many parameters, such as the use of local materials, long-lasting materials, and shell designs with thermal mass or high performance, serve as valuable examples.

4. Conclusion and Recommendations

In this study, historical and monumental architectural heritage elements of the Anatolian Seljuk Period Konya mosques are investigated in terms of life cycle environmental sustainability. Traditional architecture has a sustainable design approach that adapts to the environment. Traditional architecture incorporates sustainable features that consider the climate, topography, and natural environment.

The findings show that monumental mosques with their traditional construction techniques and design properties have great importance in terms of environmental impact. The findings

show that traditional mosques have architectural designs, construction techniques and material characteristics that adapt to the climate and environment.

Traditional buildings, with their unique and valuable features, can serve as a reference for today's architecture and help modern buildings survive for a long time. Traditional architectural methods can offer creative solutions and provide answers to today's energy challenges. Considering that mosques today are constructed of reinforced concrete, this study can be said to shed light on this issue for designers. Furthermore, while research on this topic is limited, it is also a valuable contribution to the literature.

Thanks and Information Note

The article complies with national and international research and publication ethics. Ethics Committee approval was not required for the study.

In the study, data from the Scientific Research Project (BAP) titled “Research on the Comfort Parameters and Energy Efficiency of the Monumental Architectural Heritage, Seljuk-Ottoman Period” completed at Mimar Sinan Fine Arts University, led by Prof. Dr. Ümit ARPACIOĞLU, are used.

All authors contributed equally to the article. There is no conflict of interest.

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Preservation of Cultural Heritage and Promotion of Tourism in the Demre Region: An Overwiev of Physical Renovation Projects from a Single Transformation Example

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Abstract

This study aims to evaluate the conservation of cultural heritage in the Demre region and its integration into tourism through the relationship between single-building transformations and physical renewal projects. In the city center, the gradual thinning of architectural heritage at the building scale and the limited continuity of the residential fabric make it necessary to construct a conservation strategy not around an 'extensive urban fabric,' but around a small number of buildings and focal points. Methodologically, a literature review was conducted alongside a descriptive analysis of photographs from selected field cases, and a thematic evaluation was carried out under the headings of single-building transformation, physical renewal, and tourism impact.

The findings indicate that tourism impact concentrates around strong attraction nodes such as the Myra Archaeological Site and the Church of St. Nicholas. In contrast, the limited heritage stock in the city center, including houses that continue their residential function after renewal, the Bayraktar Mansion, a house in the bazaar area, and an underused house near Santa Claus Square, remains insufficiently integrated into the visitor experience. Although renewal and adaptive reuse at the residential scale are observed, the qualitative threshold of interventions and the continuity of use constitute a critical area of discussion.

By proposing a layered 'heritage network' that links visitor flows to ancient and religious heritage nodes with the city center and nearby traditional settlements, the study offers an applicable framework that strengthens sustainable tourism and cultural heritage management together through physical renewal instruments such as pedestrian connections, wayfinding, and public-space improvements.

Keywords: Demre, cultural heritage, single-building transformation, physical renewal, sustainable tourism

Introduction

Cultural heritage is among the most fundamental values that sustain societies' identity, sense of belonging, and historical continuity. It also plays a decisive role in the formation of collective consciousness. In this context, the conservation of cultural heritage has today become a major field of debate at both national and international levels.

At the current point reached by conservation thinking, the scope of what requires protection has expanded beyond buildings to include the broader set of values and meanings as well (Değirmenci and Köşklük Kaya, 2020). Dynamics such as globalization, urbanization, tourism, and economic pressures make it necessary to develop new approaches and strategies for safeguarding cultural heritage (Ertürk, 2020). For this reason, the place of cultural heritage within contemporary conservation debates emerges as a multidimensional issue that must be addressed within the principles of sustainability and participatory governance. Sustainable tourism approaches refer to a holistic planning and management perspective aimed at balancing tourism's environmental, economic, and socio-cultural impacts.

In cultural heritage conservation, sustainability is one of the main headings of current discussions. Sustainable cultural heritage management aims to maintain, over the long term, the relationship between cultural heritage, society, and the environment (Öksüz Kuşçuoğlu

and Taş, 2017). In this process, local governments assume an important role as the first competent authorities responsible for the protection of historical and cultural assets in their regions (Basmacı, 2017). The participation and support of local residents are critical to the implementation of sustainable tourism approaches.

The relationship between tourism, conservation, and local development occupies a central position in today's debates on sustainable development. Tourism's role in local development is not limited to economic returns; through its social, cultural, and environmental effects, it directly influences local communities' quality of life and identity. Studies show that, alongside stimulating the local economy, tourism also has a transformative impact on social and cultural structures (Kılıçoğlu and Yıldız, 2018).

Cultural tourism, by valorizing cultural and historical assets through tourism, both generates economic input and contributes to the conservation and visibility of cultural heritage (Davutoğlu and Erol, 2023). However, unplanned and intensive tourism activities bring risks such as excessive commercialization, detachment from context, and loss of authenticity (Soylu and Şahin, 2023; Alpan and Danışık, 2024). Therefore, the tourism–conservation–local development relationship needs to be addressed through a holistic approach aligned with sustainability principles. The success of sustainable tourism policies is directly associated with inter-stakeholder cooperation, a participatory governance approach, and attention to carrying capacity (Varol, 2020).

The conservation of cultural heritage is a multidimensional process shaped by sustainability, participatory governance, the role of local governments, and the impacts of tourism. The balance between safeguarding cultural and natural heritage and supporting local development can be achieved by viewing tourism not as an end in itself but as a planned, holistic tool. This general framework makes it necessary, in destinations such as Demre with multi-layered heritage values, to re-establish the conservation–use balance through spatial instruments.

In Demre, the gradual thinning of architectural heritage at the building scale within the city and the limited continuity of a residential fabric mean that strategies for conservation and integration into tourism should be formulated not through an 'area-wide, extensive fabric,' but through the limited number of remaining buildings and focal points. Within this framework, the Myra Ancient City and the Church of St. Nicholas (Santa Claus) in Demre, which form the area's strong heritage cores, are approached not only as standalone visitor sites but also as the backbone of a 'layered heritage route' together with the city's limited number of Ottoman-period buildings and adaptive-reuse examples that raise qualitative concerns. The research positions single-building transformation not as a preference but as a necessary strategy in a context where architectural continuity has weakened, and it seeks answers to the following questions: How can a single-building transformation approach spread the strong attraction power generated by Myra and the Church of St. Nicholas into the urban fabric? How can Ottoman traces, although few in number yet high in representational value, be turned into meaningful stops through high-quality adaptive reuse? And how can physical renewal projects strengthen sustainable tourism by linking these focal points through pedestrian connections, wayfinding and interpretation elements, public-space improvements, and carrying-capacity management? In doing so, the risk of 'over-concentration at a single point' in Demre is reduced; the visitor experience is diversified; cultural layers become more legible; and the limited building stock is transformed, through well-designed single-building

transformations, into a conservation–tourism network whose impact expands at the urban scale.

2. Conceptual and Theoretical Framework

2.1. The Concepts of Cultural Heritage and the Historic Environment

The concepts of cultural heritage and the historic environment are today addressed through an interdisciplinary approach and are among the fundamental elements that shape societies' identity, sense of belonging, and historical continuity. The concept of cultural heritage is not limited solely to tangible assets that bear traces of the past; it also encompasses knowledge, skills, traditions, customs, and rituals embedded in social memory and transmitted from generation to generation (Lenzerini, 2011). The historic environment refers to the areas where this heritage becomes tangible on a spatial plane and where traces of the past are integrated into contemporary life.

The scope of the cultural heritage concept has expanded over time in parallel with changing conservation approaches. Particularly with the rise of conservation awareness in the twentieth century, it has been acknowledged that cultural heritage is not confined to buildings alone but also includes a broader set of values and meanings (Değirmenci and Köşklük Kaya, 2020). UNESCO's 1972 Convention Concerning the Protection of the World Cultural and Natural Heritage and the 2003 Convention for the Safeguarding of the Intangible Cultural Heritage represent major turning points in framing cultural heritage as a whole related to social memory and identity beyond structural elements (Değirmenci and Köşklük Kaya, 2020).

Today, the conservation and sustainability of cultural heritage are evaluated not merely as a technical matter but as a holistic management process addressed through social, economic, and environmental dimensions. The cultural heritage management approach aims to consider and implement all phases of historic environment conservation within an overall management process. In this context, it is emphasized that conservation principles should be prioritized, and that site-specific research and analysis models, along with parameters such as budget, feasibility, and effectiveness, are decisive (Altınörs Çırak, 2021).

The concept of sustainability in cultural heritage conservation aims to ensure the continuity of the relationship between cultural heritage, society, and the environment not only for the present but also for future generations. In this direction, participatory approaches seek to integrate cultural heritage with social life, contribute to economic and social development, and protect the integrity of heritage value throughout use processes (Öksüz Kuşçuoğlu and Taş, 2017).

2.2. The Concepts of Single-Building Transformation and Adaptive Reuse

The concept of transformation is often addressed in different disciplines primarily at collective and macro scales. However, processes of change that occur at an individual, object-specific, or micro scale are handled under the concept of single-building transformation, offering a distinct analytical framework. Studies in the literature on urbanization and urban transformation show that transformation is generally evaluated through social, environmental, and economic dimensions, while the effects at the scale of a single parcel or building often remain in the background (Kartal and Kartal, 2020; Tekedar and Polat, 2020).

Single-building transformation is particularly important in historic environments for analyzing how building-scale interventions affect spatial integrity and cultural continuity. In

this regard, adaptive reuse and adaptable reuse approaches stand out as one of the most prominent fields of application for single-building transformation.

Adaptive reuse refers to a building acquiring a new function after losing its original one, while preserving its existing physical and cultural values. This approach is identified as a key strategy for integrating historic buildings into contemporary urban life and ensuring cultural continuity (Özçakır, 2023; Zaarir et al., 2025). Adaptable reuse, within the framework of sustainability, aims to adapt buildings to contemporary uses while conserving architectural, economic, social, and cultural values (Kapoor and Yadav, 2024). In Türkiye, the adaptive reuse of historic buildings for functions such as museums, cultural facilities, or public use contributes both to the preservation of architectural fabric and to urban and cultural life (Selimoğlu and Halaç, 2023; Engin, 2024).

In the adaptive reuse process, the selection of the new function, the compatibility of spatial interventions with the original structure, and their reversibility are critical to preserving the building's identity (Korkut and Erarslan, 2020). In addition, energy efficiency and environmental sustainability criteria are considered important for the long-term viability of the contemporary use of adaptively reused historic buildings (Balçık and Yamaçlı, 2022).

Single-building transformation and adaptive reuse approaches constitute the core theoretical framework that enables building-scale interventions in historic environments to be evaluated within the context of sustainability, cultural continuity, and spatial integrity.

3. Materials and Method

3.1. Method

This research is a qualitative, descriptive, and interpretive study that evaluates the conservation of cultural heritage in the Demre region and its integration into tourism through the axes of "single-building transformation" and "physical renewal." The study does not employ quantitative measurement, surveys, or interviews; instead, the evaluation is structured around a literature review and a photograph-based spatial reading.

3.1.1. Research Design

The research follows a two-layer design. In the first layer, a theoretical framework is established around conservation, sustainable tourism, cultural heritage management, adaptive reuse, and single-building transformation. In the second layer, heritage nodes and settlement fragments in Demre are read through photographs, and the current condition, transformation practices, and physical renewal needs are assessed. In this way, "general theory" and "local spatial conditions" are addressed within a single framework through the following components:

- **Literature sources:** Secondary sources such as academic publications, theses, research reports, and legislation-based references.
- **Photographs:** Photographic records that make heritage nodes in Demre and their immediate surroundings visible. The photographs are approached through a logic of "core zone, transition zone, and urban link," in order to capture the relationship between the building scale and the environmental context.

3.1.2. Data Analysis and Evaluation Framework

The literature review is conducted thematically in order to define the study's conceptual keywords and evaluation criteria. Photographs are assessed by classifying frames that make the spatial condition legible, including the physical condition of buildings, patterns of use, and the state of the surrounding environment.

The data are analyzed using a descriptive analysis approach. By matching themes derived from the literature with findings read from the photographs, three main lines of inquiry are established:

1. **Reading single-building transformation:** The qualitative level of building-scale interventions (adaptive reuse, small-scale repair or improvement, change of use) and their impact on the surroundings.
2. **Reading physical renewal:** The spatial performance of the area's relationship with tourism, assessed through pedestrian continuity, public-space quality, environmental arrangement, wayfinding and interpretation, and traces of basic infrastructure.
3. **Reading tourism impact:** How strong attraction nodes (for example, ancient and religious heritage sites) and the limited architectural traces within the city together produce an experience, and the spatial indicators of the risk of "over-concentration at a single point."

3.2. Materials

3.2.1. Demre's Historical and Cultural Structure

Demre is a district in Türkiye's Mediterranean Region, located in the west of Antalya Province, and stands out with its multi-layered historical and cultural heritage. Its integrated character, shaped by ancient cities, religious buildings, traditional ways of life, and the natural environment, places Demre in a distinctive position within Anatolia's cultural heritage geography.

Demre's historical development can be read through the ancient city of Myra. As one of the important settlements of the Lycian civilization, Myra constitutes a core component of the region's archaeological heritage. In addition, the Church of St. Nicholas is one of Demre's internationally recognized religious and cultural heritage sites and functions as an important center in the history of Christianity (Fındık, 2015). These sites demonstrate that Demre contains not only local but also universal cultural values.

Demre's cultural structure is not limited to archaeological heritage; it also exhibits an integrated character with the region's natural environment and economic activities. In particular, greenhouse agriculture, as one of the main elements of the local economy, influences traditional ways of life and spatial organization. The use of natural resources and environmental conditions plays a decisive role in shaping Demre's socio-cultural structure (Avcı et al., 2019).

Elements of intangible cultural heritage also occupy an important place in Demre's cultural identity. Local language and dialect features have been preserved due to the area's geography and relatively limited external migration. This linguistic continuity makes the intangible dimension of Demre's historical and cultural continuity visible (Bölük, 2022).

Demre's natural and cultural values also shape its tourism potential. In addition to sea-sand-sun tourism, cultural and natural routes such as the Lycian Way make Demre attractive in terms of alternative forms of tourism. This potential, jointly offered by the natural environment and cultural heritage, contributes to Demre's economic and social sustainability (Zayım et al., 2022). Demre has a multidimensional cultural structure through its ancient cities, religious buildings, traditional production practices, linguistic features, and natural environment. This holistic structure makes the protection and sustainable valorization of Demre a necessity in terms of local development policies.

3.2.2. The Relationship Between Tourism and Settlement in Demre

Demre is a distinctive geography where ancient areas, traditional settlements, and a rural-spatial structure coexist. This settlement fabric carries traces of different civilizations through historical processes and is currently undergoing transformation under the influence of tourism. This relationship between tourism and settlement requires a holistic assessment, especially in terms of the conservation–use balance.

Rural areas that developed around ancient and traditional settlements in Demre historically displayed an integrated structure with modes of production and living. It is emphasized that ancient settlements evolved through spatial and economic interaction with surrounding rural areas, and that this condition determined settlement continuity (Aydınoğlu, 2020; Aydınoğlu, 2021). Today, however, this holistic structure has entered a process of transformation under the spatial pressures created by tourism.

Linking traditional settlement areas with tourism offers significant potential for making cultural heritage visible and supporting local economic dynamism. It is noted that integrating traditional settlements into tourism while conserving their architectural and environmental values contributes to socio-economic sustainability (Akyıldız et al., 2020). Conversely, unplanned and identity-less construction stands out as one of the major problems threatening traditional settlement fabric.

The conservation of rural settlements is important not only in terms of architectural values but also for the sustainability of local ways of life. Studies conducted across Türkiye show that traditional rural houses are compatible with local materials and production methods, whereas contemporary unplanned construction damages this authenticity. Therefore, inventory studies and holistic approaches are necessary for the conservation of rural settlements (Öztürk and Akın, 2025). In this context, rural tourism can be considered a strategic tool for strengthening the tourism–settlement relationship in Demre in a sustainable manner. It is stated that rural tourism creates income and employment opportunities for local people and contributes to the conservation of traditional settlements (Civelek et al., 2014). Planning this process in line with sustainability principles by local governments is important for managing the tourism–settlement relationship in a balanced way (Güven and Dülger, 2016).

4. Findings and Discussion

4.1. The Need for Building-Scale Conservation and Renewal in Demre

Demre is an important destination exposed to intense tourism pressure due to its natural and cultural heritage values. Ancient cities, religious buildings, and natural landscape areas place Demre at the forefront of cultural tourism. However, this rich heritage faces multidimensional problems such as physical deterioration, loss of function, and uncontrolled tourism pressure.

Within this framework, it is important to interpret “tourism pressure” not only through visitor numbers, but also through traces of wear in space and patterns of concentrated use.

Physical deterioration is one of the main problems threatening the integrity of historic structures in Demre. The corrosive effects of time, natural conditions, and human interventions may cause historic buildings to lose their original qualities. This makes it necessary to address conservation and renewal efforts in a systematic and holistic manner.

Loss of function is a secondary problem observed in a significant portion of historic buildings in Demre. The adaptive reuse approach aims to refunction historic buildings in line with contemporary needs, thereby ensuring both their conservation and their economic sustainability (Zaarir et al., 2025). At this point, many buildings in Demre remain underused. Some of them have undergone functional change largely for accommodation purposes by the property owners. This approach provides a theoretical ground that frames the condition of transformation practices to be implemented at the scale of single buildings in Demre.

Tourism pressure, particularly during certain periods, leads to overuse and spatial wear in Demre. Unplanned tourism activities can produce negative impacts on both natural areas and cultural heritage. Therefore, sustainable tourism management and site conservation strategies need to be developed. The presence of alternative tourism types such as the Lycian Way, camping, and caravan tourism offers significant potential for Demre, yet this potential must be planned within sustainability principles (Zayım et al., 2022). Accordingly, the problem in Demre is not the existence of tourism itself; rather, it is the concentration of visitor flows at a limited number of focal points and the weakness of the relationship between this concentration and the city’s limited heritage traces.

In conservation and renewal processes, the participation of local residents is a decisive factor. Studies show that involving local communities strengthens awareness of cultural heritage conservation and supports sustainable tourism practices (Nguyen, 2025). In Demre as well, the success of conservation and renewal policies is directly related to the active participation of local residents. The need for conservation and renewal in Demre stems from locality-specific problems such as physical deterioration, loss of function, and tourism pressure. In response to these issues, adopting adaptive reuse approaches, developing sustainable tourism management strategies, and including local communities in the process emerge as fundamental necessities.

4.2. Physical Renewal and Single-Building Transformation Practices in Demre

In Demre, tourism impact is shaped through strong attraction nodes. The prominence of the Myra Archaeological Site through its rock-cut tombs, theater, and urban layout; the symbolic status of the Church of St. Nicholas within the context of a sacred pilgrimage route; and other ancient sites such as the Andriake Ancient Harbor, Simena, and Sura together define Demre as a multi-nodal cultural landscape. This attraction indicates that conservation and renewal interventions influence both the visitor experience and the local economy and cultural awareness, within a setting where settlement areas and historic fabrics can contribute directly to tourism.

At the residential scale, physical renewal projects in Demre are carried out largely by property owners. In this context, examples of single-building transformation become visible mainly through building-scale renewal and refunctioning practices. In Demre, single-building transformation appears through the use of former stone houses as boutique hotels or

workshops, and the stages of physical renewal and refunctioning contribute to both the conservation of cultural heritage and its integration into tourism.

One example in this scope involves a dwelling built in the 1950s that was renewed through intra-family stewardship and converted to an accommodation function. Read through an “old state–new state” comparison, it presents a single-building transformation realized in situ, where renewal and improvement interventions on the building envelope can be observed directly (Figure 1).



Figure 1. The Old and New State of Taş Konak (Taş Konak, Demre, 2024)

In the context of adaptive reuse, the Bayraktar Mansion can be considered a single-building transformation example for its location (Figure 2). It is stated that the building was constructed in 1960, is among Demre’s early-period buildings, has been preserved without disrupting its natural character, and was placed under protection by the Ministry of Culture and Tourism in 2014. These data indicate that, in Demre’s center, single buildings constitute a “small but critical” heritage inventory. Therefore, high-quality conservation and refunctioning decisions carry decisive importance for cultural continuity within the city.



Figure 2. Bayraktar Mansion (Bayraktar Mansion, 2022)

Within the residential fabric, two different situations are observed simultaneously. In Demre’s center, in the area referred to as the “bazaar,” there is an example that continues its residential function. In contrast, again in the bazaar area, at Santa Claus Square in a pedestrianized zone, there is also a dwelling that is currently unused (Figure 3). This duality indicates that the single-building transformation agenda should be discussed not only through restoration, but also through “continuity of use” and “function selection”: transforming idle buildings located in pedestrian-priority focal spaces is a strategic tool that can distribute visitor impact into the city rather than concentrating it solely in ancient sites.



Figure 3. Residential Examples in Demre Center (Çetinkaya, 2025)

Rural settlements and single-building transformation examples make Demre's heritage capacity beyond the center visible. Traditional settlements such as Beymelek, Hoyran, and Köşkerler are characterized by features including stone architecture, courtyard plan typologies, and a way of life intertwined with rock-cut tombs.

This suggests that a strategy to strengthen sustainable tourism in Demre should be structured around "starting from single-building transformation examples in the center and supporting nearby rural settlements through holistic conservation and appropriate physical renewal." The emphasis that spatial integrity must be observed in conservation and renewal projects can be read as a key criterion for a renewal logic in Demre that establishes relationships between focal points.

5. Conclusion and Recommendations

This study shows that tourism impact in Demre is shaped primarily through strong attraction nodes and that these nodes, such as the Myra Archaeological Site, the Church of St. Nicholas, the Andriake Ancient Harbor, Simena, and Sura, form a multiple cultural landscape system. By contrast, the limited architectural continuity at the building scale in the city center makes it necessary to formulate conservation and tourism-integration strategies not around an "extensive fabric," but around a small number of urban buildings and public spaces. In this context, physical renewal projects in Demre aim to conserve and integrate historic fabric into tourism through the restoration of historic inns and churches and through street and landscape arrangements, and together with examples of single-building transformation they form the infrastructure of sustainable tourism.

The main approach that can contribute to sustainable tourism and cultural heritage conservation in Demre is to establish a layered "heritage network" that links visitor flows arriving at ancient and religious attraction nodes with the limited heritage examples in the city center, and then with rural traditional settlements in the surrounding area.

Thanks and Information Note

The article complies with national and international research and publication ethics.

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Deployment, Construction, Coordination, and Management of Lookout Towers for the Protection and Monitoring of Protected Areas

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Abstract

Protected areas are a sensitive issue not only for a single country but for all countries and peoples around the world, given their significance for the environment and cultural heritage. In this context, protected areas within a country's borders have consequences for the rights and interests of those directly or indirectly related to that protected area. For this reason, international institutions and organizations such as UNESCO, which are already primarily concerned with this issue on a global scale, carry out legal regulations, activities, and structures for the protection of this heritage.

The deployment and construction of protection towers, their coordination and supervision, based on the characteristics, category, structure of the protected area's geography and topography, and the content of plant and animal ecosystems within the protected areas, is the fundamental key to the effective and efficient execution of the surveillance function. Particularly, considering technological developments worldwide, the separation of these structures and the smart design of their construction equipment will ensure that protected areas are not further physically and aesthetically degraded and that the habitat integrity of flora and fauna structures is preserved. The physical, visual characteristics, and architecture of these structures must be constructed in accordance with the function they will carry.

The study was prepared based on the location, physical structure, and equipment of lookout towers in protected areas in Turkey and around the world. In this context, interviews were conducted with tower management teams, and research was carried out using online sources related to the appearance and functions of the towers to obtain reliable findings. Within this scope, studies in literature were examined, and models were proposed in terms of the types of protected areas, considering the positioning of the towers, the determination of their physical characteristics, the functionality of the structures, and the determination of their architectural and technological features, as well as the effectiveness and efficiency of the monitoring function. Similarly, opportunities for linking observation towers with viewing terraces or enriching and repurposing their functions have been suggested, ensuring that ecological and aesthetic harmony in these areas is not compromised.

Keywords: Land management, sustainable structures, construction management, protected areas, lookout towers.

1. Introduction

Protected areas, in which all people are stakeholders in the context of 'human rights', are a matter that transcends national borders in terms of their security and usage system; therefore, they are not only a problem for that country but for all countries in the world. For this reason,

all processes and actions, from deployment to the operation of structures and facilities, must comply with international standards.

The location and construction of protection towers, their coordination and supervision, and the effective and efficient execution of surveillance functions are key to the protection area's characteristics, category, the structure of its geographical and topographical protection, and the plant and animal ecosystem content within the protected areas.

Particularly, considering technological developments around the world, the separation of these structures and the smart design of their construction equipment will ensure that protected areas are not further damaged physically and aesthetically and that the habitat integrity of flora and fauna structures is preserved. The physical, visual characteristics and architecture of these structures must be constructed in accordance with the function they will perform.

Our work is based on the location, physical structure and facilities of observation towers, which are seen as the rightful partners and obligations of all people around the world, and aims to use them more effectively and efficiently by deploying, functionalizing, restructuring, managing and operating these areas and structures in a way that integrates them with the world.

The process of constructing and repurposing watchtowers and surveillance towers is a multidimensional problem that requires an integrated analysis of strategic, topographical, economic, climatic, and ecological variables, beyond a simple engineering decision (Gonsalves, 2018). In sensitive geographical areas such as protected areas, ecological and strategic factors have the highest priority in determining the vital importance of the project. In the initial Feasibility and Screening Phase, the alignment of strategic objectives with the mission and the visibility efficiency of the topographical location should be considered as ‘veto factors’. Subsequently, economic sustainability and climate resilience guide the Design and Implementation Phases of the project. This hierarchical scoring framework enables the most efficient use of resources and allows the towers to fulfil their intended mission with maximum effectiveness (Amiri et al., 2022; Arid & Rofiq, 2023).



Picture 1: London Eye lookout tower

2. Research Methodology

Our study will be conducted in two stages. The first stage will involve observation, monitoring and assessment (situation analysis), while the second stage will involve drawing conclusions from various types of transport vehicles, camouflage materials, and examples of underground observation or watchtowers, using the findings obtained and the pilot region method, to draw conclusions about observation – observation tower example. Various types of transport vehicles, camouflage materials, oxygen or protective clothing and materials in underground observation or observation towers are used. As our work is a phased study, the continuation of the process is important in terms of the visibility of the work and the effectiveness of its outputs through presentations, articles, reports, press conferences, declarations, and other types of actions and activities.

Interviews were held with the managers of the institutions and organizations responsible for the observation/surveillance towers in the protected areas and with those directly managing and operating the maintenance and operation of the structures. Research was conducted using online sources on the appearance and functions of the towers to obtain reliable findings.

In this context, studies in the literature were examined, and models were proposed in terms of the types of protected areas, considering the positioning of the towers, the determination of their physical characteristics, the functionality of the structures, and the determination of their architectural and technological features, as well as the effectiveness and efficiency of the monitoring function. Similarly, opportunities for linking observation towers with viewing terraces or enriching and repurposing their functions have been suggested, ensuring that ecological and aesthetic harmony in these areas is not compromised.

2.1. Oriented Methodology:

Our research employs the inductive method in examining and identifying system infrastructures, while in the processes of positioning, relocating, and repurposing surveillance areas, the inductive method is used in some cases and the deductive method in others, depending on the basic function of the observation tower and its geographical characteristics in a continental sense.

In terms of the system design and integration of observation and surveillance structures, deductive reasoning is used for database management, while inductive reasoning is used for local hosting.

2.2. Thematic Analyses and Findings

Protected areas have been categorized and/or systematically addressed according to their strategic, climatic, ecological, topography and economic differences. A multi-layered analysis will be conducted to establish a comprehensive and logical framework for a multi-variable and complex decision-making process. Within this scope, each category has been scored using priority and precedence logic, and based on these scores, it has been recommended to either construct new observation towers or repurpose existing ones, either through a swot analysis or based on the results of systematic scoring. In this context, the variability factors presented have been scored as follows.

The suitability of watchtowers in terms of legislation has been taken as the basis for their positioning, repositioning and functionalization. If there are no legal provisions that are not

based on physical structure (e.g., not allowing construction closer than x distance to drinking water dams), the necessary changes can be made to the domestic legal regulations governing the relevant areas. For this, cost-benefit analysis and the concept of Public Interest will come to the fore. This is because sometimes a deployment that may be appropriate in terms of public interest may not be suitable from a physical and climatic perspective. Similarly, even if physical and climatic suitability exists, if species or habitats protected by international legislation (international agreements) are present, it may not be legally feasible to implement the deployment, even if there is no public interest objection.

For the positioning, repositioning and repurposing of observation and surveillance towers, external factor flexibility coefficients (Table 2) have been provided for the ranking, prioritization and precedence scoring to be carried out at national level (Table 1). By overlapping the coefficients of these factors, both prioritization and precedence scoring can be carried out. By measuring the flexibility coefficients of variable factors (Table 3), options related to the relocation, functional increase or decrease of the towers can also be calculated. For example, the positioning and construction of fire observation towers in forested areas is more dependent on topographical factors. (Çoban, & Bereket, 2020) Similarly, observation towers with different functions exhibit varying degrees of flexibility in response to different external variables.

Table 1: Scoring of variables for the construction and repurposing of watchtowers in terms of priority and precedence

Variable Factors	Priority (Level of Importance)	Ratings Justification	Precedence (When Feasibility) Levels	SCORE
Strategic Factors	Mission Alignment, Security Coverage Area, Risk Reduction Potential, Ease of Access (Transportation)	**Highest:** Forms the basis for why the tower exists. Mission success is directly dependent on this factor. (e.g. Does it cover a critical area?)	0,35 (Highest)	1
Topographical Factors	Observation Height, Field of View (No Obstacles), Ground Stability, Slope/Terrain Morphology, Presence of Significant Points in the Surrounding Area	**Highest:** The tower is the physical basis for where and how to observe. Choosing the wrong location can render the tower useless. (e.g. Where is the widest field of view provided?)	0,25 (High)	2
Economic Factors	Construction/Refurbishment Cost, Operating and Maintenance Cost, Financing Sources, Return on Investment (ROI), Contribution to the Local Economy	**Medium-High:** Vital for the project's feasibility and sustainability. Insufficient funding will prevent the project from starting or cause it to be abandoned. (e.g. Is the budget being adhered to?)	0,20 (Medium High)	3

Climatic Factors	Wind Load, Snow Load, Temperature Fluctuations, Humidity Level, Lightning Risk, Fog Frequency	**Medium:** Important for the structure's durability and lifespan. Determines construction costs and risks. (e.g. Will the structure withstand the worst wind load?)	0,10 (Medium)	4
Ecological Factors	Impact on Habitat, Proximity to Sub-zones within Protected Areas, Sustainability of Building Materials, Environmental Planning and Landscape	**Low-Medium:** Important for the project's legal compliance and social responsibility. The requirement not to harm the environment is critical, but it does not directly affect the mission as much as Strategic/Topographical considerations. (For example: Is construction permitted in the conservation area?)	0,10 (Low-Medium)	5
Reference: Authors' Research Documentation				

Scoring System (Weighted Grading)

Each main category has been assigned a **Weighting Factor (W_i)** with a total sum of 1.00.

$$\sum_{i=1}^{5} W_i = 1.00$$

W Strategic =0,35
W Topographical=0,25
W Economic =0,20
W Climatic =0,10
W Ecological =0,10
A Suitability Score for each sub-variable (between 1 and 10)
A A Suitability Score (S_{ij}). has been assigned for each sub-variable (ranging from 1 to 10).

The Final Priority Score (P) shall be calculated using the following formula:

$$P = \sum_{i=1}^{5} W_i X \left[\frac{\sum^{j} S^{ij}}{N_i} \right]$$

Number of sub-variables in categories N_i and i

Ranking in Terms of Priority:

Precedence indicates the logical sequence of a variable in the project timeline and which decision enables the next decision. In the Watchtower project, this determines the Elimination Stages.

Table 2: Preliminary qualification stages

1. Screening/Feasibility (High Priority)	Strategic & Topographical	Initial Elimination: If the tower cannot achieve its mission objectives (Strategic) or provide an adequate field of view (Topographical), the project should be eliminated immediately. These two factors constitute the answer to the question, 'Should we proceed?'
2. Design and Budgeting	Ecological & Climate	Second Screening: For locations deemed suitable from a strategic and topographical perspective, the cost (economic) and construction method (climatic) are determined. At this stage, climatic data influences material selection and basic costs.
3. Permissions and Implementation	Ecological & Economic	Application Condition: All legal permits (including ecological restrictions) are completed. The final budget and financing (economic) are secured. Ecological factors influence the manner in which the construction is carried out (when, with which tools).

Reference: Authors' Research Documentation

In preliminary calculations, the Critical Elimination Score (CES) is determined between 1 and 5, depending on the stage of the project (Feasibility, Design, Implementation) at which the variable will be decided.

- Key threats in these areas (poaching, fire, threats to biodiversity,
- The role of observation towers in countering these threats
- Early detection
- Prevention
- Interception and prevention against the risk of failure to stop

3. The Need for Systematic Categorization in the Deployment and Reconfiguration of Protection Towers

The deployment, redeployment, and reconfiguration of protected areas have been addressed under eight fundamental categories, with subcategories for each category also specified. Fundamental and subcategories that present differences in new deployment and redeployment have been added to this categorization.

In the deployment of these structures, the challenges posed by geographical location can fundamentally alter design parameters. Tropical, desert, polar and continental climates each carry unique risks of humidity, temperature fluctuations, wind and corrosion. For example, while corrosion-resistant composite materials and concealment techniques that minimize impact on biodiversity are essential for observation towers in tropical areas, sand-proof optics and insulation against extreme thermal fluctuations become vital for stations in desert climates Particularly in special environments such as underwater or underground, completely different engineering disciplines and special materials come to the fore, such as pressure resistance, corrosion, and geological stability. This situation highlights the fact that a single standard tower type cannot meet all needs. In such studies, operational and technical requirements should align

with fundamental resources such as the Lookout Tower Operations Handbook (United States Forest Service, 2024).

The IUCN's detailed study on protected areas and their categorization has been utilized (IUCN, 1986, 18).

The definition and classification of protected areas is one of the most debated issues worldwide. Both broad and narrow definitions of these areas can be detrimental to the public interest. Although Yinanç and Sönmez are right in their works about the need to simplify or reduce areas with multiple conservation statuses, it cannot be said that a noteworthy proposal is put forward in this work (Yinanç & Sönmez, 2022).

Table 3. Variables and levels of impact in the deployment and redeployment of observation towers

Kategori	Variable Types	Effectiveness	Flexibility Coefficient
1	Compliance with national and international legislation (international agreements, contracts)	a) Compliance with legal regulations (the public benefit and widespread external effect of the deployment or redeployment project are the primary factors in terms of applicability. Is the construction of these structures and components large enough to require changes to PUBLIC BENEFIT and/or WIDESPREAD EXTERNAL EFFECT legislation?	1/3
2	In terms of the location of protected areas	b) The location of the tower(s) within the cadastral (architectural) structure of the protected area c) The elevation structure of the land, its terrestrial and aquatic structure and ratio, (if underwater, its depth) d) The elevation structure of the terrain, its terrestrial and aquatic structure and ratio (if submerged, its depth) e) Tropical, desert climates, mountainous areas, glacial areas, aquatic environments	1/3
3	Types of Observation and Surveillance Towers in Terms of Structure and Function	f) In terms of the type/function of protected areas, g) In terms of the type/function of observation or surveillance towers	1/3
3.1	Fauna Flora – Fauna (animal and plant observation towers/stations)	h) Animal observation towers, plant observation stations (Protection observation stations in areas where endangered animals and plants are found.	(0,2)
3.2	Climate Measurement / Monitoring and Reconditioning Stations	i) Climate change monitoring stations, particularly in desert and glacial areas j) Climate restoration stations	(0,1)
3.3	In-situ wildlife monitoring stations	k) Local wildlife research stations	(0,1)

3.4	Space Observation Stations	l)	Space observation stations have a low degree of flexibility because they cannot be used everywhere.	(0,4)
3.5	Earthquake Monitoring Stations			(0,05)
3.6	Epidemic and/or chemical radioactive isolation areas observation towers	m)	Areas of extreme sensitivity to national and international legal rules	(0,1)
3.7	Fire Lookout Towers			(0,05)
	ALL VARIABLES		TOTAL FLEXIBILITY	3
Reference: Authors' Research Documentation				

The shape/aesthetic structures and construction materials of the observation and surveillance towers have been presented in a predictable manner during the construction phase, within the framework of the data in Table 4.

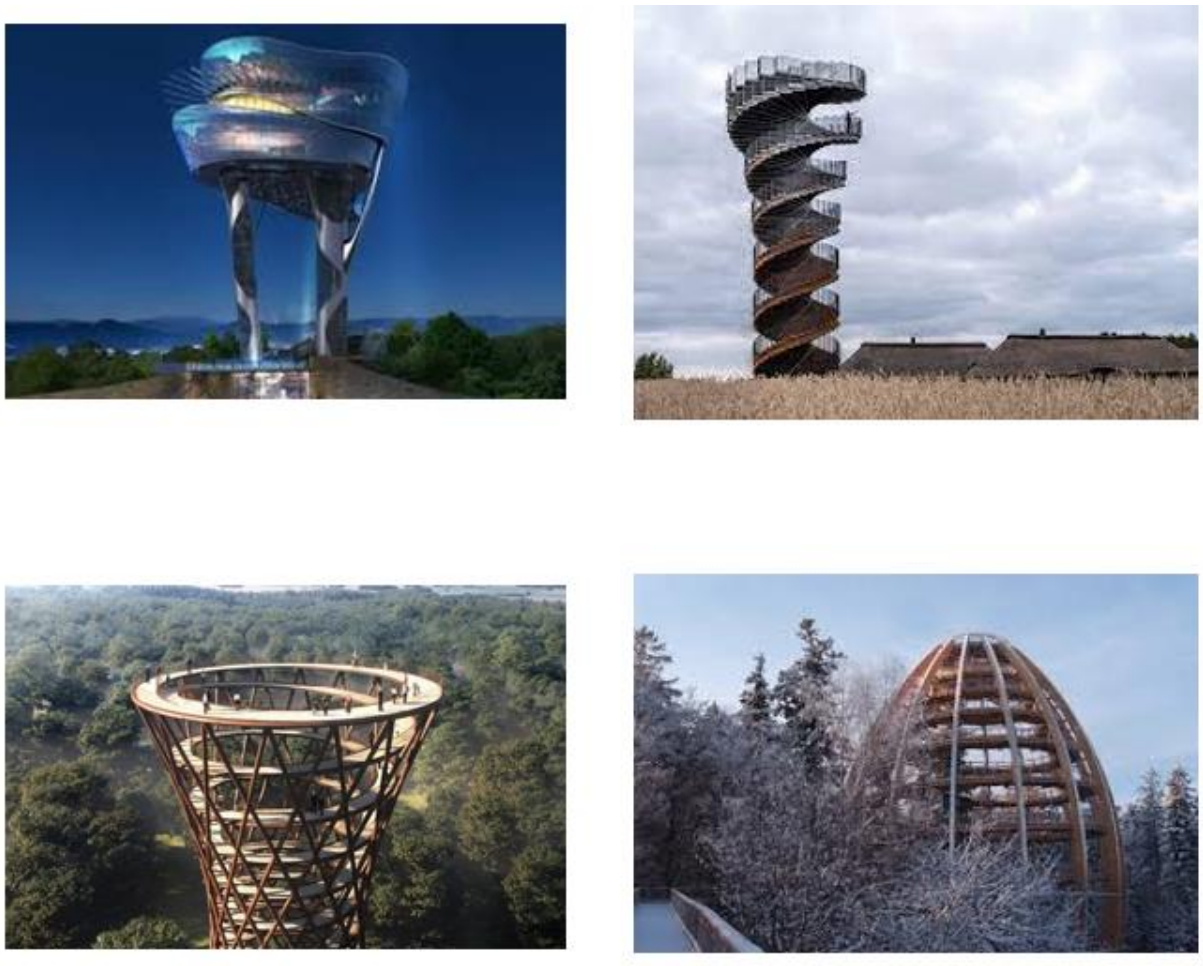


Figure 2. Type of Look Out Towers **Reference:** Design Skill, (Accessed Date: 10/11/2025) https://designskill.org/travel/a-new-spiraling-lookout-tower-opens-in-denmark/

Observation Towers According to Their Purpose of Use

Table 4. Structural separation of observation and surveillance towers

TYPE	AIM	STRUCTUR	DONATION	LOCATION
I. Terrestrial Environments (Classic Type)				
Forest Fire Tower	Early detection of fires in forested areas and determination of smoke location.	High (20-40m), Steel or Reinforced Concrete. Mostly enclosed cabins	Thermal and HD Cameras, GPS coordinate systems (Azimuth/Elevation). Radio/Satellite Communication.	Europe (Mediterranean Coast), North America, Turkey (OGM Towers).
Poaching/Activity Control Tower	Monitoring illegal entry, hunting, and tree cutting in National Parks and Wildlife Conservation Areas.	Lower, camouflaged, often made of local wood or stone materials.	Motion Sensors, Night Vision Cameras (IR/Thermal), Unmanned Aerial Vehicle (UAV) launch/tracking point.	Africa (Safari/National Parks - Poaching hotspots), Asia (Nepal, Indonesia).
II. Aquatic and Coastal Environments				
Coastal/Wetland Observation Tower	Bird watching, water quality monitoring, and control of unauthorized fishing in Ramsar Sites, Wetlands, and Coastal Parks.	Wooden or galvanized steel legs. Platforms elevated above the ground, resistant to coastal erosion.	Binoculars (high magnification), Remote Sensors (for water quality), Acoustic Monitoring Devices.	**Europe** (Netherlands, **Baltic** Coast), **Asia** (Mangrove Areas in **Southeast Asia**).
Marine Biological Monitoring Platforms (Tower Type)	Monitoring coral reefs, Marine Protected Areas (MPAs), or pollution monitoring points.	Special structures fixed to the water surface or anchored to the seabed, containing underwater enclosures.	Sonar systems, Underwater Cameras, Oxygen/pH Sensors, Current meters.	**Australia** (Great Barrier Reef area), **Japan**, and Tropical Marine Protected Areas..
III. Extreme Environments				
Polar and Arctic Observation Station (Tower/Platform)	Monitoring and researching polar ecosystems (ice movements, wildlife, climate change).	Highly wind-resistant and frost-resistant, thermally insulated, modular structures. Some are mounted on glaciers.	Meteorological Stations, GPS/GNSS receivers (for monitoring glacier movement), Thermal and Wide-Angle Panoramic Cameras.	**Antarctica** and the Arctic (near scientific research centers), **Canada** (polar regions).
High Altitude/Mountainous Area Tower	Monitoring biodiversity (endemic species) and collecting meteorological data in hard-to-reach mountainous areas.	Primarily local stone, wood, or prefabricated lightweight materials. Modules transportable by helicopter.	Remote Power Source (Solar/Wind), UAV charging stations, Animal tracking cameras (Trap-Cam).	**Asia** (Himalayas), **South America** (Andes Mountains).

Reference: Authors' Research Documentation

4. Predictions Regarding the Construction Phase of Observation and Surveillance Towers

Sub-variables and action flexibility in terms of different basic categories are also provided in Tables 5 and 6. Our assessments regarding the location of protected areas are addressed in Table 7. The materials that can be used in the construction processes in these areas have been differentiated in terms of observation and covert surveillance stations.

If the observation and covert surveillance stations are to be integrated into the same station, these materials can naturally be used in an integrated manner.

Table 5. Main variable action flexibilities

Main Category	Sub-Variable	1-5 Rating Scale (Example)
1. Ecological (W=0.30)	1.1. Protection Status Compliance	1=Construction in a restricted area, 5=Construction in a completely degraded/industrial area
	1.2. Habitat Impact (Biodiversity)	1=Direct harm to critical species, 5=Minimal or zero impact
	1.3. The Need for a New Approach to Accessibility	1=Wide new road required, 5=Existing road/path sufficient
	1.4. Visual Pollution/Landscape Impact	1=Completely disrupts the landscape, 5=Camouflaged into the natural environment
2. Strategic (W=0.25)	2.1. Mission Scope (Surveillance/Monitoring)	1=Covers low-priority areas, 5=Covers the most critical/risky areas
	2.2. Response Time to Incidents	1=Remote and difficult to respond to, 5=Quick access and centralized response
	Communication Infrastructure (Data Transmission)	1=Additional expensive infrastructure required, 5=Easy integration into existing networks
3. Topographical (W=0.20)	3.1. Field of View Efficiency	1=Many obstructions, 5=Unobstructed, full circular field of view
	Ground/Geological Suitability	1=Major foundation reinforcement required, 5=Excellent, solid ground
	Height Advantage	1=Lower than the surroundings, 5=Highest natural point in the surroundings

Table 5. Main variable action flexibilities		
Main Category	Sub-Variable	1-5 Rating Scale (Example)
4. Economic (W=0.15)	4.1. Construction Cost Estimate	1=Significant budget overrun, 5=Low cost, standard solution
	4.2. Operational Costs (Maintenance, Energy)	1=Very high annual cost, 5=Low or renewable energy solution
	4.3. Cost-Effectiveness of Repurposing	1=The existing structure is unusable, 5=Suitable for use with minimal alterations
5. Climatic (W=0.10)	5.1. Extreme Weather Conditions Risk (Wind/Ice/Lightning) 1=High-risk area	1=High-risk area

Reference: Authors' Research Documentation

Table 8 also presents the structure, construction and materials of observation and surveillance towers in terms of their location using a material matrix. Accordingly, the fundamental challenges and basic requirements of the variables in terms of location are specified. The material selection for the durability (resistance) of the towers or stations, energy requirements and operational costs are predicted. Again, the study attempted to proceed on the basis of circularity in terms of material selection and energy use.

Table 8: Structural and Finishing Materials in Terms of the Locations of Observation and Surveillance Towers			
Location Category	**Key Challenges**	**Observation Tower Requirements**	**Covert Surveillance Station Requirements**
Tropical Areas	High humidity, heavy rainfall, corrosion, biodiversity necessitate concealment.	Stainless steel/composite materials, lightning protection, elevated position above dense vegetation, good ventilation.	Waterproof/high IP protection class enclosure, thermal/acoustic camouflage, solar energy.
Desert Climates (Arid)	Extreme temperature differences (day/night), sandstorms, UV	Thermal insulation, sand-proof filters (optical and mechanical), low	Self-cleaning optics, ultra-low power consumption,

Table 8: Structural and Finishing Materials in Terms of the Locations of Observation and Surveillance Towers

Location Category	Key Challenges	Observation Tower Requirements	Covert Surveillance Station Requirements
	radiation, water supply issues.	maintenance, concrete/steel construction.	subsurface/rock camouflage.
Polar Regions (Cold)	Ice load, Extreme winds, Fragile environment, long periods of darkness (Winter).	Durable, aerodynamic design, heated sensors, special frost-resistant steel, wind/solar hybrid energy.	Cryptic, integration into snow/ice, high-capacity battery/energy storage, low heat dissipation.
Continental Climates	Significant temperature differences (thermal stress), Four-season load conditions (snow/wind).	Standard engineering solutions are applicable, but attention must be paid to thermal expansion.	Moderate concealment is sufficient, reliable operation of standard sensors.
Underwater/Subsurface (Aquatic Environments)	Pressure, Salinity/Corrosion, Currents, Marine life interaction.	Hydrophones, sonars, ROV integration, Titanium/special alloy housings, mooring systems.	Autonomous underwater vehicles (AUVs), ocean floor anchoring, wireless communication (acoustic/optical).
Underwater/Underground (Terrestrial Environments)	Enclosed space ventilation, humidity control, geological stability, seismic monitoring.	Tunnel/cave support structures, geotechnical monitoring sensors, dehumidification and climate control systems.	Seismic sensors, radar-resistant underground housing, ground embedding.

Reference: Authors' Research Documentation

In Table 9, the deployment, functionalization and re-functionalization work of fauna surveillance and observation towers and/or stations are presented in separate matrices due to the uniqueness of the function.

The construction, structure, fixtures and fittings of Fauna surveillance and observation towers, in terms of their focal point, are presented on a legal basis, along with the technologies and materials that can be used.

From a functional perspective, the purposes for which surveillance structures are used are decisive in terms of the technology they house and their operational requirements. Fauna Monitoring functions (Flora-Fauna) require high-resolution sensors, thermal cameras, and artificial intelligence-supported automatic recognition systems (European Union JRC, 2023), whereas when the focus is on Climate Monitoring, precise meteorological measurement stations and long-term data collection capabilities take precedence. The study found that, particularly after the 2000s, technological devices came into play, causing a shift in the function of towers, and structures evolved towards Observation Towers (Küçük et al., 2021; Parr, 2006). This initially led to an expansion in the function of these towers. Observation Towers, on the other hand, focus on stability and powerful optics for Remote Observation and on personnel and visitor safety for Local Observation. This functional distinction is key to transforming a watchtower from a passive structure into an active information gathering platform with a specific purpose.

The visitor experience in protected areas should not be overlooked when positioning and repurposing observation towers. Scientific measures in this regard will form the basis for the sustainability of such structures. In their work, Akten and Gül discuss the importance of social amenities in such areas and highlight the significance of the distance between amenities and visitor needs (Akten & Gül, 2014).

Table 9. (Flora – Fauna) Monitoring and climate monitoring towers matrix

Subcategory	Focus	Equipment technologies	Critical Design Requirement
Animal Monitoring Towers	Monitoring the movement, behavior, and migration routes of a specific species or population.	High-resolution/thermal cameras, artificial intelligence-supported automatic recognition (AI), telemetry receivers.	High optical quality and silent operation (to avoid disturbing the animals).
Plant Monitoring Stations	Monitoring vegetation health, growth rate, biomass change or disease spread.	Spectral cameras (NDVI), Lidar, light, humidity and temperature sensors, dendrometers.	Accurate positioning for precise microclimate measurements, low shadow effect.
Measurement Stations	Long-term weather, temperature, humidity, wind, precipitation and	Anemometers, thermometers, hygrometers, barometers, rain gauges.	Pole/tower structure with standard measurement height,

Table 9. (Flora – Fauna) Monitoring and climate monitoring towers matrix			
Subcategory	Focus	Equipment technologies	Critical Design Requirement
	atmospheric pressure data collection.		unaffected by external elements.
Re-climatization Control Stations	Typically (though incorrectly named) used to monitor controlled environments or habitat restoration areas for species vulnerable to climate change.	Greenhouse environment control sensors, irrigation/humidification systems, UV filtration.	Ability to maintain the integrity of the controlled environment and isolate it from the external environment.
Reference: Authors' Research Documentation			

5. Changes in the Functionality of Observation Towers

Until 2000, observation towers in protected areas were primarily used for physical observation or surveillance. However, since 2000, the default observation method has been carried out using technological devices (cameras and multifunctional measuring devices). This has led to a shift in the basic function of the towers, which have increasingly evolved into viewing terraces over the last quarter of a century. This has initially led to an expansion of the functions of these towers. New functions and facilities such as viewing terraces, dining areas, and live experience units have begun to be added to these spaces.

Observation towers in areas where specially cultivated plants and endangered plants and animals are located, particularly in the context of plant and animal observation towers, have been increasingly equipped with technology-intensive features. These facilities have been made much more functional by adding other means and methods such as remote monitoring, online tracking, and online paid viewing, and efforts have been made to expand the availability of goods and services. This process continues at an increasing rate.

Both the ease and difficulty of change within these boundaries pose problems in terms of sustainability (Fidan, 2017).

6. Conclusions and Recommendations:

Within the climatic context, the deployment and construction of protection towers, their coordination and supervision, and the effective and efficient execution of surveillance functions are fundamental to the protection area's characteristics, category, the structure of its protection geography and topography, and the content of its plant and animal ecosystems.

Particularly, considering technological developments worldwide, the separation of these structures and the smart design of their construction equipment will ensure that protected areas are not further physically and aesthetically degraded and that the habitat integrity of flora and

fauna structures is preserved. The physical, visual characteristics and architecture of these structures should be constructed in accordance with the function they will serve.

The process of constructing and repurposing observation towers (OT) is a multidimensional problem that requires an integrated analysis of strategic, topographical, economic, climatic, and ecological variables, beyond a simple engineering decision. In sensitive geographical areas such as protected areas, ecological and strategic factors have the highest priority in determining the vital importance of the project. In the initial Feasibility and Screening Phase, the alignment of strategic objectives with the mission and the visibility efficiency of the topographical location should be considered veto factors. Subsequently, economic sustainability and climate resilience guide the design and implementation phases of the project. This hierarchical scoring framework enables the most efficient use of resources and allows the towers to fulfil their intended mission with maximum effectiveness.

When deploying these structures, the challenges posed by geographical location can fundamentally alter design parameters. Tropical, desert, polar and continental climates each carry unique risks of humidity, temperature fluctuations, wind and corrosion. For example, while corrosion-resistant composite materials and concealment techniques that minimize impact on biodiversity are essential for a G.K. in a tropical area, sand-proof optics and insulation against extreme thermal changes become vital for a station in a desert climate. Particularly in special environments such as underwater or underground, completely different engineering disciplines come to the fore, such as pressure resistance, corrosion and geological stability. This highlights the fact that a single standard tower type cannot meet all needs.

From a functional perspective, the intended use of surveillance structures is decisive in terms of the technology they house and their operational requirements. Fauna Monitoring functions (Flora-Fauna) require high-resolution sensors, thermal cameras, and AI-powered automatic recognition systems, whereas when the focus is on Climate Monitoring, precise meteorological measurement stations and long-term data collection capabilities take precedence. Observation Towers, on the other hand, focus on stability and powerful optics for Remote Observation, and on personnel and visitor safety for Local Observation. This functional distinction is key to transforming a surveillance tower from a passive structure into an active information gathering platform tailored to a specific purpose.

Ultimately, the successful integration of Observation and Monitoring structures is possible by intersecting the elements of Priority (How Important?) and Timing (When Should It Be Done?) with the constraints imposed by Location and Functional objectives. Every decision taken in a protected area should prioritize ecological sensitivity and legal compliance then reinforce the mission strategy with Topographical and Climatic data. The systematic analysis of this complex matrix not only guarantees structural resilience and operational efficiency but also ensures the long-term success of the project by enabling the most effective and responsible use of limited conservation budgets.

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The Role of St. Nicholas in Shaping City Image and Tourism Branding from Antiquity to the Middle Ages

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Abstract

This study examines urban identity and branding through the role of Saint Nicholas, tracing a process that extends from the ancient city of Myra to European centers such as Bari and Venice during the Late Middle Ages. Urban identity is defined as a multi-component structure formed through the combination of physical, cultural, religious, and social elements, while urban branding refers to the strategic process of rendering this identity visible at national and international levels.

The research discusses the formation of Myra's urban identity through its position and commercial functions within the Lycian League in antiquity, as well as through Saint Nicholas's episcopacy, miracles, healing role, and dream visions during the early Christian period. The burial site and church of Saint Nicholas functioned as fundamental elements that enhanced the city's international religious prestige, enabling Myra to assume a central role within pilgrimage routes. With the transfer of Saint Nicholas's relics to Bari and Venice, the cult of the Saint expanded, intensifying interurban competition for religious prestige and, by supporting pilgrimage culture, became a strategic instrument in the branding of religion.

Within the framework of Lynch's urban image approach, Myra and later central cities are analyzed through symbolic, spiritual, and physical elements. The religious identity and miracles of Saint Nicholas emerge as decisive factors in the formation of the religious, cultural, and touristic brands of both Myra and the cities to which the Saint's relics were transferred.

Keywords: Myra, Urban Identity, Urban Branding, Saint Nicholas, Relics, Pilgrimage Culture, Religious Tourism.

Introduction

Urban identity and city branding have become fundamental concepts in contemporary scholarship aimed at understanding and rendering visible the historical, cultural, and social values of cities. Urban identity presents a holistic structure shaped not only by the physical fabric of a settlement but also by its collective memory, religious practices, and historical continuity. City branding, in turn, is defined as the process through which these elements of identity are strategically foregrounded in order to confer symbolic value upon a settlement at national or international scales.[1]

Studies on urban identity demonstrate that the perception of a city depends not solely on its spatial organization but also on the symbolic meanings it embodies and its rootedness in social memory. The concept of the urban image, articulated by Lynch (1960) through mental maps, reveals how individuals perceive cities and how these perceptions influence the formation of identity.[2] Relph (1976), through the notion of "sense of place," emphasizes the importance of emotional and cultural attachments to space in identity formation, while

[1] Kavaratzis & Ashworth, 2005, 506-514.
[2] Lynch, 1960, 46-91.

Caniggia and Maffei (2001) stress the necessity of evaluating social life, the physical environment, and economic relations in an integrated manner.[3]

These modern theoretical approaches are also functional for assessing urban identities in historical periods. In Late Antiquity and the Middle Ages, the urban identity of Myra was similarly shaped within a framework in which the physical environment was intertwined with religious and cultural practices. The most decisive factor in the city's prominence was undoubtedly the identity of Saint Nicholas, Bishop of Myra, and the powerful cult that gradually developed around him. The miracles attributed to Nicholas, his protective qualities, and the sanctity associated with his tomb elevated Myra beyond a regional episcopal center, transforming it into a city recognized throughout the Christian world. While Nicholas's activities during his episcopacy strengthened Myra's position within the Lycian region, the cult practices that emerged after his death facilitated the spread of the city's reputation across various parts of the Mediterranean.

Texts written by pilgrims, icons, liturgical traditions, and dramatic representations of the saint that emerged in Western Europe contributed to the transformation of Nicholas into an international figure. In this process, Myra became embedded in the shared religious memory of the Middle Ages as a city identified with the saint's life and miracles. Consequently, Myra acquired an identity recognized and remembered not only through its ancient architectural heritage but also through the sacred values represented by Saint Nicholas. Thus, the city's historical continuity was shaped by the guiding influence of religious memory. This study aims to evaluate this process of identity formation in light of both modern theoretical approaches and historical sources.

The Urban Identity of Ancient Myra

Ancient Myra (modern Demre), located in the Lycian region between the Alaca Mountains and the Mediterranean Sea along the banks of the Myros River, together with its harbor Andriake, ranks among the region's prominent strategic settlements due to its geographical features and natural setting (Fig. 1). Strabo's description of Myra as "one of the six largest cities with three voting rights" indicates that the city possessed a strong economic structure as well as political privileges associated with its status as a major metropolis.[4] Owing to the harbor of Andriake, Myra became a significant hub within international trade networks throughout antiquity and developed into a frequented center on both regional and global scales.[5] The city's ancient theater, rock-cut tombs, and the basilicas, granary, agora, baths, shops, and workshops located around the harbor demonstrate that social life, religious rituals, and economic activities in Myra evolved in close interrelation. The nymphaeum structure further reveals that rituals associated with water cults and public activities were integrated with harbor life, thereby exerting a substantial influence on the city's social fabric (Fig. 2).[6]

Nevertheless, the urban identity of ancient Myra appears to have been shaped largely around religious structures and the rituals performed within them. The Temple of Artemis Eleutheria in the city likely served as a center for major cult activities and festivals, accentuating Myra's

[3] Relph, 1976; Caniggia & Maffei, 2001.
[4] Strabo, 1917-33; Foss, 1994, 1-52.
[5] Bean, 1998; Tekinalp, 2000; Marksteiner, 2013, 281-290.
[6] Tekinalp, 2000, 289-310; Çevik & Bulut, 2022, 21.

sacred character.[7] Similarly, the Apollon oracle at Sura—considered a sacred site—and the basilicas later constructed there represent notable examples of religious and cultural transformation in the region.[8] These sacred spaces undoubtedly played a decisive role in the formation of Myra's social, cultural, and symbolic values. At the same time, the presence of archaeological evidence belonging to different ethnic and religious communities, such as a synagogue, reveals the cosmopolitan character of Myra.[9] Taken together, these elements indicate that Myra developed a holistic urban identity in which economic, public, and religious functions were closely intertwined.

The Spread of Christianity in Myra

From the first century onward, the dissemination of Christianity through Paul's missionary journeys to Lycia led to significant transformations in Myra's religious and social structure (Fig. 3).[10] Apocryphal sources dating to the second century CE report that Paul's preaching and miracles in Myra contributed to the weakening of pagan beliefs and facilitated the acceptance of Christianity.[11] This process proved decisive in the city's religious transformation and established Myra as an important center for early Christian communities.

Although the pace of Christian expansion in the city during these centuries is generally considered to have been slow, inscriptions discovered at Arycanda provide valuable information regarding the Christian population in the region.[12] At the same time, during the Roman Imperial period, Myra played a strategic role within the maritime trade networks of the Eastern Mediterranean. Paul's transfer in Myra to another grain-laden ship arriving from Alexandria during his journey to Rome indicates the city's function as a transshipment hub along the Egypt–Italy grain route.[13]

The Religious Role of Saint Nicholas

This early process of Christianization acquired a new dimension in the third and fourth centuries with the emergence of Saint Nicholas. Born in Patara around 270 CE, Nicholas was appointed Bishop of Myra during the reign of Constantine (Fig. 4).[14] He played a decisive role in the formation of the institutional structure of Christian communities in Lycia and was regarded throughout the region as a "common Church Father."[15] As noted in the hagiographic account of Michael the Archimandrite, Nicholas was remembered as the figure who demolished the Temple of Artemis down to its foundations and eradicated the cult beliefs

[7] Neumann, 2007, 21.
[8] Çevik & Bulut, 2022, 7-74.
[9] Çevik & Bulut, 2022, 25.
[10] Bennett, 2015, 28; The Holy Bible, New Testament, Acts 27:5-6. (English Standard Version). (2001); Crossway Bibles; *The Acts of Paul,* http://www.earlychristianwritings.com/text/actspaul.html **Erişim:** 10.11.2025.
[11] Schneemelcher, 1992, 246; Elliott, 2005; Bennett, 2015, 1-29; Karaman, 2021, 966-977.
[12] Bennett, 2015, 28.
[13] Stathakopoulos, 2004, 213.
[14] Jones, 1978.
[15] [15]https://www.oca.org/saints/lives/2025/12/06/103484-saint-nicholas-the-wonderworker-archbishop-of-myra-in-lycia Erişim: 10.11.2025; Bennett, 2015, 1-29; V. Nic. Sit. 76 (F 31); Φθάσαντος δὲ τοῦ καιροῦ τῶν Ῥοσσαλίων τοῦ προπάτορος ἡμῶν τοῦ ἁγίου Νικολάου, κτλ.

associated with the goddess. Such narratives positioned the saint as a central figure in the struggle against paganism and as a protector and defender of Christianity.[16]

Accounts of the saint's life emphasize his assistance to the poor, orphans, and those in distress; his protection of individuals who were unjustly accused; and his miraculous rescue of sailors facing danger at sea, all of which enhanced his esteem within society.[17] The belief that Saint Nicholas performed miracles both during his lifetime and after his death was a decisive factor in his recognition among the saints.[18] The institutionalization of this cult became a key element in the formation of the Christian urban identity of Myra and its harbor, Andriake.

The Council of Nicaea and Opposition to Arius

In traditional narratives, particularly the *Vita per Michaelem*, Nicholas is described as having taken a stance against Arius at the Council of Nicaea in 325. Although the historical accuracy of this account remains contested, it is significant in illustrating how the saint gradually acquired a powerful symbolic identity within the context of Myra (Fig. 5).[19] While the event itself lacks historical certainty, the portrayal of Nicholas as a bishop defending Orthodox belief at the Council of Nicaea reflects the formation of the symbolic value attributed to the bishopric of Myra. This tradition demonstrates that the religious heritage shaped during the early Christian period in the city continued to be referenced and reinforced in the centuries following the fourth century.[20]

The Tomb of Nicholas

Saint Nicholas's death in Myra and his burial in the tomb constructed for him constituted one of the fundamental elements of the city's spiritual and cultural identity. Following his death, the church built in proximity to his tomb quickly became a pilgrimage center on a regional scale, serving as a major attraction for visitors arriving from various parts of the Mediterranean (Figs. 6–7). According to tradition, the fragrant oil (*myrrh*) believed to emanate from the saint's tomb possessed healing properties, which played a significant role in the spread of the cult of Nicholas.[21] Archaeological and historical evidence indicates that the church in which he was traditionally buried can be associated with the structure that survives today.[22]

[16]Anrich, 1913, I, 113-139; Michael the Archimandrite. (2014). *St. Nicholas of Myra: Life (Vita per Michaelem)* (J. Quinn & B. Sewell, Trans.). In *Bibliotheca Hagiographica Graeca* 1348. (Original work written ca. 9th-10th c.). https://www.roger-pearse.com/weblog/wp-content/uploads/2015/03/vita-per-Michaelem.pdf Erişim: 09.11.2025; *The Real St. Nicholas.* https://www.ewtn.com/catholicism/library/real-st-nicholas-5783 Erişim: 09.11.2025.

[17] Rostovsky, D. (2011). *Life of St. Nicholas the Wonderworker, Archbishop of Myra in Lycia.* http://www.johnsanidopoulos.com/2011/12/life-of-saint-nicholas-wonderworker.html Erişim: 10.11.2025.

[18] Hayes, 2016. 492–512.

[19] Michael the Archimandrite. (2014). *St. Nicholas of Myra: Life (Vita per Michaelem)* (J. Quinn & B. Sewell, Trans.). In *Bibliotheca Hagiographica Graeca* 1348. (Original work written ca. 9th-10th c.). https://www.roger-pearse.com/weblog/wp-content/uploads/2015/03/vita-per-Michaelem.pdf Erişim 10.11.2025; Anrich, 1913,113-139.

[20] Bennett, 2015, 28 vd.

[21] Peschlow, 1975, 303-359; Peschlow, 1990, 207-258; Ötüken, 2006, 523-536.

[22] Fındık, 2023 1-23.

Myra as a Metropolis

This spiritual significance became even more visible in conjunction with developments in Myra's institutional status. Myra's elevation to metropolitan status took shape during the reign of Theodosius II (408–450), as part of the reorganization of the administrative and ecclesiastical structure of the Lycian region, and is historically confirmed by the signature lists of the Council of Chalcedon in 451, in which Bishop Anastasius of Myra is recorded as "Metropolitan of Lycia." The *Notitiae Episcopatuum* indicate that this status was maintained uninterruptedly from the sixth century onward.[23]

Myra's elevation to metropolitan status significantly enhanced the city's religious and administrative importance.[24] From the fifth century onward, there is clear evidence of an intensification in the construction of churches and martyrial buildings both in the harbor district of Andriake and in the urban center of Myra.[25] This architectural development emerged from the combination of the administrative authority conferred by metropolitan status and the pilgrimage appeal generated by the cult of Nicholas, and may be regarded as a significant phenomenon that strengthened the city's religious and social identity.[26]

The Vita of Nicholas of Sion

The evolving religious identity of Myra is clearly traceable in written sources. The earliest record indicating that Saint Nicholas was buried in Myra is found in the *Vita S. Nicolai Sionitae*, transmitted by a student of Nicholas of Sion.[27] According to this text, Nicholas of Sion participated in a synod held in Myra on December 6, 564.[28] These accounts support the view that Myra developed a sacred urban identity recognized not only as a bishopric center but also for housing the saint's relics and for its regular pilgrimage activity.

The day of his death was associated with the Christianized form of the Rosalia festival celebrated in antiquity, and the annual ceremonies held on December 6 played a central role in the city's social and religious life.[29] In this way, the saint's tomb and liturgical rituals strengthened Myra's religious authority and established the city's recognition at regional and international levels as "the city of Saint Nicholas."

Dream Visions and Healing Identity

Dream visions and healing miracles were also decisive in the formation of this religious identity. These phenomena, which can be examined under the heading of "Dream Visions and Healing Identity," were among the primary factors that enhanced Myra's visibility in Late Antiquity. In the *Miracle of Stratelates*, the saint enters the dreams of Emperor Constantine and Governor Ablabius to secure the release of three generals who had been unjustly imprisoned; in another account, Ioannes Orphanotrophos reports that Nicholas

[23] Darrouzès, 1981, 143.
[24] The pilgrim marks at the western courtyard entrance of the Church of Saint Nicholas indicate this widespread veneration.
[25] Foss 1994, 25; Tekinalp 2000, 289-310.
[26] Hierokles. (1913). *Hieroclis Synecdemus* (A. Burckhardt, Ed.). 684, 2, B. G. Teubner. (Original work composed ca. 6th century) https://topostext.org/work/567 Erişim 10.11.2025.
[27] Ševčenko & Ševčenko, 1984.
[28] Anrich, 1913, 40-41; Ševčenko & Ševčenko, 1984. 84, 91.
[29] Kokkinia, 1999, 209-210.

appeared in his dream, instructing him to go to Myra to receive healing.[30] These visions not only reinforced the saint's recognition at the imperial level but also contributed to positioning Myra as a sacred and prestigious center among both the populace and the court.

Contemporary sources indicate that healing practices around the tomb constituted the core of the cult. The myrrh (*myron*) believed to exude from the saint's bones was regarded as a sacred oil that provided miraculous cures through direct contact; pilgrims likely sought healing by touching the tomb, collecting the myron, or applying it to their bodies via cloths. These rituals enhanced Myra's importance as a regional pilgrimage and healing center.[31] In this context, the statement attributed to Constantine VII Porphyrogenitus is noteworthy: he describes Myra as "the city of God's servant, the mighty Nicholas, thrice blessed and flowing with myrrh in accordance with his name."[32] In this way, the cult of Nicholas, by combining dream visions and healing miracles, became a lasting factor shaping the religious, social, and economic identity of Myra.[33]

Myra's Role as a Pilgrimage Center in the Middle Ages

This strong religious identity and its character as a healing center help explain Myra's position within the pilgrimage geography of the Middle Ages. As discussed in this section, the relics of Saint Nicholas and the associated miraculous healing practices enabled Myra to emerge as a prominent center on international pilgrimage routes during the medieval period (Figs. 4–10). Indirect accounts from pilgrims such as the Russian Daniel and the English Saewulf indicate that Myra was located on the Eastern Mediterranean pilgrimage route.[34] The cult of Nicholas emerged as a fundamental factor shaping Myra's religious, social, and economic life, and the city became an exemplary case of an urban identity developed around a sacred space in the Late Antique Mediterranean.

During this period, the city's ancient religious structures, ritual spaces, and public areas were reorganized to accommodate Christian worship and societal needs, leading to the construction of churches, martyrial sites, and spaces for early Christian communities.[35] Ancient sources report that by the sixth century, the city contained the "Hagios Eirene Cathedral," the "Bishop's Palace," "Dioskori Square," the "Leo Quarter," the Church of Saint Kallinike, and churches dedicated to Myra's martyrs, Saint Kreskens and Saint Dioskorides.[36]

Archaeological evidence—such as pilgrim crosses at church entrances, various inscriptions, and European-origin coins—provides tangible proof of regular pilgrim visits and indicates that these visits constituted a long-standing tradition.[37] Evaluated within Lynch's (1960) "urban image" framework, Myra's urban identity was shaped not only by architectural and topographic elements but also by the symbolic and spiritual values carried through the experiences of pilgrims.

[30] Anrich, 1913, I, 67-91.
[31] Anrich, 1913, I, 34-36; Maguire, 1996, 147, 169, 194; Doğer & Borstlap 2023, 58-120; Torun, 2018.
[32] Bean, 1998, 125
[33] Maguire, 1996, 147, 169, 194.
[34] Daniel of Kiev. (1888). *The pilgrimage of the Russian abbot Daniel in the Holy Land, 1106-1107 A.D.* (C. W. Wilson, Trans. & Annot.). London: I, Adam Street. 7. (Original work published 12th century); Garnett, 2000.
[35] Tekinalp, 2000; Karakaya, 2005, 288-309.
[36] Anrich, 1913, I, 69.
[37] Doğan & Fındık, 2018.

The Crusades and Myra's Strategic Position

Myra's significance persisted indirectly during the Crusades. Although the city did not witness direct conflict during the First Crusade (1097), Anna Komnena (1083–1153) emphasizes the logistical importance of the Byzantine southern coast and notes that Lycian ports were critical for the imperial navy.[38] In this context, the Myra–Andriake corridor functioned as a secure zone providing indirect support to the Crusaders. During the Second Crusade, Odo of Deuil's accounts report that German forces suffered losses in the interior regions of Anatolia; although Myra is not directly mentioned, it is evident that the Crusader contingents sought access to the sea through this area.[39]

While Myra did not serve as a battlefield in these events, it retained its importance as a symbolic pilgrimage center in the Eastern Mediterranean through the cult of Saint Nicholas. The transfer of the saint's relics from Myra to Bari by sailors from Bari in 1087 increased interest in the cult and led Crusader armies to adopt Saint Nicholas as a protective figure for their maritime journeys.[40]

The Spread of the Saint's Cult in Europe

The dissemination of the cult of Saint Nicholas in Europe was also facilitated through Byzantine court culture. Empress Theophanu, granddaughter of Constantine VII and daughter of Romanos II, transmitted Byzantine court culture and the Orthodox saintly tradition to the Holy Roman Empire through her marriage to Otto II in 972. The chapel consecrated in 1058 at Worms Cathedral in honor of Nicholas is associated with a relic of the saint allegedly brought from Byzantium by Theophanu.[41] In the seventeenth century, it was reported that this relic, a "finger bone," was displayed in the chapel and later preserved in the cathedral sacristy, stored in oil similar to the example in Bari.[42]

This process facilitated the adoption of Nicholas as a protective saint, particularly among sailors, merchants, and urban communities. From the eleventh and twelfth centuries onward, the cult of Saint Nicholas rapidly spread throughout Western Europe, with numerous vitae, miracle accounts, and liturgical texts produced in England, Germany, and France. These texts contributed to the perception of Nicholas as a bishop and miracle-working protective saint, leading to the institutionalization of his cult across Europe.[43]

Le Jeu de Saint Nicolas

A striking example that illustrates the cultural and social impact of this dissemination is Jean Bodel's *Le Jeu de Saint Nicolas*, written at the end of the twelfth century. The play demonstrates how the cult of Saint Nicholas in medieval Europe was employed as a tool for

[38] Komnena, A. (2021). *Alexiad: Malazgirt'in sonrası / Anadolu'da ve Balkan Yarımadası'nda İmparator Alexios Komnenos döneminin tarihi* (B. Umar, Çev.). İstanbul: İnkılap Kitabevi. (Original work 12th century.)
[39] Odo of Deuil, 1948.
[40] Cioffari 2011, 43-108.
[41] Economou, E. M. L. (2021). *Kaiserin Theophano: The political, economic, diplomatic and cultural deeds of a Byzantine princess who became empress of the Holy Roman Empire of the German Nation* (MPRA Paper No. 107530). Department of Economics, University of Thessaly. https://mpra.ub.uni-muenchen.de/107530/ Erişim: 09.11.2025; Engels, 2002, 29-48.
[42] https://www.stnicholascenter.org/gazetteer/4742 Erişim: 09.11.2025.
[43] Jones, 1978.

propaganda and social guidance in the context of the Crusades.[44] In the play, the saint is depicted as a figure who delivers justice and performs miracles; the conversion of a Muslim emir and his people to Christianity occurs through the saint's miraculous intervention.

The primary aim of the play was to mobilize soldiers and boost morale for the Crusades by leveraging the authority of a religious figure.[45] At the same time, the work indirectly enhanced the recognition of Myra and strengthened the prestige of Saint Nicholas across Europe.

The Transfer of the Relics to Bari and the Formation of a New Urban Image

The spread of the cult in Europe was further reinforced through the physical relocation of relics from Myra. A group of sailors and merchants from Bari, concerned that the sacred remains of Saint Nicholas in Myra might be left unguarded or lost, took the saint's bones and transported them to their own city. Upon arrival in Bari, a grand ceremony was held, and the construction of the *Basilica di San Nicola* to house the relics was initiated.[46] This event led the city to acquire a new religious identity centered around the name of Saint Nicholas.

With the arrival of the relics in Bari, practices and narratives associated with Nicholas—such as healing, myrrh, dream experiences, and votive rituals—spread rapidly. These accounts ensured a continuous flow of pilgrims to the city, and the harbor became integrated into a network of visits intertwined with Mediterranean trade. Consequently, Bari acquired a strong brand value in the Middle Ages, being recognized as "the city of Saint Nicholas."[47] This process parallels Venice's transfer of Saint Mark's relics from Alexandria in 828 and the construction of its urban identity around San Marco.[48] Both examples demonstrate that sacred relics in medieval cities functioned not only as religious symbols but also as strategic instruments generating political visibility, economic vitality, and international recognition.

The Second Transfer by the Venetians

Historical sources report that after the First Crusade, the Venetians took some small bone fragments of Saint Nicholas from Myra; however, the details of the event and claims of coercion remain uncertain. Twelfth- and thirteenth-century Venetian chronicles describe monks being pressured and relics removed secretly, whereas Byzantine sources provide no direct record of the incident.[49] Consequently, historians suggest that this "second translation" may partly reflect Venice's effort to legitimize its religious policies, although there is consensus that the relics did indeed reach *San Nicolò al Lido*. According to the accounts, the

[44] Fındık, E. F. (2016). "*Jeu de Saint Nicholas*: Power of Propaganda and the Role of Myra in the Period of the Crusades." Unpublished paper, Jordan.
[45] Zink, 1978, 31-46.

[46] Markou, 1994; Corsi, 2006; Orthodox Church in America. (2014, May 9). *Translation of the Relics of St. Nicholas from Myra to Bari.* OCA Lives of the Saints. Orthodox Church in America. https://www.oca.org/saints/lives/2014/05/09/101336-translation-of-the-relics-of-st-nicholas-the-wonderworker-from-m *Erişim: 10.11.2025.*
[47] Orthodox Church in America. (2014, May 9). *Translation of the Relics of St. Nicholas from Myra to Bari*. OCA Lives of the Saints. https://www.oca.org/saints/lives/2014/05/09/101336-translation-of-the-relics-of-st-nicholas-the-wonderworker-from-m *Erişim: 10.11.2025.*
[48] Veronese & Zornetta, 2021, 54-75.
[49] *Venice and first Crusade: The Lido Text, Part I* (2016). https://akritesblog.wordpress.com/2016/11/19/venice-and-the-first-crusade-the-lido-text-part-1/ Erişim: 09.11.2025.

bones were brought to Venice around 1100, preserved in the monastery, and placed in a prominent location facing the harbor.[50]

Although the precise details remain unclear, this action exemplifies the "competition for sacred relics" typical of the Middle Ages. The placement of Saint Nicholas's relics at Lido functioned as a symbolic tool representing Venice's maritime identity, serving as the first religious structure visible to approaching ships.[51] Through this transfer, Venice linked its sacred image—previously established by the relics of Saint Mark from Alexandria—to the maritime heritage of the Mediterranean via Nicholas, thereby enhancing the city's religious prestige and urban authority. This second relic translation serves as a significant example of how sacred remains were employed in the Middle Ages to shape urban identity, diplomacy, and propaganda.

The Continuing Symbolic Importance of Myra

Independent of Bari and Venice, Myra retained its symbolic significance throughout the Middle Ages. Although the relics of Saint Nicholas were relocated, Myra continued to exist as an important religious center. In the twelfth and thirteenth centuries, the city experienced demographic and economic decline due to political turmoil in the region and attacks along the Mediterranean coast.[52] Nevertheless, the Church of Saint Nicholas and the saint's cult continued to attract pilgrims—particularly sailors—and the church, housing the saint's actual tomb, maintained its significance in collective memory as a sacred site. The spread of the cult in the West, following the transfer of the relics, enhanced Myra's spiritual appeal; the city transcended its physical boundaries to acquire an international identity and continued to be remembered in European Christian memory as "the city of the Saint." In 1254, the offerings made to Saint Nicholas by Queen Marguerite and her husband Louis IX during their stormy voyage off the coast of Cyprus illustrate the enduring symbolic and religious authority of the saint in the medieval Mediterranean.[53]

Myra's religious and symbolic influence persisted into the Late Middle Ages. In 1361, during attacks by the Lusignans, an important icon of Saint Nicholas from Myra was taken to Cyprus. It is believed that the icon was installed in the city's religious center, the Famagusta Cathedral (St. Nicholas Cathedral, 1308–1312).[54] This icon played a significant role in shaping the city's religious and symbolic identity and contributed to the spread of the cult of Saint Nicholas under Lusignan rule in Cyprus. Churches dedicated to the saint were constructed across the island, and in regions where the saint's icons or cult were relocated, a new "cult-centered urban image" emerged. Particularly in maritime cities, Nicholas's identity as the "patron of sailors" was regarded as a spiritual guarantor of trade routes and harbor security. Considering the importance of Cypriot ports in Eastern Mediterranean trade during the fourteenth and fifteenth centuries, the cathedral and the icon in Famagusta likely reinforced the city's religious and symbolic role.

[50] Grant, 2015, 247-265.
[51] *Tra la laguna e il mare: la chiesa e il monastero di San Nicolò del Lido*. (2025). https://www.dicea.unipd.it/convegno-san-nicolo-lido-2025 Erişim: 10.11.2025.

[52] Peschlow 1990, 210-211
[53] Rônière, 1976.
[54] Peschlow 1990, 211.

Conclusion

This study has demonstrated how the urban identity of Myra was shaped from its commercial and administrative significance in antiquity through the Middle Ages, focusing on the religious identity and miracles of Saint Nicholas. During Late Antiquity and the Middle Ages, the cult of Saint Nicholas transformed Myra from a local religious center into a city recognized at an international level, contributing to the development of a distinctive urban identity and brand value in its early period.

The relics and icons transferred from Myra fostered the emergence of similar religious focal points in the recipient cities, enhancing their prestige and social visibility. This process illustrates that the influence of the cult was not confined to Myra but extended beyond its borders. Consequently, the cult of Saint Nicholas and the relocation of his relics and icons to other cities enabled these urban centers to strengthen their historical and religious heritage as a form of brand value. Today, these sites continue to retain their significance as key elements of cultural and touristic appeal.

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Fig. 1. Myra (Mod. Demre) and Myros River



Fig. 2. Andriake ancient city



Fig. 3. Journeys of St. Paul



Fig. 4. Life of St. Nicholaos on the wall paintings



Fig. 5. Council scenes at the church





Fig. 6-7. St. Nicholaos Church of Myra





Fig. 8-10. Visitors of the St. Nicholas Church (?)