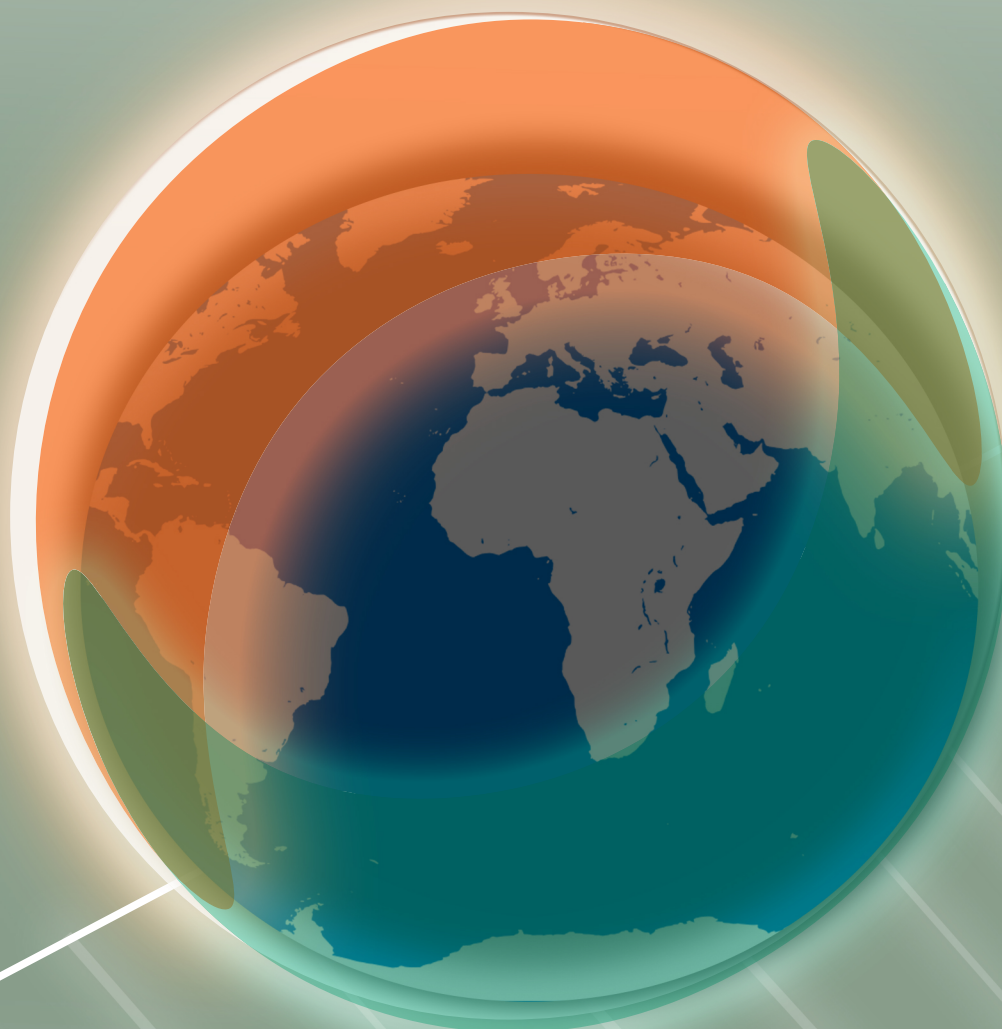




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CONTENTS

Research Articles	Page
1. Viewing Nature Conservation from a Biocultural Diversity Perspective: An Evaluation Based on Kazdağı National Park <i>(Doğa Korumaya Biyokültürel Çeşitlilik Perspektifinden Bakmak: Kazdağı Milli Parkı Üzerinden Bir Değerlendirme)</i> Yılmaz ARI	01-17
2. Reconsidering BIM-LCA Integration for Environmental Assessment and Decision-Support Processes in the Construction Industry <i>(Yapı Endüstrisinde Çevresel Değerlendirme ve Karar Destek Süreçleri için BIM-LCA Entegrasyonunun Yeniden Değerlendirilmesi)</i> Neriman Gül ÇELEBİ & Ümit ARPACIOĞLU	18-26
3. Narrative Landscape Design for Strengthening Place Identity: A Case Study of Böcüzade Park (Isparta, Türkiye) <i>(Yer Kimliğinin Güçlendirilmesine Yönelik Anlatısal Peyzaj Tasarımı: Böcüzade Parkı (Isparta, Türkiye) Örneği)</i> Gizem DİNÇ & Nisanur GEDİK	27-46
4. A Framework for Evaluating the Sustainability of Multilayered Historic Rural Cultural Landscapes: The Case of Tahtalı Neighborhood, Bursa <i>(Çok Katmanlı Tarihi Kırsal Kültürel Peyzajların Sürdürülebilirliğinin Değerlendirilmesine Yönelik Bir Çerçeve: Bursa Tahtalı Mahallesi Örneği)</i> Lale KARATAŞ BİLLOR	47-59
5. A Smart Support System for Renewable Energy Sharing in Small Off-Grid Facilities: Evaluating the “Stronger Together” Prototype from Design Science and Protected Area Management Perspectives <i>(Şebekeden Bağımsız Küçük Tesislerde Yenilenebilir Enerji Paylaşımı İçin Bir Akıllı Destek Sistemi: “Birlikte Daha Güçlü” Prototipinin Tasarım Bilimi ve Korunan Alan Yönetimi Açısından Değerlendirilmesi)</i> Cüneyd DİRİ, Y. Yasef ÖZŞALOM Eyal KOHEN, Eren BEYO Talha KILIÇ	60-78



6 HBIM-Based Cultural Heritage Information Management and Sustainability Framework for Monumental Mosques: The Case of Konya

(Anıtsal Camiler için HBIM Tabanlı Kültürel Miras Bilgi Yönetimi ve Sürdürülebilirlik Çerçevesi: Konya Örneği)

Neriman Gül ÇELEBİ & Ümit ARPACIOĞLU

79-86

7 Assessment of the Quantitative Analysis of Urban Open and Green Spaces in the Case of Eğirdir Urban Centre

(Kentsel Açık ve Yeşil Alanların Niceliksel Analizinin Eğirdir Kent Merkezi Örneğinde İrdelenmesi)

Hüseyin Batuhan DÜNDAR, Murat AKTEN

87-99

Review Article

8 Contributions of Biological Ponds in the Climate Change Adaptation Process and Planning/Design Principles

(Biyolojik Havuzların İklim Değişikliğine Uyum Sürecine Katkıları ve Planlama/Tasarım İlkeleri)

Şeymanur BAROL

100-119





Doğa Korumaya Biyokültürel Çeşitlilik Perspektifinden Bakmak: Kazdağı Milli Parkı Üzerinden Bir Değerlendirme

Yılmaz ARI ^{1*} 

ORCID: 0000-0001-7735-7890

¹ Bandırma Onyedi Eylül University, Faculty of Humanities and Social Sciences, Department of Geography –
10150, Bandırma, Balıkesir, Türkiye

* e-mail: yari@bandirma.edu.tr

Öz

Doğa koruma çalışmaları son zamanlara kadar daha çok biyolojik çeşitliliği korumayı hedeflemiştir. Ancak son zamanlarda korunan doğal alanların bazılarının insanlığın önemli kültürel miraslarını da barındırdığı anlaşılmış ve biyoçeşitlilikle beraber bu mirasın korunabilmesi için biyokültürel koruma yaklaşımı öne çıkmıştır. Bu çalışma Kazdağı Milli Parkı'nda doğa koruma çalışmalarını biyokültürel çeşitlilik perspektifiyle değerlendirmeyi amaçlamaktadır. Bunun için milli park içerisi ve yakın çevresindeki kültürel unsurlar tespit edilmiş, bunların park yönetimindeki rolü araştırılmıştır. Sonuçlar milli parkta doğa korumanın şimdiye kadar ağırlıklı olarak biyofiziki özellikler temelinde yapıldığını, oldukça zengin kültürel kaynak değerlerinin ise doğa korumanın önemli bir bileşeni olmadığını göstermektedir. Doğa koruma pratikleri daha bütüncül olarak biyokültürel çeşitliliği korumayı önceliklendirmelidir. Bunun için park içerisindeki kültürel unsurların bir envanteri çıkarılmalı ve bunların park yönetiminde nasıl kullanılacağına dair planlamalar yapılmalıdır.

Anahtar Kelimeler: Kazdağı Milli Parkı, Doğa Koruma, Biyokültürel Çeşitlilik, Biyokültürel Koruma, Biyokültürel Turizm.

Viewing Nature Conservation from a Biocultural Diversity Perspective: An Evaluation Based on Kazdağı National Park

Abstract

Biodiversity preservation has been the main focus of environmental conservation efforts until recently. However, to protect biological diversity together with cultural diversity, the biocultural conservation perspective has gained significance as it has lately been apparent that several Protected Natural Areas also include substantial cultural assets. The purpose of this study is to assess Kazdağı National Park's environmental conservation initiatives from the standpoint of biocultural diversity. To do this, cultural aspects of the national park and its vicinity were inventoried, and their function in park administration was examined. The findings show that biophysical features have been the main basis for nature protection in the national park thus far. Preserving biocultural diversity requires a more comprehensive approach to nature conservation practice. To achieve this, an inventory of cultural elements within the park should be compiled, and plans should be developed to utilize them in park management.

Keywords: Kazdağı National Park, Nature Conservation, Biocultural Diversity, Biocultural Protection. Biocultural Tourism.

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1. Giriş

İnsan faaliyetlerinin doğal alanlara verdiği zararların hızlanarak arttığı son 200 yıl, aynı zamanda doğal alanları olumsuz etkilerden koruma faaliyetlerine de tanıklık etmiştir (Dudley, 2008). Doğa koruma girişimleri resmi doğa korumanın başladığı kabul edilen 1872 yılından itibaren yaklaşık 100 yıl boyunca ekosistemlerin doğal yapısının korunmasına ve biyolojik çeşitliliğe odaklanmış, ancak son 40-50 yılda kültürel konulara dikkat çekmeye başlamıştır. Özellikle 1972 yılındaki Stockholm Konferansı sonrasında gelişmeye başlayan sürdürülebilir kalkınma anlayışı sadece ekosistemlerin değil, toplumların sosyal refahının da önemli olduğunu vurgulamıştır (Uzun & Demir, 2017). Sürdürülebilir kalkınma kavramı ilk kez 1970'lerde kullanılmaya başlanmış 1980'li yıllarda tanımlanarak (Brundtland, 1987), kalkınma çalışmalarının çerçevesini oluşturmuştur. 1972 Dünya Kültürel ve Doğal Mirasın Korunması Sözleşmesi ve 2003 tarihli Somut Olmayan Kültürel Mirasın Korunması Sözleşmesi (SOKÜM) doğal miras yanında maddi ve somut olmayan kültürel mirasın önemi ve korunması gerektiğine vurgu yapmıştır. Sonraki gelişmeler 2015 yılında Birleşmiş Milletler'in Sürdürülebilir Kalkınma Hedeflerini somut olarak tanımlaması ile devam etmiştir (Biermann vd., 2017).

Korunan Doğal Alanlar (KDA) küresel sürdürülebilir kalkınma hedeflerine ulaşmada önemli bir rol oynamaktadır (Dudley vd., 2017). KDA'lar bir yandan ekosistemin doğal dengesinin korunmasını sağlarken bir yandan da içerisinde ve çevresinde yaşayan insan topluluklarına çok çeşitli faydalar sağlar ki bunların hepsine birden ekosistem hizmetleri adı verilir (Akyiğit & Göktuğ, 2025; Daily, 1997; Saviano vd., 2018b). KDA'ların yönetiminin sürdürülebilirlik hedeflerine ulaşmayı sağlayacak yeterlilikte olması önem taşımaktadır. Bunun için KDA'ların ürettiği özellikle ekonomik ve kültürel ekosistem hizmetlerinin devamlılığının sağlanması gerekmektedir. Yerel toplumlar buralardan balık, meyve, çeşitli bitkiler, temiz içme ve kullanma suyu sağlar. Bunlar yanında KDA'lar reçine, bal, çeşitli aromatik bitkiler, yakacak ve yapacak odun temin eder. Ayrıca insan topluluklarının uzun dönemli refahında önemli paya sahip karbon depolama, hava kalitesinin iyileştirilmesi ve ısının düzenlenmesi gibi faydalar sağlarlar. KDA'ların yerel toplumlara yararlarından birisi de fırtına, taşkın, heyelan gibi doğal afetleri kontrol altında tutmada oynadıkları roldür. Turizm ve rekreasyon ise korunan alan çevresinde yaşamayan ancak doğal alanlara ilgi duyan insan gruplarına gezme ve dinlenme olanağı sağlar (MEA, 2005). KDA'lar aynı zamanda bilimsel araştırmalar ve eğitim faaliyetleri için de doğal laboratuvar işlevi görür. Bunların tamamı insan topluluklarına maddi olarak ölçülebilen katkılar sağlar (Costanza vd., 1997; TOD, 2024).

KDA'lar insan topluluklarına maddi olarak ölçülemeyen kültürel ve ruhsal faydalar da sağlar. Buralar yerel toplumların tarih ve geleneğinde önemli yer tuttıkları için bu toplulukların kimlik ve aidiyet duygularının oluşmasında kilit rol oynayabilir. Bu alanlar yerel toplumların bazı inançları ile özdeşleşmiş kutsal mekanları barındırır ve günümüze kadar devam etmiş olan ritüel mekanları olabilir (Berkes, 2012). Bu durumda bu mekanlar toplumsal sürdürülebilirliğe biyoçeşitlilik kadar katkı yapar. Eğer öyleyse doğa koruma çalışmaları bütün bu mekânları, buralardaki geleneksel ritüelleri, inançları ve bunlarla özdeşleşmiş peyzajları da kültürel miras olarak korumalıdır (Maffi, 2005). Bunun yapılabilmesi için doğa korumanın sadece biyolojik çeşitlilik perspektifi ile değil, bütün bu kültürel ve sosyal çeşitliliği de koruyacak şekilde daha bütüncül ve kapsamlı bir yaklaşımı temsil eden biyokültürel koruma perspektifi ile yapılması gerekmektedir. Bu yaklaşımda KDA'larda bulunan biyofiziksel özellikler yanında kültürel kaynakların ve toplumsal hafızanın da korunması mümkün olabilecektir (Pretty vd., 2009).

Bu açıklamalar doğrultusunda bu çalışma temelde Kazdağı Milli Parkı'nda doğa koruma uygulamalarının biyokültürel koruma perspektifini yansıtır, yansıtmadığını sorgulamaktadır. Çalışmanın temel argümanı şudur ki Türkiye'nin başka birçok korunan doğal alanında olduğu gibi Kazdağı Milli Parkı'nda da doğa koruma daha çok biyofiziksel unsurlara odaklanmış, kültürel süreçleri, kutsal alanları, dünyaca ünlü efsaneleri ve geleneksel ritüelleri doğa koruma pratiği içerisinde yeterince vurgulamamıştır. Çalışma, sosyal, kültürel ve kutsal kaynak değerlerinin doğa koruma pratiği içerisinde değerlendirilmesi gerektiğini savunan sınırlı Türkçe literatüre katkı yapmayı amaçlamaktadır.

Çalışmada bu Giriş bölümünden sonra biyokültürel çeşitlilik ve biyokültürel korumayı tartışan kavramsal çerçeve bölümüne yer verilmiştir. Devamında yöntem bölümünde araştırma alanı tanıtıldıktan sonra veriler ile veri toplama ve değerlendirme yöntemleri üzerinde durulmuştur.

Çalışmanın devamında Kazdağı Milli Parkı'nın yönetim planlarında olması gerektiği düşünülen kültürel kaynak değerlerine, kutsal doğal alanlara, efsane mekanlarına ve geleneksel ritüellere yer verilmiştir. Çalışmanın Sonuç bölümünde bütün bu kültürel çeşitliliği korumak ve doğa koruma girişimlerinin resmi bir parçası yapmak için yapılması gerekenlere değinilmiştir.

1.1. Kavramsal Çerçeve: Biyokültürel Çeşitlilik ve Biyokültürel Koruma

Doğal alanları koruma oldukça eski bir alışkanlıktır. Bazı insan topluluklarının tarihin ilk dönemlerinden beri kutsallık atfettikleri yerleri koruma altına aldıkları bilinmektedir (Berkes, 2004). Bu durum doğa korumanın ilk ve en eski şeklidir (Dudley vd., 2009). Ancak modern doğa korumanın ancak 19. Yüzyıl'ın ikinci yarısında ortaya çıktığı varsayılır. Nüfusun henüz çok artmadığı ve doğal kaynak kullanımının sınırlı olduğu sanayi devrimi öncesinde insanın doğa üzerindeki dönüştürücü ve tahrip edici etkisi kayda değer bir boyuta ulaşmamıştı. Aksine doğanın insan faaliyetleri üzerinde şekillendirici ve belirleyici etkilerinin daha önemli olduğu ifade edilmiştir. Çevresel determinizm denilen bu düşünce artık büyük ölçüde terk edilmişse de modern hali halen taraftar bulmaktadır (Diamond, 2022).

İnsan-doğa ilişkisinde asıl incelenmesi gereken etkinin insan faaliyetlerinin doğa üzerindeki değiştirici gücü olduğu düşüncesi ise 1850'lerden sonra ifade edilmeye başlanmıştır. 1850'li yıllarda ABD'nin Osmanlı elçisi olan George Perkins Marsh'ın yazdığı *İnsan ve Doğa* başlıklı kitabın insanın dağa üzerindeki tahripkâr etkilerini sistematik olarak ortaya koyan ilk çalışma olduğu bilinmektedir (Lowenthal, 2016). Marsh, uzun yüzyıllardır iskân edilen toprakların insan kullanımlarından gördüğü zararlara yer vermiştir (Marsh, 2003). Marsh'ın kitabının dünyada o yıllarda başlayan “doğa koruma çağını” açan kitap” olduğu iddia edilmiştir (Feltmate, 2006). Bu iddianın temelinde ABD'nin ilk doğa korumacılarının Marsh'ın fikirlerinden etkilenmiş olmaları ve bir anlamda onun öğrencileri olmasıydı. Gerçekten de ABD'de doğa koruma fikrinin temellerini atan John Muir, Theodore Roosevelt, Gifford Pinchot ve Henry David Thoreau Marsh'ın görüşlerinden derinlemesine etkilenmiştir (Fleischman, 2007). Doğa korumanın öncüleri sayılan bu isimlerin doğa koruma tasavvurunda doğayı “yabani” halinde olduğu gibi korumak esastı.

Doğayı “yabani” haliyle koruma fikri biyolojik çeşitliliğin ve doğal ekosistemlerin hiçbir insan müdahalesine izin vermeksizin olduğu gibi korunmasını öngörüyordu (Nash, 1967). Her ne kadar o zamanki koşullarda bu düşünce mantıklı görünse de zamanla bunun uygulanabilir olmadığı anlaşılmıştır (Leopold, 1949; Cronon, 1995). Bu değişimin altında yatan gerçek, doğal alanların sadece bozulmamış ekosistemler ve yüksek biyolojik çeşitlilik yanında bazı geleneksel toplumları da barındırıyor olmasıydı. O geleneksel toplumları dışlayan, onları yaşam alanlarından ayıran, göç etmeye zorlayan, geleneksel yaşam alışkanlıklarını değiştiren ve sonunda kültürlerini gerileten anlayışların aslında doğal alanların zarar görmesiyle sonuçlandığı anlaşılmıştır. 1970'lerden sonra kültürel ekoloji, politik ekoloji ve çevre sosyolojisi konularında yapılan birçok araştırma aslında insanların doğal olarak adlandırdığı birçok alanın aynı zamanda insanların uzun zamandır şekillendirdiği kültürel peyzajlar olduğunu göstermiştir (Phillips, 1998).

“İnsansız koruma” (Arı, 2024) ya da “kale koruma” (Brockington, 2002) olarak bilinen katı koruma anlayışı ile ilgili uygulamada çok sayıda problemle karşılaşılması üzerine uluslararası kuruluşlar doğa koruma anlayışında temel bir değişim öngören bazı kararlar almışlardır (Gül, & Kurdoğlu, 2021; Kurdoğlu, 2007). Önceleri geleneksel toplumların KDA'ların kaynaklarına bağımlı olduğu dolayısı ile onlarla yönetilmesi gerektiği düşünülürken son 20-30 yılda yapılan çalışmalarda aslında geleneksel toplumların KDA'larla ilişkilerinin bununla sınırlı olmadığı, bu ilişkinin çok daha kapsamlı ve karmaşık olduğu anlaşılmıştır (Saviano vd., 2018a). Bunun temel nedeni bazı durumlarda kültürel çeşitlilik alanlarının biyolojik çeşitlilik alanları ile örtüşmesi ve ikisi arasında ayrılmaz bir bağ olmasıdır (Maffi & Dilts, 2014).

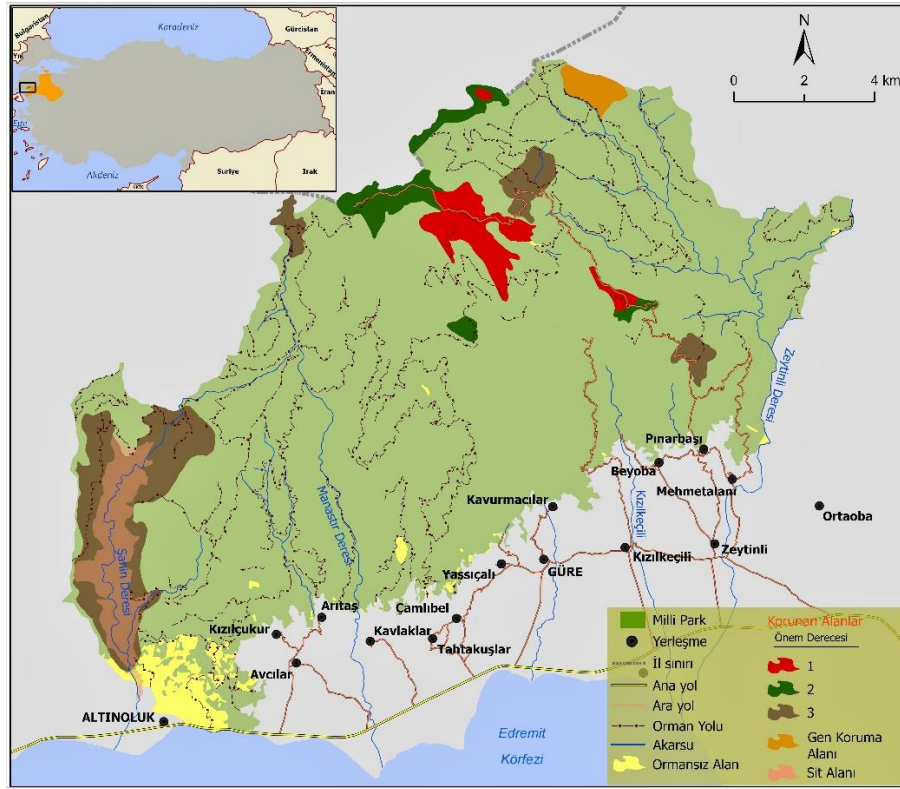
Biyokültürel çeşitlilik, “karmaşık bir sosyo-ekolojik uyum sistemi içinde birbiriyle ilişkili olan tüm biyolojik, kültürel ve dilsel yaşam çeşitliliğini içerir” (Maffi, 2012:5). Biyokültürel bakış açısı daha önce ihmal edilen maddi kültür öğeleri yanında somut olmayan kültürel mirası da içerir. Somut olmayan bu unsurlar geçmişten kalan yaşam tarzlarını, Geleneksel Ekolojik Bilgiyi (GEB), dini ritüelleri, sosyal ve kültürel uygulamaları, doğaya ilişkin kutsal inançları, geleneksel kutlama ve festival ya da panayırıları, bunlarla ilgili nesilden nesile aktarılan bilgileri, el ve gösteri sanatları ile bunlarla ilgili bilgi ve becerileri

de içerir (Lukawiecki vd., 2022; Nemoga vd., 2022). Biyokültürel yaklaşımda bütün bu kültürel çeşitliliklerin yaşatılması teşvik edilir, bunlara saygı duyulur ve sürdürülebilirliğinin sağlanmasına özen gösterilir (Bridgewater & Rotherham, 2019). Bu anlayışa göre kültürel çeşitliliğin zarar görmesi biyolojik çeşitliliğin de gerilemesi anlamına gelir.

2. Materyal ve Yöntem

2.1. Çalışma Alanı: Kazdağı Milli Parkı

Kazdağı Milli Parkı esas Kazdağı kütlesinin güney yamacını oluşturan alandaki biyolojik çeşitliliği, endemik türleri, jeomorfolojik özellikleri ve kültürel kaynak değerlerini korumak amacıyla 17.04.1993 tarihinde Bakanlar Kurulu kararı ile milli park ilan edilmiştir (Arı & Soykan, 2006a). Milli park doğuda Zeytinli Çayı, Batıda Mıhlı Çayı, kuzeyde Balıkesir-Çanakkale il sınırı ve güneyde de yaklaşık olarak Kazdağı eteklerindeki yerleşmeler ile sınırlandırılmış ve 21,452 hektarlık bir alanı kaplamaktadır. Kazdağları olarak bilinen dağ silsilesinin esas Kazdağı kısmı milli park ilan edildiği için milli parkın ismi de bu durumu yansıtır. Milli parkın içerisinde Hasaboğuldu Günübürlük Kullanım Alanı, Pınarbaşı Günübürlük Kullanım Alanı ve parkın hemen kuzeydoğusunda Kazdağı Göknaarı Tabiatı Koruma Alanı ve batısında Darıdere Tabiat Parkı bulunur (Şekil 1).



Şekil 1. Kazdağı Milli Parkı yer bulduru haritası ve korunan alanlar.

Milli park içerisindeki biyofiziki kaynak değerleri dikkat çekicidir. Şimdiye kadar Kazdağı'nda 32'si bu bölgeye endemik olan 800 taxa bitki tespit edilmiştir. Burada aynı zamanda kanyonlar, derin vadiler, tepeler ve uçurumlar gibi ilginç jeomorfolojik şekiller vardır. Alan yaban hayatı bakımından da oldukça zengindir (Satıl, 2009). Milli park içerisinde ve çevresindeki çeşitli doğal ve kültürel peyzajlar, Edremit Körfezi ve yakındaki Troya Milli Parkı önemli çekiciliklerdir. Kazdağları bölgesi astım başta olmak üzere çeşitli hastalıkları tedavi ettiğine inanılan bir iklime sahiptir. Kıynın hemen gerisinde 1776 metre yükseltiye ulaşan Kazdağı ısınma farkından dolayı Edremit körfezine özellikle sıcak yaz aylarında sağladığı serin esintisi sayesinde yörenin iklimatik konfor seviyesini yükseltir. Bunun sonucu olarak özellikle milli parkın ilanından sonra Edremit Körfezi kıyıları refah göçmenlerinin akınına uğramıştır. Refah göçmenlerinin buraya yerleşmesinin temel nedeni güzel manzara, temiz hava ve Kazdağı'nın bol su kaynakları gibi algılanan pozitif değerlerdir (Hurley & Arı, 2011). Bunun sonucu olarak bölgeye olan talep artmış ve bölge arazileri aşırı değerlenmiştir (Hurley & Arı, 2018). Mitolojide "bin pınarlı İda" olarak bilinen bölge zengin su kaynakları sayesinde gittikçe daha fazla refah göçmenini çekmektedir.

Bölgeye yerleşen refah göçmenlerine ek olarak yıllık 2.000.000'dan fazla turist de burayı ziyaret etmektedir (Özkan & Uzun, 2019; Uzun & Özkan 2019). Yerel ziyaretçilere ek olarak bu turistlerden 100.000'den fazlası milli parkı ziyaret etmektedir (Güney Marmara Kalkınma Ajansı, 2020). Bölge sahip olduğu altın rezervlerinden dolayı aynı zamanda uluslararası maden şirketlerinin de dikkatini çekmiş, milli park sınırlarına yakın mesafede altın aramaları ve çıkarımı yapılmıştır (Avcı, 2017; Hurley & Arı, 2011; Ilgar, 2025; Onay, 2025).

2.2. Araştırma Tasarımı

Bu çalışmada nitel araştırma yöntemlerinden birisi olan durum çalışması yöntemi kullanılmıştır. Durum çalışması bu çalışmada da olduğu gibi bize bir yerle ilgili konuların gerçek bağlamı içerisinde derinlemesine çalışılmasını sağlayan bir araştırma metodolojisidir (Creswell, 2009; Yin, 2018). Bu metodoloji coğrafi çalışmaların doğası gereği olan genellemeleri yapabilmek için ele alınan konuya bütüncül olarak bakılmasını olanaklı kılar. Bu yöntem anketler ya da deneysel yöntemlerle fark edilemeyen bağlam duyarlı ilişkiler ve süreçlerin anlaşılmasında daha avantajlı olarak kabul edilir (Creswell & Poth, 2018). Durum çalışması yöntemi metodolojik esneklik sağlar ve çalışma esnasında hipotezlerin değiştirilmesi ya da beklenmedik durumların ortaya çıkması gibi hallerde değişiklik yapılmasını olanaklı kılar. Böylece karmaşık ve çok değişkenli durumlar hakkında daha ayrıntılı analizler yapılmasını sağlar. Durum çalışması incelenen durumla ilgili ayrıntıların çalışılarak yeni teoriler geliştirilmesini de mümkün kılar (Flyvbjerg, 2006; Stake, 1995). Bu yöntem doğal ve kültürel faktörler arasındaki ilişki ve etkileşimleri daha iyi anlamaya imkân sağlayacağı düşünüldüğünden tercih edilmiştir. Böylece geliştirilen bütüncül bakış sayesinde çalışmanın hem güvenilirliği arttırılmış olur hem de derinlemesine analiz yapmak mümkün olur.

Bu çalışmada Kazdağı Milli Parkı'nda park yönetimi pratiği açıklanan bütüncül çerçevede incelenmiştir. Parkta ziyaretçi yönetiminin başlatıldığı 2001 yılından 2025 yılına kadar uygulanan yönetim modeli saha gözlemleri ve resmî belgelerden incelenmiştir. Park yönetimi ile ilgili olaylar katılımsız olarak gözlemlenmiş, yerel halkın parkı kullanım biçimleri önceki literatürden ve ilgili dokümanlardan elde edilen bulgulardan değerlendirilmiştir. Bu çalışma aslında alanda daha önce yaptığımız çok sayıdaki araştırma bulgularının biyokültürel bakış açısı ile yorumlanmasından oluşmaktadır. Çalışmada etik kurul izni gerektiren kişisel görüşmeler ya da kişisel veriler kullanılmamıştır, bu veriler ilgili dokümanlarda ve önceki literatürde yer aldığı şekli ile burada kullanılmıştır. Park yönetiminde nelerin ön plana çıkartıldığı ve hangi kaynak değerlerinin yeterince vurgulanmadığı ya da görünür hale getirilmediği doküman analizi yöntemi ile tespit edilmiştir. Milli parkla ilgili incelenen web sayfaları şunlardır:

- <https://www.kulturportali.gov.tr/turkiye/balikesir/gezilecek yer/kaz-dagi-da-dagi>
- <https://ekotaban.tarimorman.gov.tr/alan/54>
- <https://www.facebook.com/KazdagiMilliParkiSefligi>

Web sayfaları yanında tanıtım bültenleri, sosyal medya bildirimleri, uzun devreli gelişme planları ve milli parklar uygulamasında alanla ilgili yer alan bilgiler incelenmiştir. Sonuçta elde edilen verilen betimsel ve tematik analiz yöntemleri ile değerlendirilmiştir.

3. Bulgular ve Tartışma

3.1. Kazdağı Milli Parkı'nda doğa koruma

Parkin korunmasındaki temel motivasyon biyoçeşitliliği ve peyzaj değerlerini koruma ve turizmdir. Bu amaçla parkta bir nevi "kale koruma" denilen doğa koruma modeli uygulanmaya başlanmıştır. Bu doğrultuda 2001 yılından itibaren yerel halkın parka girişi yasaklanarak, alan kılavuzluğu sistemi başlatılmış, bu kılavuzlar eşliğinde ancak izinli ve kontrollü girişlere izin verilmeye başlanmıştır. Milli park ilan edilen alana önceden serbestçe giren, buralarda ormancılık yapan, hayvanlarını otlatan, yakacak ve yapacak odununu temin eden Odun Dışı Orman Ürünleri (ODOÜ) toplayan yerel halk artık bunları yapamaz duruma gelmiştir (Arı & Soykan, 2006b). Bir anlamda yerel halkın parka girişleri kısıtlanmış ve dağ ile olan geleneksel ilişkileri kesilmiştir. Hatta geleneksel olarak ağustos ayında dağın zirvesinde yapılan Sarıkız etkinliklerine de önce kısıtlamalar getirilmiş son birkaç yıldır da tamamen

yasaklanmıştır. Diğer taraftan parkta turizm altyapısı geliştirilmiş ve daha fazla turist alana girişi teşvik edilmiştir. Böylece yerel halkın parka girişi engellenirken, turistlerin parka girişi özendirilmiş, bölgede insan-çevre ilişkisi kökten değiştirilmiştir (Dereli & Arı, 2012).

Yeni düzenleme milli parkı bir turist destinasyonuna dönüştürmeyi hedeflemiş ve bunu biyofiziki özellikler üzerinden planlamıştır. Milli parkın kaynak değerleri olarak bitki çeşitliliği ve endemik bitkilere, jeomorfolojik ve iklimatik özelliklere vurgu yapılmıştır. Bu yaklaşım milli park için yapılan uygulamada da görülebilmektedir. Nitekim Doğa Koruma ve Milli Parklar Genel Müdürlüğü tarafından hazırlanan milli park uygulamasında Kazdağı Milli Parkı için hazırlanan kısımda parkın biyoçeşitliliğine vurgu yapılmış ve diğer doğal unsurlarla ilgili düzenlemeler gösterilmiştir. Uygulamada milli park içerisindeki foto safari rotaları, kamp alanları, manzara seyir noktaları, yürüyüş rotaları ve endemik bitki gözlemciliği rotaları gösterilmiştir. Ancak efsaneler, kutsal doğal alanlar Sarıkız anma tören alanları gibi kültürel unsurlarla ilgili herhangi bir rota belirlenmemiş, işaretleme yapılmamıştır. Kanaatimizce Kazdağı aslında fiziki anlamda bir dağ kütlesi olmasına rağmen, bugün sahip olduğu tanınırlığı büyük ölçüde efsanelere, kutsal doğal alanlara ve tarihi olaylara borçludur. Yani burası doğal bir peyzaj olduğu kadar aynı zamanda kültürel bir peyzajdır. Ancak doğa koruma pratiğinde bu gerçek sistematik bir şekilde göz ardı edilmektedir.

3.2. Kazdağı Milli Parkı'nda Biyokültürel Çeşitlilik Unsurları

3.2.1. Kazdağı Milli Parkı Çevresinde Yerel kültürler

Kazdağı Milli Parkı çevresinde yaşayan yerel halk son 40-50 yıla kadar çevredeki çoğu kırsal olan yerleşmelerde yaşıyordu ve milli park alanını çeşitli nedenlerle yoğun bir şekilde kullanıyordu. Zaten parkı güneyden çevreleyen köy/mahalle yerleşmelerindeki yerel halk dağ ile içedir ve yüzyıllardır dağın kaynaklarına bağımlı olarak yaşamaktadır. Bölgede geçmişte ya da şimdi belediye yerleşmeler olan Edremit, Kadıköy, Zeytinli, Akçay, Güre, Altınoluk ve Küçükkuşu ikincil konutların ve mevsimlik turizmin son zamanlarda arttığı, aynı zamanda ülkenin farklı yerlerinden gelen refah göçmenlerinin ve emeklilerin yerleştiği yerleşmeler durumundadır. Bütün bu yerleşmelerde yaz ve kış nüfusu arasında 5-10 kat fark oluşmaktadır (Özkan & Uzun, 2019). Bölgenin cazip bir ikincil konut ve yerleşme alanı olması büyük ölçüde kıyı kesiminde gelişen deniz turizmi, hava kalitesinin yüksek olduğuna dair algı, hem kentsel hem de kırsal yaşamın bir arada olması, su kaynaklarının bolluğu ve Edremit Kocaseyit Havalimanı gibi altyapı ve ulaşım hizmetlerinin iyileştirilmesidir. Son zamanlarda deniz turizmi yanında milli parka bağlı doğa turizminin de gelişmesi bölgeye olan ilgiyi daha da arttırmıştır.

Edremit Körfezi kıyı kesimdeki bu kentsel yerleşmelerde gözlenen gelişmeler yavaş da olsa Kazdağları eteklerine doğru olan kırsal yerleşmelerde de görülmeye başlanmıştır. Milli parkın güney sınırında doğudan batıya doğru Mehmetalanı, Pınarbaşı, Beyoba, Kavurmacılar, Kızılkeçili, Çamlıbel, Tahtakuşlar, Kavlaklar, Arıtışı, Yassıçalı, Avcılar, Narlı, Doyran, Adatepe, Adatepebaşı ve Bahçedere köy/mahalleri bulunur. Buradaki köyler tarihsel olarak iki kültürel gruptan biriyle özdeşleşmiştir: Yörükler ve Türkmenler. Bu iki grubun kökenleri ve kültürel özellikleri farklılık gösterir. Yörükler Sünni Müslümanlar olarak, Osmanlıların 1336-37'de bölgeyi ele geçirmesinin ardından bölgeye Doğu'dan yerleşmeye başlamışlardır. Bu yeni göçmenler, bölgenin dağ eteğindeki bölgelere yerleşerek buralarda küçükbaş hayvancılık yapmaya başlamışlardır. Çoğunlukla göçebe halklar olarak, yazın yüksek rakımlardaki yaylalara çıkıp, kışın daha düşük rakımlı kıyı bölgelerine dönmüşlerdir. Bu ritmik hareket 1960'lara kadar devam etti (Arı & Soykan, 2006a). Bunlar, küresel gelişmelerden ve özellikle kıyı bölgelerindeki turizm gelişmelerinden aynı anda etkilenen açık toplumlardır. Dini inançlar açısından Türk halkının çoğunluğuna benzeyen bu mahalleler, benzer geçmişlerden gelen ve benzer inançları paylaşan yeni gelenlerin rahatça yerleştiği alanlardır. O nedenle bu yörük yerleşmelerinde hızlı bir değişim yaşanmaktadır (Hurley & Arı, 2018).

Bölgedeki diğer kültürel grup ise Türkmenlerdir ve bunlara genellikle Tahtacı Türkmenleri ya da ağaç erleri isimleri verilir. Sümer'e (1993) göre, Türkmen halkı Orta Asya'daki Türkistan'ın ormanlık bölgelerinde yaşamaktayken 13. yüzyılda Anadolu'ya göç ederek Toros Dağları'na yerleşmiş ve ormancılık yapmıştır. Fatih Sultan Mehmet, İstanbul'u ve Midilli'yi fethetmek için gemiler inşa etmeye karar verdiğinde, bu insanları Toros Dağları'ndan Kazdağı bölgesine getirtmiş ve gemilerin 1453'te Haliç'e yüzdürüldüğü keresteleri hazırlamışlardır. İstanbul'un fethinden sonra Türkmenler Kazdağı'nda

kalmaya karar vermişlerdir (Duymaz, 2001). Bu Türkmenler inançları ve gelenekleri bakımından çevrelerindeki Sünni topluluklardan farklı olan Alevi'dirler. Bu durum Yörük yerleşimleriyle çok az kültürel temas kuran kapalı topluluklar halinde yaşamalarına neden olmuştur. Nitekim, kapalı toplum sistemleri, dışarıdan gelenlerin serbestçe girmesine izin vermez ve köyleri sıklıkla Sünni köylerinden kesin olarak ayrılmıştır. Ekonomik etkileşimler dışında, sosyal etkileşimler genellikle dini liderleri tarafından teşvik edilmemiştir (Hurley & Arı, 2018). Dede olarak adlandırılan bu dini liderler, Alevi toplumları üzerinde güçlü bir etkiye sahiptir (Eröz, 1977). Son zamanlarda bu yapıda zayıflamalar olsa da Türkmenlerin karar alma süreçlerine kodlanmış uygulamalar halen vardır. O nedenle bu yerleşmeler diğer gruptaki yerleşmeler kadar hızlı değişmemektedir. Buralarda toplum örtülü bir şekilde buralara yerleşmek isteyen refah göçmenlerini kontrol etmektedir.

Her iki kültürel grup da tarih boyunca Kazdağları ile sıkı ilişkilere sahip olmuş ve kaynakları farklı şekillerde kullanmıştır. Türkmenler geleneksel olarak ağaç işleri yaptıkları için dağla iç içedirler. Ormancılığın tarihi olarak önemli olduğu bu yörede Türkmenlerin varlığı her zaman önemli olmuştur. Onlar ormanları işlemiş ve doğaya yakın bir yaşam sürmüştür. Bu yaşam esnasında tepeler, ağaçlar, dereler gibi dağın farklı kısımlarına manevi anlamlar yüklemişlerdir. Bu grup araziye yabancılara satmanın bugüne kadar kendilerine özgü kültürlerini koruyan büyü zedeleyebileceğine inandığı için dışarıya daha kapalıdır (Arı & Hurley, 2018). Benzer şekilde Yörükler de İslamiyet'ten önceki dönemin kültürel inanışlarını yansıtan bazı uygulamalarla dağın çeşitli kısımlarına kutsallık atfetmektedir. Onlar da buralara yerleştikten sonra geleneksel yaşamlarını devam ettirmiş, özellikle keçi sürüleri beslemiş ve dağı günlük yaşamları için kullanmışlardır.

Yörede Edremit körfezi kıyılarından başlayan zeytinlik alanlar yaklaşık 400 m yükseltiye kadar dağ eteklerine doğru devam eder. Zeytinlikler arasındaki kızılcamlar 400-500 metreden sonra yerlerini karaçam-meşe ormanlarına, daha yüksek irtifalarda da çam-köknar ormanlarına bırakır. Dağın zirve kısımlarında Alpin çayırlar ve açık alanlar yer alır. Burada 1950'ler kadar bir yandan kıyıda zeytinliklerde ülkenin en kaliteli yağının üretildiği zeytinler yetiştirilirken, bir yandan da ormancılık yapılıyor ve çeşitli tarımsal ürünler yetiştiriliyordu (Şanlı vd., 2009). O tarihten sonra kıyı alanlarda turizmin gelişmeye başlaması yerel kültürel ekolojide ilk büyük değişimi yapmıştır. Önceleri çoğunlukla dağla özdeşleşen ekonomik faaliyetler, kıyı alanlarının aniden değerlendirilmesi ile değişmeye başlamıştır. Sonuçta kıyıda zeytinlik alanlar yavaş yavaş ikincil ve tatil konutlarına dönüşmeye başlamıştır. Kazdağı Milli Parkı'nın 1993 yılında ilan edilmesi ile yörede ikinci büyük değişim başlamıştır. Bu değişim temelde yöre insanının artık "yüzünü dağa değil, denize çevirdiği" bir dönemi işaret eder.

3.2.2. Kazdağı peyzajında efsane mekanları

Kazdağı, yerel halk arasında anlatılan ve bazıları kitaplara ve filmlere de konu olmuş efsaneler nedeniyle bir bütün olarak kutsal bir peyzaj olarak algılanmaktadır (Arı, 2020). Efsaneler binlerce yıl öncesine dayanır ve bir kısmı İslam öncesi dönemin izlerini taşır. Bunlar yerel topluluklar arasında bir şekilde devam etmiş ve zamanla yenileri eklenmiştir. Günümüzde, parkın yakın çevresinde yaşayan her iki ayrı kültürel grup da Orta Asya'dan getirdikleri inançlara ek olarak bu eski görüşlerin bir kısmını da miras olarak almışlardır. Zaten Kazdağı isimlendirmesi de bir efsaneye dayanır. Bu efsaneye göre Gök Tanrı inancında en yüksekten uçan kuşun kaz olduğuna inanıldığı için dağa da bu isim verilmiştir. Bu şekilde, dağ aracılığıyla Tanrı ile bir bağlantı kurulur. İslam öncesi Türk inancında, dağlar Gök Tanrı'ya yakınlıklarından dolayı ve Tanrı'nın dağlarda yaşadığına inanılması nedeniyle kutsal kabul edilirdi. Ayrıca dağların, çevrelerinde yaşayan insanların koruyucuları olduğu düşünülürdü. Tanrı ile ilgili ritüellerin çoğu dağların tepelerinde yapılırdı. Bu şekilde Türkler, Orta Asya'da kullandıkları isimleri Anadolu'daki yerlere vermiş ve bu yerlerde kültür oluşturmuşlardır (Duymaz, 2001). Tepelere ve zirvelere birçok mezar inşa edilmiş ve ünlü kişiler bu yerlere gömülmüştür. Kazdağı peyzajı da kutsal kişilerin mezarlarını barındıran bu kutsal tepelerle doludur (Arı, 2020). Bu yerler, yerel toplulukların kurban kesmelerine, dua etmelerine ve kutsalla temas kurmalarına olanak tanıyan doğal tapınaklar haline gelmiştir (Duymaz & Şahin, 2008). Yörede bu yerlerle özdeşleşmiş çok sayıda efsane anlatılmaktadır.

Zeus efsanesi Truva Savaşlarında Zeus'un pozisyonunu konu alır ve bu efsanede Kazdağı'nın zirvesi Zeus'un mekânı olarak tarif edilir (Kapukaya, 2018). İlyada Destanı'nda Zeus'un İda dağından

hükmettiği belirtilir. Hatta Zeus'un savaşı buradan izlediği ve gerektiğinde buradan savaşa müdahale ettiği de belirtilir (Homeros, 2014). O nedenle Zeus'un mekânı olarak bilinen Kartalçimen ve hemen güneyindeki Gargaros Tepe (Karataş Tepe-Kazdağlarının en yüksek noktası) kutsal kabul edilir. Bu kutsallık sonraki kültürlere de aktarılmıştır, çünkü Zeus'un mekânı olarak bilinen Kartalçimen Sarıkız'ın kazlarını yaydığı Kazavlusu ile aynı yerdir. Kazdağlarında milli park sınırları dışında birçok yerde de tarih öncesi olaylarla ilişkilendirilen kutsal mekanlar vardır (Ilgar, 2024).

Sarıkız efsanesi yörede en bilinen ve maddi peyzajda hatırlatıcıları olan efsanedir. Efsaneye göre kendisine iftira atılan, bu yüzden babasının dağa terk etmiş olduğu bir kızın hayatının geri kalanını dağda geçirmesi konu edinilir. Sonunda babası durumu fark edip kızının yanına dağa gider, kızının artık ermiş olduğunu fark eder, ömürlerinin sonuna kadar orada birlikte yaşar ve ölürler. Sembolik mezarları da dağın en yüksek tepelerinden ikisi (Baba Tepe ve Sarıkız Tepe) üzerindedir. Bugün milli parkın en çok ziyaretçi çeken noktası da Sarıkız Türbesi'nin üzerinde bulunduğu Sarıkız Tepe'dir (Arı & Soykan, 2006a). Aynı şekilde Sarıkız'ın dağda yaşarken kaz sürülerini güttüğüne inanılan Kaz Avlusı da dağın zirvesindedir.

Hasan Boğuldu efsanesi zengin ve şehirli bir kişi olan Hasan ile Kazdağı eteklerindeki köylerden birinden olan köylü kızı Emine'nin aşkını anlatır. Geleneksel olarak, şehirlilerin yeterince güçlü ve dayanıklı olmadığına inanıldığı için böyle bir evliliğe izin verilmez. Hasan'ın Emine ile evlenebilmesi için gücünü göstermek üzere bir çuval tuzu deniz kıyısından dağın tepesine kadar sırtında taşıması gerekir. Ancak Hasan, bu zorlu görev sırasında Kızılkeçili Çayı vadisinden yukarıya tırmanırken bir kayanın yerinden kopması üzerine aşağıdaki gölete düşerek boğulur. Buna çok üzülen Emine, olay yerine gelir ve göletin yanında olan ve daha sonra Emine Çınarı olarak adlandırılan bir çınar ağacına kendini asarak intihar eder. Bugün Hasan Boğuldu Günübirlik Kullanım Alanı içerisinde kalan bu gölet ve ağaç, hikâyenin edebiyat ve filmlerde yeniden üretilmesi nedeniyle ülke çapında tanınmış, turistlerin de uğrak noktalarından biri haline gelmiştir.

Elif kaçan efsanesine göre yöredeki iki farklı gruptan bir erkek diğer gruptan bir kıza sevdalanır. Ancak farklı kültürel gruplar arasında evlilik yasaktır. Bu efsaneye göre, gençler evlenmeye karar verdiğinde, iki topluluk da bu karara karşı çıkmış; gençler bunu üzerine dağa kaçmıştır. Her iki taraf da gençleri yakalamak için aramaya çıkmış, ancak bir Dede'nin kerameti olarak aniden yoğun bir sis çökmüş ve saklandıkları yeri örtmüştür, böylece arayanlar gençleri bulamayıp, geri dönmüşlerdir. Milli parkın doğu tarafında olayın geçtiğine inanılan yere Elif Kaçan ismi verilmiştir (Arı & Soykan, 2006b).

Bu çalışmanın en çarpıcı bulgularından birisi park yönetiminin bütün bu efsane mekanlarına kayıtsız kalması, buralarda hiçbir işaretleme ya da hatırlatıcı unsura yer vermemesi ve tanıtım materyallerinde bu yerlerin ihmal edilmesidir. Aynı şekilde Kazdağları Milli Parkı isimli sosyal medya hesabından yapılan paylaşımlar arasında kültürel konular, geleneksel uygulamalar, kutsal mekanlar ve efsaneler hakkında herhangi bir paylaşıma denk gelinmemiştir.

3.2.3. Kutsal Doğal Alanlar

Kazdağları peyzajlarında bazıları yukarıda değinilen efsane mekanları olmak üzere çok sayıda kutsal doğal alan vardır. Bu kutsallıklar tarihin eski dönemlerinden beri burada yaşamış toplulukların geliştirip, kendilerinden sonraki nesillere aktardıkları, kültürler ve kuşaklar arası devamlılık gösteren uygulamalardır. Kazdağlarında kutsal doğal alanlar çeşitli kategorilere ayrılmaktadır. Çeşitli nedenlerle tepeler, peyzajlar, ağaçlar, yatırlar ve bazı su kaynakları kutsal sayılmaktadır (Arı, 2020). Kutsal mekanlardan birisi tepelerdir. Kazdağı peyzajında yukarıda değinildiği gibi efsanelerin geçtiği ya da efsane kahramanlarının yaşadığı ya da ölümlerinden sonra defnedildikleri birçok tepelik alan kutsal sayılmaktadır. Bunlardan Sarıkız Tepe, Baba Tepe ve Karataş Tepe gibi bazıları efsanelerin yaşadığı mekanlardır. Bazıları ise kerameti olduğuna inanılan dini kişilikleri ile toplumda öne çıkan kişilerin defnedildikleri genellikle tepelik alanlardır. Bazıları milli park içerisinde bazıları da park sınırları dışında olan bu yerler Dilek Dede, Kekli Dede, Şıp Şıp Dede, Kireç Dedesi, Kaşıkçı Dede, Yaren Dede, Hüseyin Dede, Yağmur Dede, Garip Dede gibi isimler verilen ve genellikle anıt mezarlarla peyzajda kendini belli eden yerlerdir.

Tepelere ek olarak bazı geniş peyzajlar da kutsal sayılır. Örneğin Zeus'un mekânı olduğuna inanılan Kartal Çimen kutsal sayılır ve bu kutsallık önceki toplumlardan şimdi yörede yaşayanlara aktarılmıştır. Bu alanda her yıl ağustos ayında Sarıkız Etkinlikleri yapılır. Bu etkinlikler sırasında yörede yaşayan Alevi topluluklar Kartal Çimen'e Sünni topluluklar da Güllüce denen zirve düzlüğünün hemen gerisindeki mevkiye çıkar, burada konaklar, adaklar adar, kurbanlar keser, dua ederler. Bir hafta 10 gün süren bu etkinliklerle ilişkili mekanlar da yöre halkı tarafından kutsal mekanlar olarak bilinir (Arı, 2004).

Yörede bazı ağaçlara da kutsallık atfedilir. Örneğin Kavurmacılar köyünün güneyindeki düz alanda bulunan Gelin Çamı kutsaldır. Yöresel inanışa göre köyde evlenen kızlar düğünden hemen sonra bu çam etrafında 7 kez dönerse doğurganlıkları artar ve hemen çocuk sahibi olabilirler. Avcılar köyünden milli parka giden yol üzerinde bulunan ve gövdesinden sürekli reçine akan Ağlayan Çam ağacı da kutsal sayılır. Yerel inanışa göre bu ağaç yüzyıllar önce bir olaya şahit olmuş ve ağlamaya (reçine akıntısına) başlamış, halen de ağlamaktadır. Hasboğuldu göletinin hemen yanında bulunan Emine Çınarı da anlatılan olayla ilgili kutsal bir ağaç olarak kabul edilmektedir. Bu kutsal ağaçlara gün geçtikçe yenileri de eklenmektedir. Bunlardan birisi Kartal Çimen'den Sarıkız Türbesine giden yolun başlangıcında bulunan Yalnız Çam Ağacı'dır. Sarıkız ritüelleri için bölgeye gelen bir kadın, rüyasında bu ağacın altında kutsal bir kişinin mezarı olduğunu ve o kişinin kendisinden rahatsız edilmemesi için üzerindeki çadırları kaldırmasını istediğini görmüştür. Bunun üzerine oradaki çadırları kaldıran kadın, Yalnız Çam'ın altına taşlar dizerek sembolik bir mezar yapmıştır. Bu ağaca her yıl Sarıkız etkinlikleri için gidenler artık ip, eşarp ya da çaput bağlamakta, dilek dilemektedir (Arı, 2020).

Kazdağlarında bazı su kaynaklarının da kutsal olduğuna inanılır. Bunların başlıcaları Kartal Çimen Çeşmesi, Sütüven Şelalesi, Dede Pınarı, Şıp Şıp Dede'dir. Dağın zirve düzlüğü olan Kartal Çimen'deki çeşme kutsal kabul edilir, çünkü suyunun "Sarıkız Şerbeti" olduğuna inanılır ve kitabesinde bu sudan içenlerin şifa bulacağı yazılıdır. Hasan Boğuldu efsanesinde Hasan'ın boğulduğuna inanılan gölet kutsal kabul edilir ve burası milli park içerisinde en çok ziyaret edilen yerlerden birisidir. Buranın birkaç yüz metre aşağısındaki Sütüven Şelalesi de kutsaldır. Şelalenin sularının dağın tüm tarihine tanıklık ettiğine ve burada yaşamış eski medeniyetlerin bu suya taptığına inanılır. Edremit ilçesinin hemen batısında bulunan bir Dede türbesinin yanındaki suyun çıkardığı sesin, bu mekânın Şıp Şıp Dede olarak adlandırılmasına kaynaklık ettiğine inanılmaktadır (Arı, 2020).

3.3. Tartışma

Türkiye'de doğa koruma pratiği halen biyofiziki faktörler üzerine kuruludur. Yapısal olarak doğa koruma ormanların, biyolojik çeşitliliğin, yabani hayvan ve bitki türlerinin korunmasını daha fazla önemsemektedir (Gül vd., 2024). Doğa koruma konusunda çalışan ilgili kamu kuruluşlarının çalışanları da bu değerleri korumak üzere eğitilir ve ilgili kuruluşlarda görev alırlar. Ancak yukarıda değinildiği üzere KDA'lar sadece biyolojik çeşitliliği ve fiziki özellikleri değil, GEB'i, sürdürülebilir insan-çevre ilişkilerini, somut ve somut olmayan kültürel varlıkları, mekanları ve süreçleri de içerir. Biyolojik çeşitlilik kaybı şüphesiz önemli sonuçlar doğuracaktır, ancak kültürel çeşitlik kaybı da benzer sonuçları doğuracaktır. Nasıl ki doğayı korumak üzere çeşitli uluslararası girişimler yapılmışsa, küreselleşmenin getirdiği tekdüzeliğe karşı kültürel çeşitliliği ve kültürel varlıkları korumak için de uluslararası ve ulusal girişimler, sözleşmeler ve anlaşmalar yapılmıştır.

Genelde Kaz dağlarının özelde ise Kazdağı Milli Parkı'nın doğal bir peyzaj olduğu kadar kültürel bir peyzaj olduğunu ortaya koyan çok sayıda akademik çalışma vardır (İlgar, 2024; Kahyaoğlu, 2022; Soylu vd., 2024; Şahin, 2014; Yolcu, 2022; Yolcu & Aça, 2022). Bu çalışmalar Kazdağı Milli Parkı içerisinde ve çevresinde çok sayıdaki kültürel varlığı, kutsal alanları ve geleneksel tören ve ritüelleri kayıt altına almıştır. Burada yaşanan her iki kültürel grup da yüzyıllardır doğa ile iç içe yaşamaktadır ve kendi gelenek ve uygulamaları ile doğal kaynakları korumaktadır. Eğer öyle olmasaydı 1993 yılında ilan edilen milli park içerisinde korunacak bir kaynak kalmayabilirdi. Bölgede milli park ilan edildiğinde yerel halka buranın korunması gerektiği, aksi taktirde doğal kaynakların zarar göreceği söylendi. Kendilerinin geleneksel yaşam şekilleri değiştirildi, dağa serbestçe gidip-gelişleri engellendi, dağın kaynaklarını kullanmaları yasaklandı ve yüzyıllardır buradaki insan-çevre etkileşiminin ortaya çıkardığı, hikayeler, efsaneler, kutsal mekanlar ve bunlarla ilgili somut olmayan kültürel miras geri plana itildi. Ancak böyle

bir yaklaşım sürdürülebilir kalkınma hedeflerine ulaşmada yetersiz kalacaktır, çünkü bu hedefler toplumun ekonomik, sosyal ve kültürel refahının birlikte düşünülmesini gerektirmektedir.

Doğa koruma günümüzde gittikçe daha fazla sosyal bilim yaklaşımını benimseyen bir dönüşüm yaşamıştır (Bennet vd., 2017). Bu dönüşüm daha önce ihmal edilen sosyal bilim yaklaşımının doğa koruma çalışmalarına entegre edilmesini önermektedir (Bennett & Roth, 2019; Chua vd., 2020; Sanborn & Jung 2021). Buna göre sosyal bilim yaklaşımı insan ve doğa arasındaki ilişkileri anlamaya ve koruma uygulamalarını ve sonuçlarını iyileştirmeye özgün katkılar sağlayabilir. Ancak sosyal bilimlerin doğa korumaya anlamlı bir şekilde entegre edilmesi önünde çeşitli engeller bulunmaktadır. Bu engellerin kaldırılması hem doğa korumayı daha bütüncül hale getirecektir hem de sürdürülebilir kalkınma hedeflerine ulaşılmasını kolaylaştıracaktır.

Kazdağı Milli Parkı özelinde baktığımızda park yönetimi önünde duran birçok sosyal konu doğa korumanın merkezine oturtulmadığı için park yönetimine ve idari yapıya önemli zorluklar çıkarmaktadır. Parka izinsiz girişlerin yasaklanmasından sonra yerel halkın park alanına giriş çıkışlarının düzenlenmesi, yerel kılavuzların seçimi, eğitimi ve kılavuzluk sisteminin işletilmesi, park alanında kalan özel mülklerin kullanımı, her yıl dağın zirvesinde, milli park içerisinde yapılan konaklamalı geleneksel Sarıkız etkinlikleri, milli park içerisinde kalan gününbirlik kullanım alanlarındaki faaliyetler, parkın çeşitli noktalarından parka kaçak ve izinsiz girişler, yöre halkının ODOÜ'lerini izinsiz toplaması, park içerisindeki su kaynakları üzerindeki kadim haklar, başka KDA'larda olduğu gibi (Akten & Gül, 2014) parkın belli bölümlerinin yılın belli zamanlarında taşıma kapasitesinin üzerinde ziyaretçi girmesi gibi sorunlar biyoçeşitliliği koruma yanında park yönetiminin sürekli olarak karşılaştığı sorunlardan bazılarıdır. Bunlar doğası gereği sosyal bilim konularıdır, ancak Türkiye'de doğa koruma yönetiminde bu tür sorunları çözme konusunda eğitim almış sosyal bilimciler çalıştırılmamaktadır. O nedenle yerel halk ile park yönetimi arasında zaman zaman şiddetlenen anlaşmazlıklar yaşanmıştır (Arı & Soykan 2006b).

4. Sonuç ve Öneriler

Kazdağı Milli Parkı ile ilgili gözlemler ve incelenen dokümanlar milli parkta uygulanan doğa korumanın alanın biyolojik çeşitliliği, endemik bitkileri, yaban yaşamı ve jeomorfolojik ve hidrolojik özelliklerine odaklanıp, alanda yüzyıllardır gelişen ve yaşayan yerel kültürleri, ritüelleri, kutsal mekanları ve GEB'i yeterince vurgulamadığını göstermektedir. Doğa koruma, günümüzde yalnızca biyolojik çeşitliliğin devamlılığı için değil, aynı zamanda ekosistem hizmetlerinin sürekliliği, insan refahı ve kültürel değerlerin korunması için de kritik öneme sahiptir. O nedenle sadece biyolojik çeşitlilik, yabani türler, jeomorfolojik ve hidrolojik özellikler gibi biyofiziki özellikler üzerine odaklanan bir doğa koruma pratiği yerine daha kapsamlı ve bütüncül koruma sağlamayı vadeden biyokültürel bir yaklaşım benimsenmelidir. Kültürel yerler ve olaylar insanların çoğunda merak ve ilgi uyandırır. Biyokültürel yaklaşımda korunan doğal unsurlarla beraber KDA'lar ve çevresinde yaşayan yerel toplumların geleneksel yaşam tarzları, kültürü, GEB'i ve somut ve somut olmayan kültürel mirası da korunmuş olacaktır. Bu çalışma sadece biyolojik çeşitlilik üzerine bina edilmiş bir doğa korumanın Kazdağı Milli Parkı'nda geleneksel insan-çevre ilişkilerini gerilettiği, yerel toplulukların dağ ile olan ilişkilerini zayıflatarak burayı bir turizm destinasyonuna çevirdiği, geleneksel kutsal mekanların, efsanelerin ve ritüellerin bu tür bir korumada geri plana itildiği ve toplumun uzun dönemli sosyal refahının zarar gördüğünü ortaya koymaktadır.

Kültürel çeşitliliğin korunması ve sonraki nesillere aktarılması biyolojik çeşitliliğin korunmasından daha az önemli değildir. Sürdürülebilir kalkınma hedeflerine ulaşabilmek için bunun bir zorunluluk olduğu düşünülmektedir. Bunun yapılabilmesi için bugünkü doğa koruma yaklaşımının değiştirilerek sosyal bilimlere de içeren bir yaklaşımın benimsenmesi önerilmektedir. Biyokültürel yaklaşım olarak adlandırılan bu yeni yaklaşım doğa koruma pratiğinin başından itibaren planlama, koruma ve uygulama aşamalarının her birinde sosyal bilim araştırmalarının sonuçlarının kullanılmasını gerektirmektedir. Bunun için doğa koruma kurumlarındaki sosyal bilim kapasitesi artırılmalı ve sosyal bilimcilerin daha etkin olduğu disiplinler arası çalışmalar yapılmalıdır. Doğa korumacılar ve ilgili kurumlar sosyal bilimcilerle yüzeysel bir bağ kurmak yerine onların KDA'lardaki sosyal sorunlar konusunda araştırma yapmalarını teşvik etmeli ve bu araştırmaların sonuçlarını kendi uygulamalarında kullanmalıdır.

Böylece ortaya çıkan biyokültürel yaklaşım ekolojik olarak daha etkili ve sosyal açıdan daha adil bir korumayı mümkün kılacaktır.

Bilgi Notu

Makalede ulusal ve uluslararası araştırma ve yayın etiğine uyulmuştur. Çalışmada etik kurul izni gerekmemiştir.

Yazar Katkısı ve Çıkar Çatışması Beyan Bilgisi

Herhangi bir çıkar çatışması bulunmamaktadır.

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Viewing Nature Conservation from a Biocultural Diversity Perspective: An Evaluation Based on Kazdağı National Park

Summary

1. Introduction

Over the past 200 years, attempts have been made to protect natural regions from harmful effects, even though human activity has increased this degradation (Dudley, 2008). For over a century, beginning in 1872—the year formal nature conservation is said to have started—nature conservation efforts concentrated on protecting biodiversity and the natural structure of ecosystems. But throughout the past forty to fifty years, they have started to concentrate on cultural concerns. Sacred areas connected to indigenous people's beliefs are found in Natural Protected Areas (NPAs), which may also be ceremonial sites that have endured to this day (Berkes, 2012). As a result, these areas support social sustainability just as much as biodiversity. If this is the case, natural conservation initiatives must acknowledge and save all these areas as cultural heritage, together with their traditions, customs, beliefs, and related landscapes that lead to a biocultural approach (Maffi, 2005). The main question raised by this study is whether Kazdağı National Park's nature conservation methods represent a biocultural conservation viewpoint. The main contention of the research is that, while biophysical protection has been the main emphasis of environmental conservation in Kazdağı National Park, cultural processes, sacred locations, well-known legends, and traditional rites have not received enough attention.

1.1. Conceptual Framework: Biocultural Diversity and Biocultural Conservation

The idea of preserving nature in its "wild" state envisions preserving biodiversity and natural ecosystems as they are, without allowing any human intervention (Nash, 1967). While this idea seemed logical at the time, it has become clear over time that it is impractical (Leopold, 1949; Cronon, 1995). The underlying reality of this shift was that NPAs also housed some traditional societies. It became clear that the approaches that excluded these traditional societies, separated them from their habitats, forced them to migrate, altered their traditional life practices, and ultimately, weakened their cultures resulted in damage to natural areas. According to this understanding, nature conservation should focus not only on ecosystems but on all ecological processes, not on these processes independently of the existence of human communities. These intangible elements include past lifestyles, rituals, social and cultural practices, traditional celebrations, festivals, or fairs, and the knowledge and skills associated with them (Nemoga et al., 2022). The biocultural approach encourages the preservation of all these cultural diversities together with biological diversities (Bridgewater & Rotherham, 2019).

2. Materials and Methods

2.1. Study Area: Kazdağı National Park

In order to preserve the biodiversity, endemic species, geomorphological features, and cultural resource values in the region that forms the southern slope of the main Kazdağı massif, the Council of Ministers declared Kazdağı National Park on April 17, 1993 (Arı & Soykan, 2006a). The 21,452-hectare national park is surrounded to the east by the Zeytinli Stream, to the west by the Mıhlı Stream, to the north by the Balıkesir-Çanakkale province boundary, and to the south by towns roughly on the slopes of Kazdağı. This distinction is reflected in the fact that the majority of the Kaz Mountains range has been designated as a national park.

2.2. Research Design

This study employed the case study method, a qualitative research method. A case study is a research methodology that allows us to examine issues related to a place in depth within their real-world context (Creswell, 2009; Yin, 2018). This methodology allows for a holistic perspective on the topic under consideration to draw generalizations inherent in geographical studies. This study examines park management practices in Kaz Mountains National Park within the framework described above. The park's governance model, from its establishment in 1993 to the present day, was examined through

field observations and official documents. Events pertaining to park administration were observed in a non-participatory manner, and the park's use by locals was assessed using data from pertinent papers and prior research.

3. Findings and Discussion

3.1. Nature Conservation in Kazdağı National Park

The protection of the park is primarily driven by tourism, biodiversity preservation, and physical landscape values. To do this, the park has adopted "fortress protection," a nature conservation concept that excludes residents. As a result, a system of local guides was put in place, and locals were forbidden from visiting the park beginning in 2001. They were only allowed to enter with authorization accompanied by the local guides. Locals may no longer easily visit the designated national park area, participate in forestry, graze their animals, and gather Non-timber Forest Products (NTFPs) for building timber and fuel (Arı & Soykan, 2006b). In a way, the park's accessibility has been limited, breaking the locals' long-standing bond with the mountain. In the meanwhile, the park's tourism infrastructure has been enhanced, drawing additional visitors. Thus, the human-environment connection in the area was drastically changed as visitors were encouraged to access the park while locals were prohibited from doing so (Dereli & Arı, 2012).

3.2. Biocultural Diversity Elements in Kazdağı National Park

3.2.1. Local Cultures Around Kazdağı National Park

Up to the previous half century, the local population resided in the primarily rural communities around Kazdağı National Park and made extensive use of the park area for a variety of purposes. In fact, the people living in the villages and neighborhoods to the south of the park have a strong bond with the mountain and have relied on its resources for their livelihood for generations. The summer and winter populations in each of these communities varies by five to ten times (Özkan & Uzun, 2019). The region's attractiveness as a secondary residential and residential area is largely due to the development of sea tourism along the coast, the perception of high air quality, the coexistence of both urban and rural life, the abundance of water resources, and the improvement of infrastructure and transportation services such as Edremit Kocaseyit Airport.

3.2.2. Legendary Places in the Kazdağı Landscape

Because of the local tales, some of which have been included in books and movies, Kazdağı is regarded as a sacred landscape in its entirety (Arı, 2020). Some of these stories include pre-Islamic elements and are thousands of years old. In some manner, these tales continued to exist in the local communities, and new ones were added to them. Because of their closeness to the Sky God and the notion that God lived there, mountains were revered in pre-Islamic Turkish religion. In Anatolia, the Turks created cults and gave localities the names they used in Central Asia (Duymaz, 2001). Famous people were interred in several tombs that were constructed a top hills and peaks. These holy hills, which contain the tombs of sacred individuals, are also abundant in the Kazdağı landscape (Arı, 2020). There are several categories for sacred natural places in Kazdağı. For a variety of reasons, hills, landscapes, trees, shrines, and even water sources are revered (Arı, 2020).

3.3. Discussion

In Turkey, biophysical elements continue to be the foundation of nature conservation practices. The preservation of forests, biodiversity, and wild animal and plant species are structurally prioritized in nature conservation (Gül et al., 2024). The TEK, sustainable human-environment linkages, tangible and intangible cultural heritage, locations, and processes are all included in NPAs in addition to biodiversity and physical traits. Worldwide and national efforts, accords, and treaties have been adopted to conserve cultural assets in the same way as numerous worldwide projects have been made to protect nature. Kaz Mountain National Park is as much a cultural landscape as a natural environment, as several scholarly studies have shown (Ilgar, 2024; Kahyaoğlu, 2022; Soyulu et al., 2024; Şahin 2014; Yolcu, 2022; Yolcu & Aça, 2022). These studies have documented numerous cultural assets, sacred sites, and traditional ceremonies and rituals within and around Kazdağı National Park. Nature

conservation has undergone a transformation that increasingly embraces a social science approach (Bennett et al. 2017). This transformation suggests the integration of the previously neglected social science approach into nature conservation efforts (Bennett & Roth, 2019; Chua et al., 2020; Sanborn & Jung 2021).

4. Conclusions and Recommendations

The nature conservation strategy used in Kazdağı National Park, according to observations and documents reviewed, concentrates on the region's biodiversity, endemic plants, wildlife, and geomorphological and hydrological features while failing to sufficiently highlight the local cultures, rituals, sacred sites, and traditional ecological knowledge (TEK) that have evolved and endured in the area for centuries. For biodiversity protection, maintaining cultural heritage and transferring it to future generations is equally important. This is seen to be crucial for accomplishing sustainable development objectives. To do this, it is advised that a social science-based strategy to environmental conservation be implemented in place of existing conservation program. This new strategy, known as the biocultural approach, calls for the application of social science research findings at every level of nature conservation activity, including planning, implementation, and protection. To do this, multidisciplinary research including social scientists should be carried out, and social science capability inside nature conservation organizations should be enhanced. Conservationists and pertinent organizations should encourage social scientists to study social concerns in NPAs and apply the findings to their own work, rather than making flimsy linkages with them. The resulting biocultural approach will improve the social and environmental justice of conservation.





Reconsidering BIM-LCA Integration for Environmental Assessment and Decision-Support Processes in the Construction Industry

Neriman Gül ÇELEBİ ^{1*} , Ümit ARPACIOĞLU ² 

ORCID 1: 0000-0003-0478-0449

ORCID 2: 0000-0001-8858-7499

¹ Mimar Sinan Fine Arts University, Graduate School, Department of Architecture, 34427, İstanbul, Türkiye.

² Mimar Sinan Fine Arts University, Faculty of Architecture, Department of Architecture, 34427, İstanbul, Türkiye.

* e-mail: ngcelebi@gmail.com

Abstract

The construction industry is responsible for a significant portion of global energy consumption and environmental emissions. Life cycle assessment (LCA) is a crucial environmental management tool that analyzes the environmental impacts of the construction industry in an integrated and systematic way, and is vital for building carbon neutral built environments. The BIM integration approach stands out to optimize and support comprehensive LCA processes. This study aims to analyze existing studies in the field of BIM and LCA integration, identify significant gaps in this area, and propose a framework for providing an integrated and systematic perspective on integration. The proposed framework consists of four basic modules. Representative studies on BIM-LCA integration were selected and analyzed in accordance with the developed framework, and the evaluations are explained. The findings indicate a need for environmentally performance-oriented BIM-based decision support mechanisms that support LCA and multi-criteria decision-making processes. Furthermore, it provides a methodological basis for a decision support mechanism for BIM-LCA integration.

Keywords: BIM-LCA Integration, Environmental Impact, Decision-Support Process.

Yapı Endüstrisinde Çevresel Değerlendirme ve Karar Destek Süreçleri için BIM-LCA Entegrasyonunun Yeniden Değerlendirilmesi

Öz

Yapı endüstrisi çevresel küresel ölçekte enerji tüketimi ve çevresel emisyonların önemli bir bölümünden sorumludur. Yaşam döngüsü değerlendirmesi (LCA) yapı endüstrisinin çevre üzerindeki etkilerini bütünlük ve sistematik olarak analiz eden ve karbon nötr yapıyı çevre inşa etmek açısından önemli bir çevre yönetim aracıdır. Kapsamlı bir yapıya sahip LCA süreçlerini optimize etmek ve desteklemek için BIM entegrasyon yaklaşımı öne çıkmaktadır. Bu çalışmada, BIM ve LCA entegrasyonu alanında yapılan çalışmaları analiz etmek, bu alandaki önemli boşlukları tanımlamak, ve entegrasyon konusunda bütünlük ve sistematik bir bakış açısı sunmak için bir çerçeve önerilmesi hedeflenmiştir. Önerilen çerçeve dört temel modülden oluşmaktadır. Temsil niteliğinde BIM-LCA entegrasyonuna ilişkin çalışmalar seçilerek geliştirilen çerçeve doğrultusunda analiz edilmiştir ve değerlendirmeler açıklanmıştır. Bulgular, LCA ve çok kriterli karar verme süreçlerini destekleyen, çevresel performans odaklı BIM tabanlı karar destek mekanizmalarına ihtiyaç olduğunu göstermektedir. Ayrıca, BIM-LCA entegrasyonuna yönelik karar destek mekanizması için metodolojik bir temel sunmaktadır.

Anahtar kelimeler: BIM-LCA Entegrasyonu, Çevresel Etki, Karar Destek Süreci.

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1. Introduction

The construction industry is a major source of environmental problems and is responsible for a significant portion of global carbon emissions and energy consumption (Guignone et al., 2023). Life cycle assessment (LCA) is an environmental management tool developed to understand and analyze the environmental impact of the construction industry and to develop strategies accordingly (Kumar et al., 2025). Life Cycle Assessment (LCA) has been applied in the construction industry since the 1990s and is now increasingly integrated into European public policies or Environmental Product Declaration regulations (Lasvaux et al., 2015). LCA systematically and integrally evaluates the environmental performance of a product, system, or process by providing the collection and analysis of data on inputs and outputs at every stage of life cycle (Barbhuiya & Das, 2023). Decisions made in the early stages of architectural design critically determine the environmental performance of a building. Designers are faced with many decisions at these stages and generally do not have an intuitive understanding of the effects of these decisions (Basbagill et al., 2013). Approaches that will contribute to the optimization of LCA processes are required to ensure that Life Cycle Assessment (LCA), a powerful environmental management tool that has not yet been internalized by designers or decision-makers, is incorporated into the decision-making process.

Building Information Modeling (BIM) is a data information management tool and approach that supports the construction of sustainable buildings (Maglad et al., 2023). BIM is characterized by its ability to analyze building information, parametric thinking, information transfer, and connect projects from various disciplines, improve communication processes, and support interoperability between different application areas (Vaz et al., 2024). Life Cycle Assessment is invaluable for achieving a carbon neutral built environment and optimizing the life cycle environmental performance of buildings. BIM-LCA integration optimizes LCA inventory data collection and impact assessment processes, supports faster evaluation and decision-making of different design options based on parametric thinking (Parece et al., 2025). Decision making is a key factor for success in any discipline, especially a field that requires managing large amounts of information, such as the construction industry. Building construction is an important process that involves a wide range of factors and tasks to be considered. Multi-criteria decision analysis emerged to manage complex processes (Jato-Espino et al., 2014). In this context, in this study, BIM and LCA integration is considered based on their effects or contributions to environmental performance and decision support processes.

Although studies on BIM and LCA integration are increasing, current research largely focuses on software integration and data transfer. While BIM offers opportunities to incorporate sustainability performance indicators into the building design process, it remains inadequate in terms of interoperability with Life Cycle Assessment (LCA) tools (Shadram et al., 2016). In addition, methodological frameworks that place BIM's information management approach and its role in decision support processes at the center remain limited. In most studies, LCA is used to report environmental impacts, and design alternatives are compared qualitatively (Parece et al., 2025). In this respect, this study addresses BIM and LCA integration not merely as technical software integration, but as a principled approach based on decision support processes, and proposes an evaluation methodology. The proposed methodology can provide the systematic identification of the focal points of BIM-LCA studies in the literature, the research gaps in this field, and the analysis of integration methods for decision support processes. In this respect, the study aims to contribute to the methodological development of BIM-LCA integration and to provide guidance for future studies in this field.

2. Material and Method

The method proposed in this study with the aim of systematically analyzing and evaluating studies on the integration of Building Information Modeling (BIM) and Life Cycle Assessment (LCA), focusing on environmental assessment and decision-support systems, is shown in Figure 1.

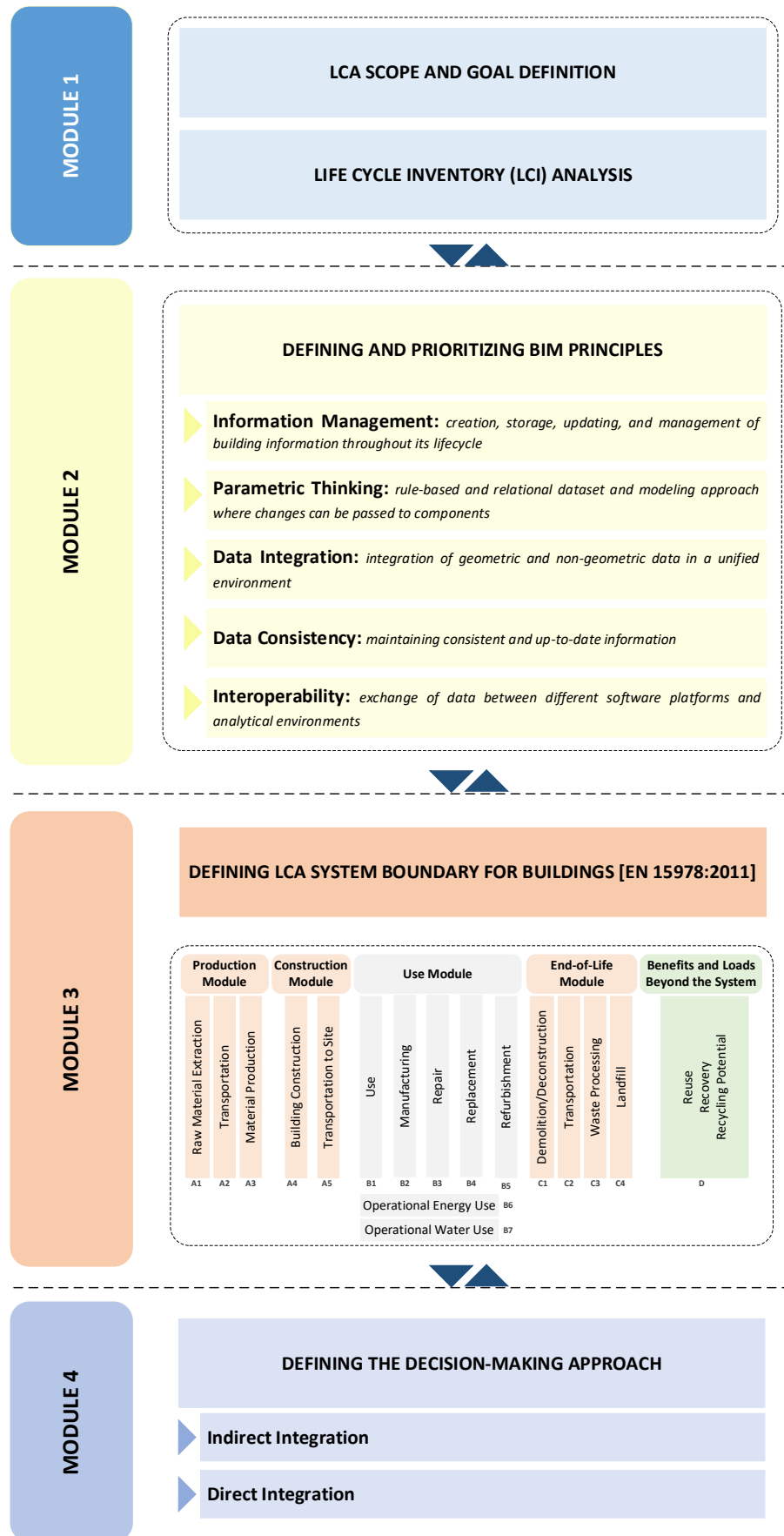


Figure 1. Proposed framework for evaluating BIM-LCA integration (Created by the authors)

The proposed framework consists of four interrelated basic modules. Module 1 comprises the sub-modules of scope and goal definition and life cycle inventory (LCI) analysis, which form the basis of the

LCA guidelines and requirements defined in ISO 14044:2006 (International Organization for Standardization [ISO], 2006). Scope and goal definition refers to defining and explaining the product, system, or process, the purpose of the study, system boundaries, impact assessment method, impact categories, assumptions, limitations, etc. Life Cycle Inventory (LCI) Analysis involves collecting data related to raw materials, energy consumption, emissions, waste, etc., to measure the inputs and outputs of the life cycle phase. The data to be used in the defined LCA study are collected and organized. It represents an inventory of the input and output data associated with the system under study. Module 2 includes the definition and prioritization of BIM principles, including information management, parametric thinking, data integration, data consistency, interoperability, and life cycle-oriented process integration. Module 2 plays a critical role in creating a system that will manage the large dataset developed in Module 1. The scope of the work can influence the prioritization of BIM principles or the creation of an integrated information management system in line with BIM principles.

Module 3 includes the definition of the LCA system boundaries for buildings and the identification of the submodules to be considered in LCA analyses in accordance with the international standard EN 15978:2011 (European Committee for Standardization, 2011). The LCA framework consists of the main modules of production, construction, use, end-of-life, and benefits and loads beyond the system boundary, together with their corresponding submodules. Throughout its life cycle, a building generates both operational and embodied environmental burdens. During the building's use, the energy consumed for heating, cooling, ventilation, and air conditioning equipment is operational energy, whereas the energy associated with all other main modules is defined as embodied energy. The building envelope directly affects the operational load, while the structural systems does not have a direct impact on operational performance. Therefore, defining the relationship between the building and its life cycle and determining the system boundaries is of great importance. Module 4 includes the definition of the integration of decision support processes with BIM-LCA. Indirect decision support integration refers to the impact of the decision-making approach on the BIM-based LCA evaluation system. Direct decision support integration refers to the direct integration of multi-criteria decision methods into the BIM-based LCA evaluation system. In terms of designing an environmentally focused approach and managing a multi-parameter process, decision support processes have been considered as the basic module of the framework.

3. Findings and Discussion

In this section, studies on BIM–LCA integration identified in the literature are analyzed in accordance with the proposed framework. An evaluation matrix has been created for the analysis and is shown in Table 1.

Table 1. BIM-LCA integration evaluation matrix (created by the authors)

Study	(Ma et al., 2024)	(Atashbar & Noorzai, 2023)	(Zhou et al., 2023)	(Hollberg et al., 2020)	(Morsi et al., 2022)
BIM Principles	Interoperability, Data Integration	Parametric Thinking	Interoperability, Data Integration, Data Consistency, Parametric Thinking	Information management, Interoperability, Data Integration, Parametric Thinking	Interoperability
BIM Tool	Autodesk Revit	Autodesk Revit	Autodesk Green Building Studio	Autodesk Revit+Dynamo	Autodesk Revit
LCA System Boundary	A1–A5; C1–C4; D	Whole LCA (A–D)	(A1–A3), (B2–B6), (C2–C4)	A1+A3+C3+C4	Cradle-to-cradle (A1–D)

Environmental Indicators	GWP (Global Warming Potential), AP (Acidification potential), EP (Eutrophication potential), Smog Formation Potential, ODP (Ozone depletion potential), Non-Renewable Energy	GWP (Global Warming Potential), Total Primary Energy, Non-Renewable Primary Energy, Fossil Fuel Consumption	Operational and Embodied Impacts (kgCO ₂ eq/m ²)	GWP (Global Warming Potential)	GWP (Global Warming Potential), AP (Acidification potential), EP (Eutrophication potential), ODP (Ozone depletion potential), POCP (Photochemical ozone creation potential), PED (Primary energy demand)
LCA Analysis Tool	Tally	Athena Impact Estimator for embodied impacts Rhino for operational impacts (Grasshopper, Honeybee and Ladybug plugins)	Tally	KBOB Swiss LCA database (<i>Ökobilanzdaten im Baubereich</i>)	One-Click LCA
Integration Method	Plugin	No explicit BIM-LCA data exchange	gbXML DOE2 simulation engine	BoQ (Bill of Quantities)+ Material ID	Plugin
Decision Support Objective and Method	Indirect decision support integration	Optimisation; NSGA-II algorithm (using Python)	Prioritisation and Optimisation; LSSVM (meta-model) Pareto Optimal Front: + NSGA-II +TOPSIS	Not specified	Indirect decision support integration

In their study, Ma et al. (2024) proposed a BIM-based LCA framework approach using Revit and Tally to examine the environmental impacts of a high-rise building with a hybrid (reinforced concrete-steel) structure system. Tally, which operates as a plugin within BIM, provides a method for analyzing embodied environmental impacts. However, it is known that databases used as software-independent tools may have limitations. The authors also stated in their study that the availability and quality of data in the life cycle inventory (LCI) databases were limited. Furthermore, it was noted that the construction phase sub-module A5 and the end-of-life phase sub-module C1, which includes demolition and deconstruction, were outside the scope of the study because they were not reported by Tally. Atashbar & Noorzai (2023) considered the selection of materials with optimum performance on the building facade to effectively reduce operational energy consumption. Within the scope of environmental impact analysis, BIM modeling, the Energy Plus engine for parametric simulations, and the Athena Impact Estimator for embodied loads were used. The NSGAI multi-objective optimization algorithm was used to determine and provide the most suitable material selection. The study explains that optimization is an approach aimed at maximizing or minimizing a given dataset in order to analyze energy consumption and determine the most suitable solution for selecting appropriate materials, and highlights its importance.

Zhou et al. (2023) investigated the balance between operational and embodied loads and the effects of design variables determined at each stage of the design process on the environmental impact of a building. A multi-objective optimization model based on BIM and LCA integration was developed to

find the design solution with the optimal balance between operational and embodied effects and the option with minimum environmental impact. The three main modules of the proposed model are: environmental impact assessment based on BIM-LCA integration, estimation of operational and embodied effects based on LSSVM (Least Squares Support Vector Machine), and multi-objective optimization based on NSGA-II (Non-dominated Sorting Genetic Algorithm II). The study noted the insufficient LCA data for some building components in Tally and the incompatibility between BIM and Green Studio as limitations and challenges of the study.

Hollberg et al. (2020) considered the correlation of quantity surveying data obtained from BIM software with an LCA database or a tool used for assessing environmental impacts. The study handled the expansion of an office building in Switzerland to evaluate continuous feedback on LCA results to provide guidance to the design team on improving environmental performance during the design phase. The study used *Ökobilanzdaten im Baubereich*, a Swiss LCA database for building materials and products developed by KBOB (2016), as the LCA analysis tool. The database provides LCA data for modules A1-A3 and C3+C4 and for the most typical building materials. Data sets related to transportation are also provided by the database, but the transportation module was not included in the study. The database is based on Ecoinvent V2.2. The inability of Dynamo to directly access volumetric information of technical elements and the lack of materials for the building's technical systems in the KBOB database were stated as challenges in the study. Morsi et al. (2023) addressed the LCA and BIM-based analysis of alternative structural systems for residential buildings. The integration of LCA and BIM was examined using the One-Click LCA plugin in the BIM platform. Furthermore, Synchro Pro, based on the Revit model, was used to investigate 4D (time) and 5D (cost) issues. Although the study mentions BIM-LCA-based decision support analysis, the integration of BIM and LCA is considered as an indirect integration that can support the decision support process.

Selected representative studies were analyzed to identify methodological trends and research gaps in BIM-LCA integration using the proposed evaluation framework. Studies on BIM and LCA integration have primarily focused on the BIM interoperability principle. Focusing solely on data transfer between software or databases directly impacts the quality of LCA data and the scope of the study, as clearly demonstrated in the studies. Some studies have indicated the presence of challenges in terms of data loss, inconsistencies, and interoperability due to the need to transfer the bill of quantities (BoQ) between tools in different formats. Ma et al. (2024) explained the modules that were excluded from the scope of the study because they were not included in the Tally database. Powerful software has been developed for life cycle assessment. França et al. (2021), in their study on life cycle assessment and cost integration, stated that two more commonly used software tools are SimaPro and GaBi. GaBi, particularly at the center of scientific research, allows users to create, customize, and manage their own datasets within the software, offering flexibility for users who need unique data for specific assessments (Gong et al., 2025).

Considering the life cycle assessment (LCA) approach in the early design phases is crucial for building a carbon neutral built environment, and supporting an integrated LCA structure is necessary. BIM has the potential to optimize LCA processes, but reducing the issue to software integration has created significant gaps in the literature. Optimizing an integrated, data quality-first, and information-managed LCA process can be achieved by adopting the fundamental principles of BIM. The limited number of studies providing a methodological framework for decision support system processes is another significant gap in the literature. The indirect impact of decision support systems on BIM and LCA integration has been widely studied. Studies integrating direct decision-making methods into BIM-LCA applications also exist and are quite valuable. However, despite the direct use of decision-making methods, interoperability can be a focal point for BIM-LCA integration, and adaptable and applicable decision support mechanisms may not be offered for buildings. Consequently, studies that address BIM and LCA integration primarily in a principled context, prioritize integrated and systematic environmental impact analysis, and embrace data quality and parametric thinking are needed for LCA process optimization.

4. Conclusion and Suggestions

The construction industry is constantly seeking solutions to environmental problems. Life cycle assessment (LCA) is a globally accepted environmental management tool in the context of energy efficiency and environmental sustainability, and it is of great importance to the construction industry. Studies are ongoing to support the comprehensive LCA processes. BIM is one of the prominent approaches to optimizing LCA processes. Machine learning is also being considered for optimizing LCA processes. Evaluating information, data, and environmental impact indicators is crucial in the LCA process. While studies on BIM and LCA integration are promising, this area still requires further development, and significant research gaps exist in the literature. In this context, this study proposes a methodology for evaluating BIM and LCA integration. It also aims to provide an integrated assessment of BIM-LCA integration, which is incorporated into software integration.

Software integration is one of the approaches that can optimize multi-criteria decision-making processes, but it is not sufficient on its own. The functionality of the BIM-based Life Cycle Assessment (LCA) approach depends on the availability of data on the Life Cycle Inventory (LCI). Integrated approaches are required for decision processes focused on environmental argument. At the same time, although BIM–LCA integration is widely considered to support a sustainable built environment, its contribution to decision-making processes often remains implicit and insufficiently structured. Therefore, a methodological framework is needed that evaluates not only technical integration but also the decision support capacity of BIM–LCA approaches. The framework proposed in this study allows for evaluations of BIM-LCA integration and also provides a basis for a BIM integrated LCA decision-support mechanism.

Acknowledgments 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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Narrative Landscape Design for Strengthening Place Identity: A Case Study of Böcüzade Park (Isparta, Türkiye)

Gizem DİNÇ ^{1*} , Nisanur GEDİK ² 

ORCID 1: 0000-0003-2406-604X

ORCID 2: 0009-0004-3199-8616

¹ Süleyman Demirel University, Faculty of Architecture, Department of Landscape Architecture, Isparta, Türkiye.

² Süleyman Demirel University, Faculty of Architecture, Department of Landscape Architecture, Isparta, Türkiye. (undergraduate student)

* e-mail: gizemdinc@sdu.edu.tr

Abstract

This study investigates the potential of narrative landscape design to strengthen place identity and spatial experience through the case of Böcüzade Park in Isparta, Türkiye. A qualitative, design-oriented methodology was adopted, consisting of conceptual review, site analysis, and development of a narrative landscape design model. Spatial, historical-cultural, and functional analyses were conducted to identify the physical characteristics, cultural references, collective memory, and identity values of the site. Based on these findings, Isparta's rose production culture, Seljuk geometric design principles, traditional production practices, and the historical legacy of the Böcüzade family were transformed into spatial design strategies. The proposed model integrates experiential routes, focal points, thresholds, symbolic elements, and sensory landscape components. The study demonstrates that narrative landscape design can contribute to making cultural memory visible, strengthening local identity, enhancing genius loci, and creating meaningful relationships between users and urban public spaces.

Keywords: Narrative Landscape Design, Place Identity, Genius Loci, Cultural Memory, Spatial Experience, Urban Public Space.

Yer Kimliğinin Güçlendirilmesine Yönelik Anlatısal Peyzaj Tasarımı: Böcüzade Parkı (Isparta, Türkiye) Örneği

Öz

Bu çalışma, anlatısal peyzaj tasarımının yer kimliğini ve mekânsal deneyimi güçlendirme potansiyelini Isparta, Türkiye'deki Böcüzade Parkı örneği üzerinden incelemektedir. Çalışmada kavramsal inceleme, alan analizi ve anlatısal peyzaj tasarım modelinin geliştirilmesinden oluşan nitel ve tasarım odaklı bir metodoloji benimsenmiştir. Alanın fiziksel özellikleri, kültürel referansları, kolektif belleği ve kimlik değerleri; mekânsal, tarihsel-kültürel ve işlevsel analizler aracılığıyla değerlendirilmiştir. Elde edilen bulgular doğrultusunda, Isparta'nın gül üretim kültürü, Selçuklu geometrik tasarım ilkeleri, geleneksel üretim pratikleri ve Böcüzade ailesinin tarihsel mirası mekânsal tasarım stratejilerine dönüştürülmüştür. Önerilen model; deneyim güzergâhları, odak noktaları, eşikler, sembolik unsurlar ve duysal peyzaj bileşenlerini bütünleştirmektedir. Çalışma, anlatısal peyzaj tasarımının kültürel belleği görünür kılma, yerel kimliği güçlendirme, genius loci algısını geliştirme ve kullanıcılar ile kentsel kamusal mekânlar arasında anlamlı ilişkiler kurma potansiyeline sahip olduğunu ortaya koymaktadır.

Anahtar kelimeler: Anlatısal Peyzaj Tasarımı, Yer Kimliği, Yerin Ruhu, Kültürel Bellek, Mekânsal Deneyim, Kentsel Kamusal Alan.

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1. Introduction

The built environment and land-use changes are shaped as a result of the relationships and interactions of natural and cultural characteristics. In urban design, cultural context is regarded as a multidimensional construct shaped by the interaction of spatial, social, economic, legal, historical, perceptual, and identity-related values inherent to a place (Aydemir et al., 2020; Dinç & Gül, 2022). As a design-oriented discipline, landscape architecture integrates natural, cultural, and spatial values into urban environments to strengthen place identity, preserve local character, and enhance the continuity of cultural landscapes (Gül et al., 2022). Today, the strengthening of users' attachment to space is closely related not only to the aesthetic dimension of design but also to its emotional and cultural aspects. The concept of "more-than-representational" geography introduced by Lorimer (2005) emphasizes that landscapes are not only represented (i.e., as plans, documents, or discourses) but are also experienced and meaningfully produced through everyday practices. In this context, the concept of "narrative landscape design" emerges as an approach that enables spaces to acquire identity through storytelling. Narrative landscapes provide visitors with not only a spatial experience but also a holistic experience embedded with meaning and a sense of belonging through narratives constructed around the history, collective memory, or natural character of a place. In this respect, narrative landscape design is directly associated with the concepts of "genius loci" and "local identity." The concept of genius loci, introduced by Norberg-Schulz (1980), refers to the distinctive atmosphere of a place beyond its physical characteristics and emphasizes the designer's responsibility to reveal and sustain this spirit.

Ayyıldız & Ertürk (2017) state that urban identity is shaped by local cultural values and spatial memory, and therefore place identity reflects "the meanings inherited from the past and how these meanings are re-produced by users." However, rapid urbanization and standardized design approaches in contemporary cities have led to the loss of identity in many urban open spaces and the weakening of genius loci. This situation prevents places from establishing a lasting presence in users' memories. Narrative landscape design addresses this disconnection by re-emphasizing the unique identity of place, preserving its spirit, and offering a powerful tool for establishing meaningful connections with users. Stories, through narrative elements that appeal to individuals' emotional worlds, have the potential to raise social awareness, influence attitudes, and shape behaviors. In this regard, narrative-based approaches in design contribute to the legitimacy and persuasive power of spatial and conceptual frameworks produced within public perception (Bulkens et al., 2015).

In the international literature, narrative landscape concepts have been addressed in order to reveal the capacity of space to produce meaning and its emotional connection with users. While Bulkens et al., (2015) emphasize the role of narrative approaches in representing collective memory within spatial planning processes, Havik & Van Haeren (2016) highlight the decisive role of storytelling in atmosphere-making and place-making processes. Similarly, Garman (2006) discusses the guiding role of narrative in constructing meaningful landscapes, and Castro (2025) demonstrates how the relationship between tourism and storytelling enriches spatial experience.

In Türkiye, however, academic studies on narrative landscape design remain limited. Existing literature generally addresses the concept of "narrative" within the context of memorial sites, thematic parks, or cultural heritage areas (Naiboğlu & Çebi, 2024; Selçuk, 2018), while it is not sufficiently represented in everyday urban open spaces and contemporary landscape design practices. This situation highlights the need to further develop the subject both theoretically and in relation to local identity and genius loci within applied design contexts.

Despite the increasing prominence of narrative landscape concepts in recent international studies, research in the Turkish context remains limited. The main reasons include the insufficient theoretical engagement with storytelling-based approaches in landscape design (except for a few examples such as the Süleyman Demirel Memorial Complex), the limited number of studies transforming the relationship between place identity and narrative into a design methodology, and the dominance of functional-spatial approaches in urban transformation projects (Ersoy, 2012; Tekeli, 2011).

Studies on narrative landscapes in Türkiye are mostly concentrated in tourism, architecture, or conservation disciplines. This creates a significant gap in landscape architecture regarding how user experience, spatial perception, and place identity can be enriched through narrative-based design approaches. Although emerging studies in Türkiye have begun to address narrative approaches in relation to memory, heritage, and landscape representation, research that explicitly conceptualizes “narrative landscape” as a design framework within contemporary landscape architecture remains limited.

This study examines the role of narrative landscape design in the perception of local identity and the preservation of genius loci through the case of Böcüzade Park in Isparta. Within the scope of the study, the historical and cultural layers of the site were addressed through a narrative-based approach, and it was explored how narrative landscape design can be translated into a spatial configuration in everyday urban open spaces. Accordingly, a landscape design project based on narrative landscape principles was developed for the study area; spatial organization, landscape elements, planting design decisions, and user experience were reconfigured in relation to the site’s historical memory and cultural narratives. Thus, the applicability of narrative elements was evaluated not only at a conceptual level but also through tangible spatial design decisions.

The study aims to fill this theoretical and methodological gap by reinterpreting the relationship between urban memory and design from a narrative landscape perspective. In this respect, it offers an original conceptual contribution to the Turkish literature while also proposing an applicable framework for design practice, thereby developing a new approach to enhancing identity, belonging, and experiential qualities in urban open and green spaces.

1.1. Theoretical Framework

Narrative landscape design is a holistic approach in which space is addressed not only through its physical characteristics but also through the production of meaning, memory, and experience. Within this approach, landscape does not merely provide a functional setting for users; it also establishes an emotional and cognitive connection through storytelling. Bulkens et al., (2015) emphasize that storytelling in spatial planning processes is an effective method for strengthening the meaning of place and making collective memory visible.

According to Garman (2006), the creation of a meaningful landscape design is possible through the translation of narrative into a spatial language. In this sense, landscape elements are not only aesthetic components but also generate symbolic, cultural, and experiential meanings. Spatial composition transforms the user from a passive observer into an active participant within the narrative structure.

This approach is further supported by cultural landscape theory, which considers landscape not merely as a physical environment but as a system of meanings shaped through human experience, memory, and cultural representation. Cosgrove and Daniels (1988) argue that landscape functions as a signifying system through which social relations, cultural values, and human interactions with the physical world are represented and reproduced. Within this perspective, landscape contains multiple layers of meaning that are interpreted through narratives, myths, and collective memories. Therefore, landscape can be understood as a readable cultural text in which physical forms and symbolic representations interact to construct place identity and strengthen the relationship between people and place (Cosgrove, 1993).

Castro (2025), in his study on the relationship between tourism and landscape, demonstrates that narrative design enriches spatial experience and deepens users’ interaction with place. In this context, the study addresses the relationship between story and space by integrating the role of symbolic elements in design with an experience-oriented landscape approach. This tripartite structure forms the theoretical foundation through which space transcends being merely a physical construct and becomes a meaning-producing and interactive experiential field.

Place identity is a multi-layered phenomenon encompassing not only the physical characteristics of a space but also its cultural, historical, and social meanings. Ayyıldız & Ertürk (2017) state that the traceability of local identity within the urban fabric is a determining factor in users’ spatial perception

and sense of belonging. In this context, the concept of *genius loci*, defined as the spirit of place, refers to the physical and symbolic components that constitute the unique character of a space. Alangoya (2015) emphasizes that *genius loci* should be understood within both natural and built environmental relationships, highlighting the importance of context in design. The spirit of place is strengthened not only through spatial atmosphere but also through historical traces and social meanings.

Selçuk's (2018) study on Mudurnu demonstrates how the spirit of place can be sustained through local culture, historical traces, and spatial memory. Similarly, Tanrıbir & Akten (2020), along with Aydemir & Durmaz (2024), highlight the decisive role of spatial perception in shaping place identity in their studies on the city center of Isparta. These studies indicate that user experience plays a central role in the formation of place identity.

Spatial identity is a multidimensional construct that emerges through the continuous interaction between the physical environment and the socio-cultural processes that shape places over time (Gül et al., 2019; Gül et al., 2020). Therefore, narrative design is considered a tool that makes this spatial identity visible and strengthens the relationship between the space and the user.

The conceptualization of space as a narrative medium is an increasingly prominent approach in the literature. Havik & Van Haeren (2016) argue that narrative methods are effective in reading atmosphere and producing space, suggesting that space can be interpreted as a "text." Moenandar & Miller (2019) emphasize that narrative plays a constitutive role in identity formation, arguing that cultural and spatial identities are largely transmitted through stories. Van der Hoeven (2019) demonstrates that digital narrative practices are effective in the preservation of urban heritage, showing that space can be continuously reinterpreted and re-signified through storytelling. Similarly, Naiboğlu & Çebi's (2024) study on imaginative field trips in design studios highlights narrative as a tool for exploration, interpretation, and meaning-making in design processes.

In this context, the relationship between narrative and space is defined through the conceptualization of space as a readable narrative surface. User experience is considered a narrative flow constructed on this surface, while routes, thresholds, and transitions emerge as key components forming different sections of this narrative. Meaning production occurs through the interaction of spatial indicators and symbolic elements, transforming space into not only a physical entity but also an interpretable narrative layer.

International examples in the literature provide important references for understanding how narrative landscape design is implemented across different cultural contexts. Francis & Hester (1990) emphasize that landscape is not merely a physical arrangement but also a structure capable of producing meaning, defining gardens as carriers of cultural narratives and collective memory. One spatial manifestation of this approach is the Awaji Yumebutai project designed by Tadao Ando, which constructs a narrative spatial sequence articulating the relationship between nature and humans and guiding users through an experiential route (Ando, 2001). Similarly, Castro (2025) demonstrates through various cultural landscape examples that story-based design approaches enhance spatial perception, particularly in the context of tourism and cultural experience, and foster a deeper connection between users and place. Thus, landscape can be understood as a readable narrative structure in which physical elements, symbolic meanings, and cultural references interact to create a meaningful spatial experience (Alon- Mozes, 2006).

2. Material and Method

2.1. Study Area

The study area of this research is Böcüzade Park, located in the city center of Isparta, Türkiye (Figure 1). Isparta is situated in the Lakes District of the Mediterranean Region of Türkiye, between 37°45' north latitude and 30°33' east longitude. The city exhibits continental climate characteristics, with hot and dry summers and cold winters with occasional snowfall. The park occupies a significant position within the historical development of the city and possesses a strong potential for place identity through its surrounding built environment, high level of social use, and presence in collective cultural memory.

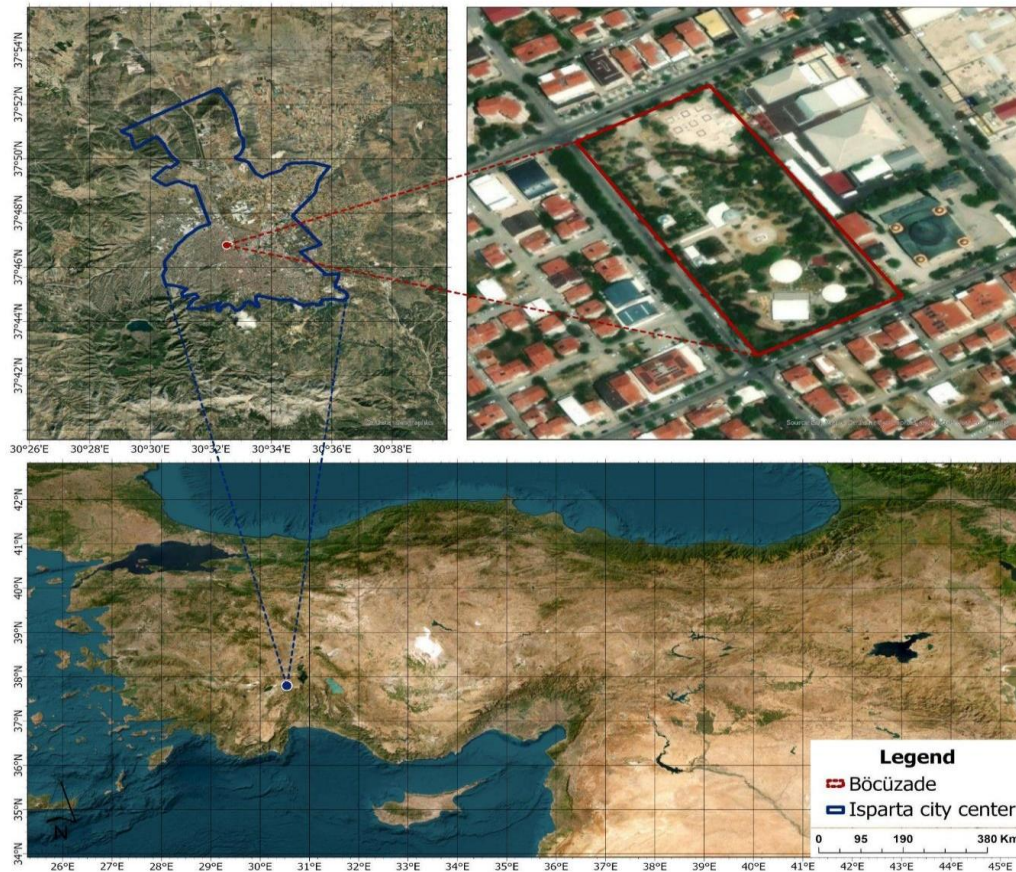


Figure 1. Böcüzade Park, Isparta (Created by the authors)

Böcüzade Park, named after the Böcüzade family, which holds an important place in the urban history of Isparta, is a significant public open space containing historical and cultural references. However, its current spatial configuration and patterns of use do not adequately reflect its historical background and local identity values. Within the framework of narrative landscape design, this condition presents an important design potential for revealing the *genius loci*, strengthening local identity, and reinterpreting the city's historical narratives through spatial representations.

Accordingly, Böcüzade Park was selected as the study area due to its potential to enable the reinterpretation of historical and cultural layers through spatial experience.

2.2. Method

This study adopts a holistic methodology grounded in a qualitative research approach to examine the effects of narrative landscape design on place identity and the spirit of place. Within this framework, the relationships between narrative, space, experience, and identity, which have been addressed in a fragmented manner across different disciplines, are systematically analyzed. Through this analytical process, common themes and relational structures are identified and reorganized into an integrated framework. The resulting conceptual synthesis is structured by considering Türkiye's specific socio-cultural and spatial context and is subsequently transformed into a design-oriented and systematic methodological model.

For instance, in the study conducted by Garman (2006), the historical and cultural layers of the site were first analyzed in order to develop a meaningful landscape design. Based on this analysis, a narrative structure was constructed and subsequently translated into spatial design decisions. Similarly, Bulkens et al., (2015) emphasize that narrative-based approaches in spatial planning integrate data collection, interpretation, and design development processes within a holistic framework, thereby strengthening the meaning of place. These studies collectively demonstrate that conceptual analysis, site interpretation, and design development should be regarded as

complementary stages within narrative landscape design, thus providing theoretical support for the methodological approach adopted in this research.

The methodology consists of three main stages: (I) Conceptual Review, (II) Site Analysis, and (III) Development of a Narrative Design Model. This structure enables the integration of both theoretical and spatial data, aiming to develop narrative-based design decisions on a scientific and systematic foundation (Figure 2).

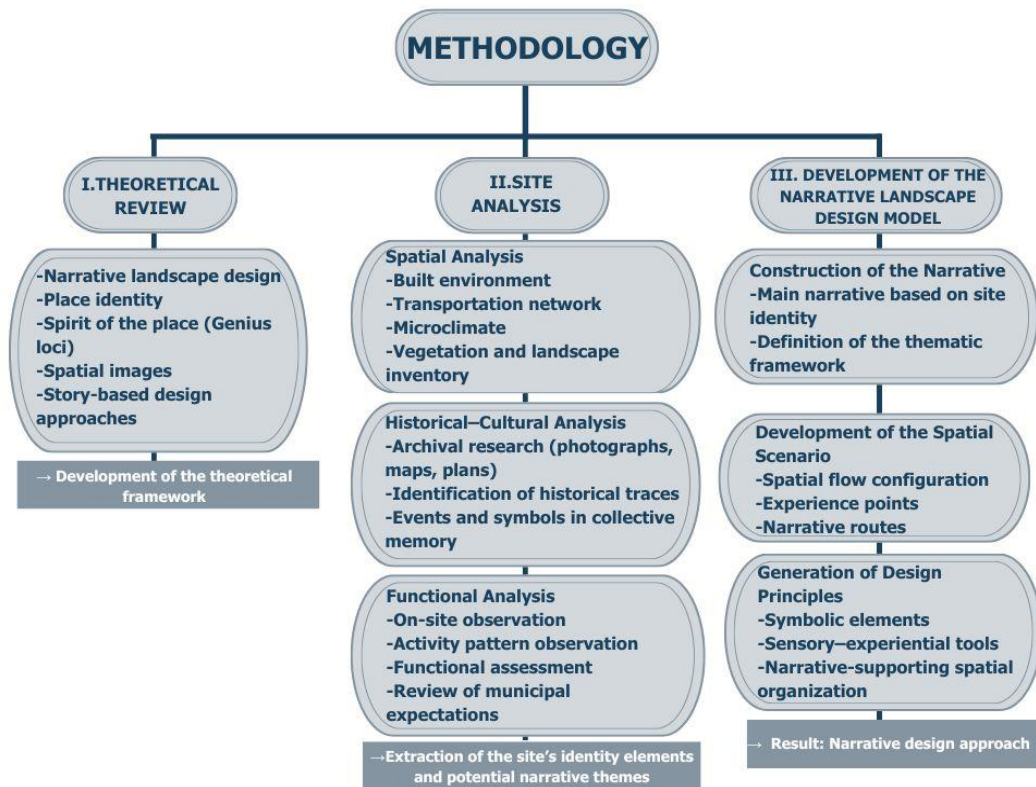


Figure 2. Methodological flowchart (Created by the authors)

In the first stage of the study, a comprehensive theoretical review was conducted on narrative landscape design, place identity, genius loci, spatial imagery, and story-based design approaches. This literature review aimed to define the conceptual boundaries of narrative landscape design, to clarify the relationships between place identity and the spirit of place, and to evaluate international approaches regarding how narrative elements are translated into spatial design. This stage provided the analytical conceptual framework that forms the basis for the subsequent site analysis and design model development.

The second stage of the research consisted of a comprehensive site analysis based on a multi-layered evaluation approach. This stage integrated spatial, historical–cultural, and functional analyses to identify the physical characteristics, existing conditions, and operational performance of the study area.

The spatial analysis focused on the built environment, transportation network, microclimatic conditions, and vegetation and landscape inventory. On-site surveys, photographs, sketches, and field notes were used to document the physical and spatial characteristics of the site. In addition, network analysis, service area analysis, and spatial distribution analysis were conducted to evaluate accessibility, connectivity, and the spatial relationships between the study area and its surroundings.

The historical and cultural analysis examined the historical development, cultural identity, and heritage values of the site through archival documents, planning reports, and relevant literature. This analysis identified the cultural elements and historical characteristics that influenced the spatial structure and informed the design process.

The functional analysis comprised on-site observation, activity pattern observation, functional assessment, and a review of municipal expectations. These analyses were carried out to evaluate the existing use patterns, functional organization, and operational deficiencies of the site and to identify the primary design requirements for the proposed landscape interventions.

In the final stage of the methodology, the data obtained from the conceptual review and site analysis were integrated to develop a narrative landscape design model specific to the study area. This model was structured around three main steps aimed at making the identity of the site visible, strengthening the spirit of place, and enriching spatial experience. First, during the story-building phase, a central narrative reflecting the historical, cultural, and spatial identity of the site was constructed and transformed into a thematic framework consistent with the character of the place. Second, within the development of the spatial scenario, the spatial correspondences of these narrative themes were defined, and a structured arrangement of spatial flow, experiential points, and narrative routes was created to enable users to experience the story step by step. Finally, design principles were generated based on symbolic spatial elements, sensory and experiential design tools, as well as spatial organization and formal strategies that support the narrative. In this way, a holistic design approach was developed that strengthens place identity, establishes a meaningful relationship with users, and reinterprets the spirit of place while preserving its essence.

3. Findings

Böcüzade Park, located in the city center of Isparta, functions as a public open space with strong potential to establish pedestrian connectivity with its surrounding urban fabric. However, the spatial analysis indicates that this potential is not adequately translated into spatial quality or experiential continuity in its current state. The existing patterns of use and spatial configuration fail to sufficiently reveal the park's historical background and local identity, and the area primarily functions as a recreational green space. In this context, narrative and symbolic layers are not effectively represented within the spatial structure of the site.

3.1. Spatial Analysis

Böcüzade Park and its immediate surroundings offer significant potential in terms of alternative transportation systems and pedestrian accessibility due to its central location within the city and high levels of pedestrian movement. In order to develop a holistic and user-oriented design approach for the area, walkability and service area analyses were first conducted. According to the results of these analyses, two additional park areas were identified in the vicinity: Location 3, situated approximately 463 m away and within a 5-minute walking distance, and Location 2, located approximately 638 m away and within a 7.5-minute walking distance. When these three park areas are evaluated together, they function as accessible green spaces for six different neighborhoods. In particular, Böcüzade Park is located within approximately a 10-minute walking distance from five neighborhoods and corresponds to a service area of approximately 189 hectares (Figure 3).

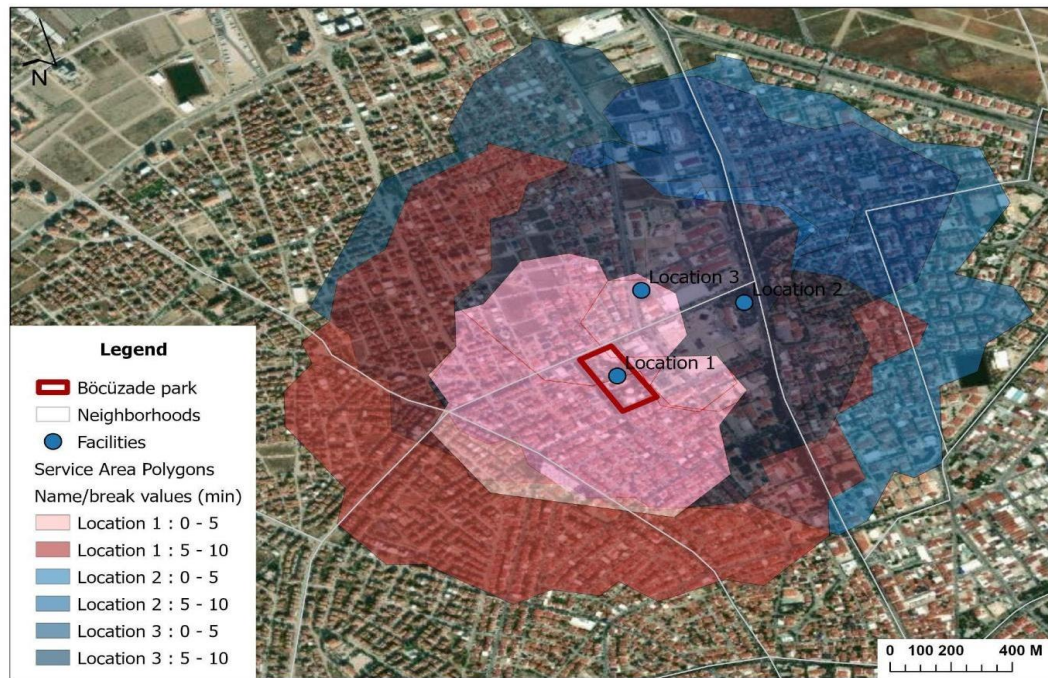


Figure 3. Pedestrian accessibility analysis (5–10 min) of Böcüzade Park and its surroundings (Created by the authors)

In addition, the central location of the study area within the city and the diversity of surrounding land uses present significant potential in terms of urban accessibility (Figure 4). The presence of various urban functions such as shopping centers, places of worship, a community center, and parking areas indicates that the region operates as a multifunctional urban node that supports pedestrian mobility. Enhancing pedestrian routes between these functional areas is essential for improving walkability, promoting sustainable mobility models, and ensuring spatial continuity in public spaces. Furthermore, strengthening these connections has the potential to enhance both the narrative landscape character of Böcüzade Park and its identity as an accessible and highly attractive public space.



Figure 4. Land-use distribution in the vicinity of Böcüzade Park (Created by the authors)



Figure 5. Site analysis of Böcüzade Park (Created by the authors)

Böcüzade Park is located in a centrally positioned urban fabric surrounded by dense built-up areas and major transportation corridors. High-traffic arterial roads are located along its northern and southern boundaries, while residential areas lie to the west and a mosque and other public uses are situated to the east. In addition, the surrounding area includes a shopping center, food and beverage establishments, and various commercial functions, all of which contribute to increased daily user mobility within the site (Figure 5).

Microclimatic assessments indicate that the prevailing wind direction is northwest–southeast. Vegetation cover is primarily concentrated along the northern and southwestern edges of the site, which plays an important role in partially mitigating wind effects and enhancing shading capacity. However, due to the relatively high proportion of open space, the park is exposed to high levels of solar radiation throughout the day, and shading requirements increase particularly during the summer season.

3.2. Historical and Cultural Analysis

Isparta has a multi-layered historical development process extending from the Pisidia region to the Seljuk, Hamidoğulları, and Ottoman periods. The city's historical formation has been shaped around agricultural production, craft activities, and local trade relations, and this production-oriented structure has played a decisive role in the configuration of the urban fabric and everyday life practices (Doğan, 2009; Temurçin & Babacan, 2006). Particularly during the Ottoman period, the distribution of population, settlement patterns, and economic activities in the Isparta district developed in direct relation to the social organization of urban space (Ustaoğlu, 2020).

Architectural and spatial organization principles from the Seljuk period can still be observed in many surviving structures in and around Isparta. Geometric stone craftsmanship, star motifs, symmetrical compositions, and the use of glazed brick, which are particularly evident in the madrasas, mosques,

and caravanserais of Eğirdir, Uluborlu, and Atabey, represent key elements reflecting the aesthetic and spatial understanding of the period (Kılıcı, 2010). Rather than functioning solely as ornamental features, these geometric configurations also constitute a strong design language in terms of orientation, focalization, and spatial coherence.

Structures such as the Atabey Ertokuş Madrasa, Eğirdir Inn, and various congregational mosques are considered significant cultural references shaping the historical identity of Isparta (Kılıcı, 2010). In this context, Seljuk geometric spatial organization and star motifs provide a historical and cultural foundation for the narrative landscape approach developed within the scope of this study.

Another key component shaping urban identity is craft-based production culture. It is known that Turkic communities living in the region from the 12th century onward engaged in carpet weaving, and these products acquired commercial value and were exported to different regions. The widespread use of weaving looms, locally known as “ıstar,” within residential spaces indicates that production was deeply integrated into daily life and directly influenced spatial organization.

With the Republican era, the development of industry, commerce, and public institutions became a transformative process that reshaped the city’s spatial character and social structure. Economic activities between 1923 and 1980 reconfigured the functional organization of the city center and patterns of public space use (Yüzbaşı & Akça, 2021). During this period, educational buildings, religious structures, parks, and public open spaces evolved as key nodes supporting modern urban life, while social interaction and public space utilization in the city center significantly increased (Çakılıcı & Duran, 2025; Haştemoğlu & Tekin, 2023).

One of the most defining elements of Isparta’s urban identity is rose cultivation. Introduced in the late 19th century by Müftüzade Gülcü İsmail Efendi from the Kazanlak region of Bulgaria, oil-bearing rose cultivation rapidly became a fundamental component of the city’s economic and cultural structure. Since the 1890s, rose oil production has evolved beyond agricultural activity to become a cultural practice shaping urban identity. The establishment of the first rose oil factory in 1935 and the founding of Gülbirlik in 1954 for the organization of producers institutionalized this production system, positioning Isparta as one of Turkey’s leading rose oil production centers (Küçük et al., 2024). Beyond its economic value, the rose also holds a strong symbolic meaning associated with love, beauty, aesthetics, and healing, making it a significant cultural element within the city’s identity (Özçelik & Gül, 2018). In this sense, rose production represents a multi-layered structure intertwined with collective memory, everyday practices, and spatial experience.

The spatial development of Isparta’s city center can also be interpreted through local actors and influential families. In this context, the Böcüzade family occupies an important position in urban memory. Narratives concerning the family emphasize the introduction of sericulture to the region and its relationship with local trade, and the name “Böcüzade” is believed to have emerged from this production-based context. Böcüzade Süleyman Sami Bey served as mayor prior to the Second Constitutional Era and later became a parliamentary representative for Isparta in 1908, demonstrating the family’s influence on urban governance and public life.

Despite its historical continuity and strong potential in terms of local memory, the site where Böcüzade Park is located does not adequately reflect this potential within its current spatial configuration. The absence of symbolic, narrative, or spatial indicators referencing the site’s name and historical background limits the representation of place identity in the physical environment, thereby weakening the park’s capacity to express its *genius loci* (Alangoya, 2015; Selçuk, 2018).

In this regard, Böcüzade Park is considered a highly promising site for reinterpretation through a narrative landscape approach, given its multi-layered structure that can be read through both the cultural heritage of rose production and the local historical context.

3.3. Functional Assessment

The functional assessment was conducted to evaluate the existing operational conditions of Böcüzade Park and to identify the main spatial and functional issues affecting its performance. On-site

observation revealed various physical deficiencies affecting the quality and usability of Böcüzade Park. Irregular and deteriorated natural stone pavements were identified along pedestrian routes, reducing walking comfort and accessibility. Surface deterioration caused by weathering and user interventions was also observed on retaining walls and other structural elements. In addition, several designed landscape features, including the rose sculpture, ornamental pool, bridges, and artificial waterfall, were found to be physically deteriorated or non-functional, resulting in a loss of visual continuity and spatial coherence (Figure 6).



Figure 6. Deteriorated spatial elements in Böcüzade Park (Gedik, 2026)

Activity pattern observation indicated that the park is primarily used for passive recreational activities, pedestrian circulation, and short-term resting. The intensity of use was concentrated along the main circulation routes and seating areas, while several sections of the park remained underutilized due to the deterioration of landscape elements and the limited functionality of existing spaces.

The functional assessment demonstrated that the current organization of open spaces, planting areas, circulation network, and site furnishings does not adequately support a coherent spatial structure. The discontinuity between green spaces, hard landscape elements, and recreational facilities weakens spatial legibility and limits the overall functionality of the park. Consequently, although Böcüzade Park continues to serve as an urban open space, its existing physical condition and functional deficiencies reduce its capacity to represent a distinctive place identity.

Finally, the review of municipal design requirements identified the primary expectations of the local authority for the redevelopment of the park. These requirements emphasize strengthening the identity of Böcüzade Park through landscape elements representing Isparta's rose culture, geometric compositions inspired by the Seljuk period, and design components reflecting the city's cultural heritage. Accordingly, the proposed landscape design aims to improve the functional performance of the park while reinforcing its local identity and cultural significance.

4. Narrative Design Model

The narrative landscape design model developed for Böcüzade Park aims to reinterpret the historical, cultural, and spatial identity of the site through an integrated design approach. The primary objective of the model is to transform the park from a conventional recreational open space into a public landscape that reveals Isparta's cultural memory, strengthens users' relationship with place, and enhances the sense of place (*genius loci*).

The proposed model is based on the idea that landscape can function as a narrative medium where cultural values, historical references, and user experiences are spatially represented. In this context, the park is considered not only as a physical environment but also as a dynamic setting where past and present are connected through experiential sequences. Symbolic elements, spatial arrangements, and sensory landscape components are integrated to create a readable narrative structure that guides users through different layers of meaning (Francis & Hester, 1990; Garman, 2006).

The development of the narrative design model was based on the integrated evaluation of physical, cultural, and perceptual characteristics obtained from site analyses. The main narrative components of the design were identified as Isparta's rose production culture, Seljuk geometric design principles, traditional production practices, and the historical contribution of the Böcüzade family to the urban memory. These components were transformed into spatial strategies that support identity formation, orientation, and experiential interaction.

Accordingly, the narrative landscape design model consists of three main stages: (i) construction of the narrative framework, (ii) development of the spatial scenario, and (iii) translation of narrative principles into design decisions (Figure 2).

4.1. Construction of the Narrative Framework

The first stage focuses on identifying the historical and cultural references that form the basis of the park's narrative structure. Within this process, the physical characteristics of the site were evaluated together with local identity components, collective memory, and cultural practices.

Among these components, rose culture was considered as a fundamental narrative element representing not only Isparta's agricultural identity but also collective memory, sensory experience, and cultural continuity. The visual, olfactory, and seasonal characteristics of roses were interpreted as design opportunities that strengthen users' emotional connection with the landscape.

Another important component of the narrative framework is the reinterpretation of Seljuk design principles. Geometric patterns, particularly star motifs and spatial ordering approaches, were considered not as direct historical reproductions but as abstract design principles that contribute to spatial organization, rhythm, orientation, and the creation of focal points (Figure 7).

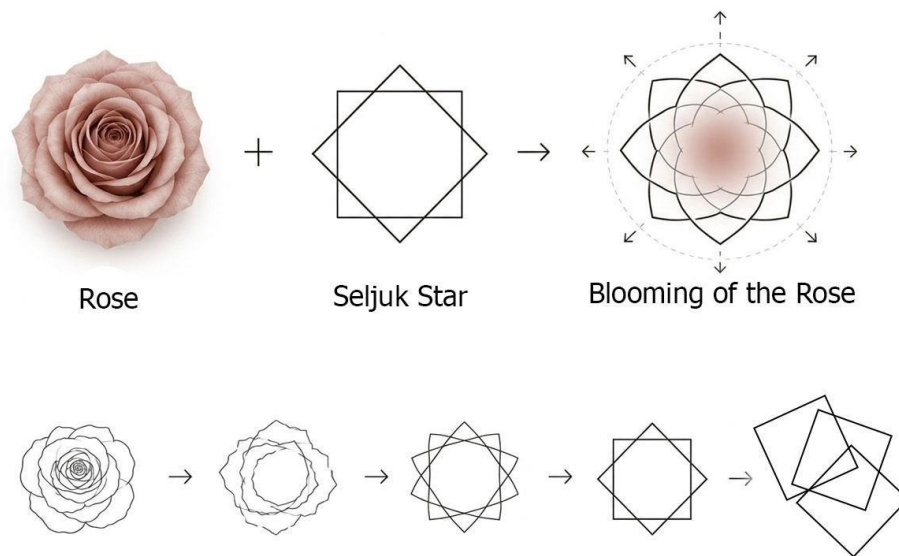


Figure 7. Design concept (Created by the authors)

Within this framework, the main narrative concept of Böcüzade Park was defined as a "living public landscape that reveals Isparta's production culture and historical memory through user experience." Accordingly, the park is envisioned as an experiential landscape where cultural references are transformed into spatial sequences and where users actively engage with the historical layers of the site.

During the spatial interpretation of the narrative framework, symbolic elements, thematic spaces, and transitional zones were used as primary design tools. Focal areas were organized as spatial nodes that support orientation and strengthen memory, while connections between different thematic zones

were designed to maintain narrative continuity. Therefore, circulation was considered not only as a movement system but also as an experiential sequence through which users encounter different layers of the story.

4.2. Development of the Spatial Scenario

In the second stage, the spatial counterparts of the previously constructed narrative were developed. Within this scope, experience routes, focal points, thresholds, and transition zones that guide user movement within the park were redefined. The design approach conceptualizes user experience through a non-linear yet continuous narrative flow. In this way, the aim is not only to enable users to circulate within the park, but also to encourage them to “read” and experience the space. This scenario transforms the user’s relationship with space from passive use into an experience-based interaction (Bulkens et al., 2015).

In the spatial scenario, the entrances of the site are designed as “welcoming and orientation zones,” where symbolic elements representing Isparta’s cultural identity are proposed. Through a guiding spatial framework along pedestrian axes, users are directed toward different experiential nodes (Dönmez et al., 2019). These nodes consist of resting areas, focal spaces, planting design zones, and symbolic spatial components that support the cultural narrative. Following a creative placemaking approach, these spatial components integrate cultural identity into the design process, transforming the park into a place that encourages social interaction, cultural engagement, and a stronger sense of place beyond its functional and aesthetic qualities (Childs, 2026). By promoting continuous public activity and a more readable spatial structure, the narrative landscape approach contributes not only to strengthening place identity but also to improving the social functionality and perceived safety of the park.

In the design scenario, the rose theme is addressed through the principles of sensory landscape design. By integrating sensory qualities such as scent, color, texture, and seasonal variation into the user experience, the site is intended to offer not only a visual but a multi-sensory narrative environment. Accordingly, the use of different rose species and aromatic plant compositions is proposed. In this context, the planting design adopts an ecological placemaking approach by integrating site-specific ecological characteristics with culturally significant plant species, positioning sustainable landscape elements at the core of users’ spatial experience (Childs, 2026).

Seljuk-period geometric spatial organization principles are reinterpreted through both planting and hardscape design within a contemporary landscape design language. These principles inform the formal organization of circulation axes, seating areas, focal nodes, and planting compositions, while geometric patterns derived from traditional star motifs are employed as abstract spatial ordering elements to strengthen orientation and spatial coherence. Rather than directly replicating historical motifs, the design reinterprets their underlying organizational logic, integrating them into the overall spatial structure in a contemporary and context-sensitive manner.

4.3. Design Principles

In the final stage of the narrative design model, a set of fundamental design principles was developed for the study area. These principles were formulated in accordance with the objectives of strengthening place identity, enhancing user experience, ensuring spatial continuity, and making the sense of place (*genius loci*) more perceptible.

The key design principles developed within this framework can be summarized as follows:

- The use of symbolic spatial elements that make the site’s historical and cultural memory visible.
- The reinterpretation of rose culture and Seljuk geometric design principles within a contemporary landscape design language.
- The creation of a pedestrian-oriented, accessible, and continuous spatial organization.

- The integration of sensory landscape components that enhance user experience.
- The formation of a narrative spatial flow through focal points, transition zones, and thresholds.
- The holistic treatment of lighting, site furniture, and planting design decisions within a unified identity framework.
- The integration of spatial visibility, continuous circulation, lighting strategies, and active use scenarios to enhance perceived safety and encourage user diversity.
- The creation of a legible and cohesive spatial character by reducing the fragmented nature of the existing site.
- The adoption of environmentally sustainable strategies, including permeable surfaces, low-water-demand plant species, and climate-responsive landscape decisions.
- The integration of bicycle routes and accessible circulation networks that support alternative transportation systems.
- The incorporation of artistic and narrative elements that reinforce spatial identity and are integrated into the user experience.

Accordingly, the narrative landscape design model developed in this study aims to transform Böcüzade Park from a purely physical recreational space into an experience-oriented public landscape that makes urban memory visible, strengthens local identity, and establishes meaningful relationships with its users. The model also offers an application-based example of narrative landscape design, a relatively underexplored approach in Turkey, and contributes a new design perspective on the relationship between place identity and spatial experience.

5. Spatial and Planting Design Decisions

Within the design approach developed for Böcüzade Park, spatial and planting design decisions constitute the fundamental components of the narrative landscape framework. These decisions were formulated through the integrated evaluation of the site's existing physical characteristics, historical and cultural layers, and the findings obtained from the functional analysis.

User circulation within the park is organized along the main axis extending eastward from the main entrance. Additionally, a north–south pedestrian axis has been established to support daily pedestrian movement and accessibility (Figure 8).



Figure 8. Proposed landscape design project for B c zade Park (Created by the authors)

The first spatial element encountered along this eastward route extending from the main entrance is the existing building located at the center of the site, which has been adaptively reused as an interpretation center and museum. Situated in the northeastern part of the park, the building functions as a narrative center presenting the rose culture of the Seljuk period together with the historical landscape heritage of the region. It also serves as a living cultural space by hosting periodic Seljuk tile workshops, thereby supporting both production and learning activities. In this way, visitors are immediately introduced to the historical and cultural context of the site through a strong interpretive starting point.

Surrounding this building, a rose garden has been designed to recreate the atmosphere of traditional rose fields. Within this area, sculptural figure depicting rose harvesters make the themes of production, craftsmanship, and labor visible. The design aims not only to encourage visual appreciation of the landscape but also to immerse visitors in the narrative experience. This concept is reinforced through dense rose planting beds integrated with a continuous pedestrian circulation network.

From the central space, the narrative expands radially toward the northern section of the park, where visitors encounter the tree of life, one of the most significant symbolic elements of the Seljuk period. Located in the northeastern part of the site, this composition has been reinterpreted together with surrounding rose species, creating both a symbolic landmark and a botanical focal point. The space is conceived as a representative landscape that reflects the Seljuk perception of nature through the themes of life, continuity, and rebirth. Opposite this zone, beyond the northern entrance, a dedicated rose product experience area and cafe complex is proposed to showcase traditional food and beverages made from Isparta's local roses

Continuing southward along the main axis, visitors reach a symbolic distillation still sculpture inspired by the traditional rose oil production process. This element serves as a prominent focal point representing Isparta's production culture and rose heritage while making the industrial and cultural dimensions of the narrative visible. It also functions as the final thematic destination within the park, symbolically concluding the story of rose production and completing the narrative sequence (Figure 9).



Figure 9. AI-generated conceptual illustration of the proposed sculpture

To complement the proposed spatial framework, a bicycle route was incorporated to diversify mobility within the park. The route was integrated with the surrounding pedestrian network and designed to support both recreational use and sustainable transportation. It is configured as a visually continuous yet physically separated corridor, ensuring safe and comfortable movement for both pedestrians and cyclists. In addition, bicycle parking facilities are proposed near the main entrances and key activity nodes. Accordingly, the proposed design aims to promote environmentally friendly mobility, reduce carbon emissions, and support sustainable transportation behaviors.

Travertine stone was selected for pedestrian pathways due to its compatibility with the site's natural character and its historical associations. In hardscape areas, basalt paving and permeable surface materials are proposed to enhance durability while supporting ecological sustainability.

Geometric pavement patterns inspired by Seljuk star motifs are incorporated into the spatial design, allowing surface materials to function not only as physical elements but also as narrative components that reinforce the historical identity of the site and strengthen the narrative landscape concept.

Urban furniture was designed through an integrated approach that reinforces the overall spatial identity. Seating elements, lighting fixtures, wayfinding signage, waste receptacles, and resting areas are conceived not merely as functional amenities but as design components that contribute to the spatial narrative and enhance users' experience of the park.

Within the planting strategy, rose cultivation, one of the most distinctive components of Isparta's historical and cultural identity, was adopted as the central design theme (Figure 9). Planting beds distributed throughout the circulation network constitute the primary supporting elements of the narrative landscape framework. *Rosa damascena*, *Rosa chinensis*, *Rosa gallica*, and *Rosa canina* were selected to create a multi-layered landscape experience through seasonal variation as well as sensory qualities such as fragrance, color, and texture. Consequently, movement through the park is intended to become more than a physical journey, offering visitors an immersive spatial experience through

which the historical and cultural layers extending from the Seljuk period to the present can be interpreted.

Within this framework, *Rosa damascena*, the principal species used in oil rose cultivation, was proposed together with *Rosa odorata* (Korkmaz & Özçelik, 2015). The flowering period of *Rosa damascena*, which is limited to May and June, provides a distinctive seasonal experience by creating a period of intensified visual, olfactory, and cultural interaction. *Rosa odorata*, on the other hand, is recognized as an important genetic resource in the development of garden, cut, and landscape roses (Özçelik & Orhan, 2014). To enhance biodiversity and ecological resilience, naturally occurring species in the region, including *Rosa foetida*, *Rosa sempervirens*, *Rosa phoenicia*, *Rosa arvensis*, *Rosa canina*, *Rosa dumalis*, and *Rosa gallica*, were also incorporated into the planting design. The inclusion of these locally adapted species aims to strengthen ecological sustainability while reinforcing the regional botanical identity.

In addition, *Rosa chinensis* and its hybrids, commonly referred to as "ever-blooming roses" because of their extended flowering period, were incorporated into the planting scheme. These species flower from May until October or November, depending on frost conditions, ensuring prolonged seasonal displays of color, fragrance, and visual interest throughout most of the year.

Vegetation also functions as a spatial element that defines boundaries, frames views, and establishes focal points. Seasonal variation further enriches the temporal dimension of the landscape, allowing the park to offer diverse sensory and visual experiences throughout the year.

Ecological and functional strategies aimed at improving user comfort were integrated into the planting design. Considering the heavy traffic corridors located along the northern and southern boundaries of the site, vegetated buffer zones were proposed to mitigate traffic-related noise. Dense evergreen and screening plant species were selected to improve the park's acoustic environment while creating a greater sense of enclosure and comfort.

These vegetated buffers also serve as narrative landscape components by defining spatial boundaries and subtly directing visitor movement throughout the site. Accordingly, planting design is conceived not only as an ecological and functional intervention but also as an integral element that reinforces spatial identity and supports the overall narrative structure.

Given Isparta's continental climate and the increasing risk of summer drought, a climate-responsive and sustainable planting strategy was adopted. Priority was given to drought-tolerant, low-water-demand, and locally adapted plant species. Based on xeriscape principles, multi-layered planting compositions were developed to reduce water consumption while enhancing the ecological resilience of the landscape.

To further improve environmental sustainability, lawn areas were minimized, permeable surfaces were increased, and planting strategies that enhance soil moisture retention were adopted. Mulching, shade-providing tree groups, and ground-cover species were incorporated to reduce evapotranspiration, while drip irrigation systems were proposed for the rose parterres and aromatic planting areas to ensure efficient and controlled water use.

In conclusion, spatial and planting design decisions aim to transform Böcüzade Park into more than a functional recreational space by creating an integrated design system that makes place identity visible, enhances user experience, and embeds the narrative landscape approach into the site.

6. Conclusion

Urban open spaces play a significant role in preserving local identity and cultural continuity while responding to contemporary social and spatial needs. Within this context, narrative landscape design offers a promising perspective by integrating historical, cultural, and spatial values into the design process. The proposed model contributes to this perspective by providing a structured approach that translates place-specific narratives into tangible landscape design decisions.

The Böcüzade Park case demonstrates how symbolic landscape elements, spatial organization, and cultural references can be systematically incorporated into a coherent design process. Rather than treating historical and cultural values as isolated design features, the proposed framework integrates them with functional and spatial considerations to support the development of context-sensitive landscape interventions.

The study is limited to the development of a conceptual design model and does not include post-implementation evaluation. Therefore, future research should investigate the performance of the proposed model through post-occupancy evaluations and user-based assessments to examine how narrative landscape interventions influence place identity, spatial experience, and the long-term use of urban open spaces. Such studies would further strengthen the empirical basis of narrative landscape design and support its application in different urban contexts.

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Author Contribution and Conflict of Interest Disclosure Information

All authors contributed equally to the article. There is no conflict of interest.

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A Framework for Evaluating the Sustainability of Multilayered Historic Rural Cultural Landscapes: The Case of Tahtalı Neighborhood, Bursa

Lale KARATAŞ BİLLOR ^{1*} 

ORCID 1: 0000-0001-8582-4612

¹ Bursa Technical University, Faculty of Architecture and Design, Department of Architecture, Bursa, Türkiye

* e-mail: lale.karatas@btu.edu.tr

Abstract

This study examines Tahtalı Neighborhood in Nilüfer district of Bursa as a multilayered rural cultural landscape area where layers from the Ancient, Byzantine, and Ottoman periods can be read together. The research employed a qualitative method; literature review, historical data analysis, fieldwork, on-site observation, photographic documentation, and spatial analyses were considered together. The findings show that historical layers from the Ancient, Byzantine, and Ottoman periods can be read together within the same topographical system in Tahtalı Neighborhood. The area has been documented as a multi-layered rural cultural landscape where defensive structures, religious sites, necropolis areas, rural settlement patterns, and social memory are integrated. Accordingly, the study proposes a holistic and relational assessment framework called the "Multi-Layered Rural Cultural Landscape Continuity Framework" for the preservation and evaluation of multi-layered rural cultural landscapes.

Keywords: Cultural Landscape, Spatial Continuity, Rural Heritage, Tahtalı Neighborhood, Cultural Heritage and Conservation.

Çok Katmanlı Tarihi Kırsal Kültürel Peyzajların Sürdürülebilirliğinin Değerlendirilmesine Yönelik Bir Çerçeve: Bursa Tahtalı Mahallesi Örneği

Öz

Bu çalışma, Bursa'nın Nilüfer ilçesindeki Tahtalı Mahallesi'ni, Antik, Bizans ve Osmanlı dönemlerine ait katmanların birlikte okunabileceği çok katmanlı bir kırsal kültürel peyzaj alanı olarak incelemektedir. Araştırmada nitel yöntem kullanılmış; literatür taraması, tarihi veri analizi, saha çalışması, yerinde gözlem, fotoğrafik dokümantasyon ve mekânsal analizler birlikte ele alınmıştır. Bulgular, Tahtalı Mahallesi'nde Antik, Bizans ve Osmanlı dönemlerine ait tarihi katmanların aynı topografik sistem içinde birlikte okunabildiğini göstermektedir. Bölge; savunma yapıları, dini mekanlar, nekropol alanları, kırsal yerleşim düzenleri ve sosyal hafızanın bütünleştiği çok katmanlı bir kırsal kültürel peyzaj olarak belgelenmiştir. Bulgular, tarihi katmanlar arasındaki mekânsal sürekliliğin ve topografik ilişkilerin bölgenin kültürel kimliğini şekillendirdiğini ortaya koymaktadır. Buna göre, çalışma, çok katmanlı kırsal kültürel peyzajların korunması ve değerlendirilmesi için "Çok Katmanlı Kırsal Kültürel Peyzaj Süreklilik Çerçevesi" adı verilen bütünsel ve ilişkisel bir değerlendirme çerçevesi önermektedir.

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1. Introduction

Rural cultural landscapes emerge as a result of long-term interactions between people and the natural environment. These areas are complex heritage sites where spatial, social, and cultural layers from different historical periods. They are gathered within the same settlement system (UNESCO, 1992; Taylor & Lennon, 2012). These areas contain complex heritage elements and these areas are more than physical structures. Beyond the physical building complex, they contain all the tangible and intangible elements representing the area. Topography, defense systems, religious structures, settlement structures, production relations, and elements of social memory are some of these elements. However, in current conservation approaches, all these tangible and intangible elements contained within complex, layered rural landscapes are often evaluated, individually or in combination with a few other elements. Consequently, this fragmented approach makes it difficult to read the historical continuities and spatial relationships in the area as a whole. This situation obscures the relationships between the layers of the cultural landscape and leads to the invisibility of the area's identity (Mitchell et al., 2013; Jones, 2003).

An examination of previous studies on cultural landscape conservation in the literature reveals the following: Firstly, the most important priority in these studies should be the holistic assessment of settlements with all their elements. Studies, particularly those focusing on European countries, indicate that the topography, defense systems, road layouts, and settlement patterns in rural areas are also elements of heritage. They emphasize, the need for careful research and holistic evaluation of all landscape elements in the area (Fowler, 2003; ICOMOS-IFLA, 2017). UNESCO's 1972 World Heritage Convention defines cultural heritage elements in rural cultural landscapes : "the joint effort of man and nature" (UNESCO, 1992). This approach underscores, the need for the holistic conservation of these multi-layered landscapes. It is reflect historical, social, and spatial traces accumulated over time.

An examination of research on rural cultural heritage landscapes in Türkiye highlights several key issues. Firstly; these studies often focus on individual structures. For example, areas such as Cumalıkızık, Safranbolu, Mardin, and Cappadocia are frequently studied. However, within the Turkish context, studies comprehensively examining the continuity and legibility of layers from different historical periods, within the same spatial system are still limited. In particular, the spatial relationship between archaeological heritage and living rural structures is clearly not adequately addressed. Significant methodological gaps are observed in studies It is conducted in Türkiye regarding the integrated evaluation of cultural memory elements and physical landscapes. In this context; this study aims to address this gap in the literature by proposing an evaluation framework, for the integrated assessment of physical landscapes. The study area is the Tahtalı neighborhood in the Nilüfer district of Bursa. The study aims to evaluate the continuity of the multi-layered rural cultural landscape structure of the Tahtalı neighborhood through the proposed evaluation framework. The proposed "Multilayered Rural Cultural Landscape Continuity Framework" offers a holistic approach to understanding the multilayered structure of the area by considering its various dimensions (historical layers, spatial relationships, topographical continuity, cultural memory, and legibility).

1.1.State of art

The concept of cultural landscape in conservation has experienced a major leap in the second half of the 20th century. In 1992, UNESCO officially included the definition of "cultural landscape" in its World Heritage Operational Guidelines. This changed the perspective that cultural landscapes are the natural and monumental elements within an area. The idea that cultural landscape elements are the product of long-term interaction between humans and nature, and that they are formed by accumulating layer by layer over the years, began to take root (UNESCO, 1992). With this perception, conservation efforts have brought multi-layered rural cultural landscapes to the forefront.

Current literature research has begun to include spatial, social, economic, and symbolic dimensions (Taylor & Lennon, 2012). In successful examples from Europe, the long-term relationship between topographic continuity and cultural practices has been analyzed and concluded in detail. Val d'Orcia in Italy (UNESCO, 2004), the Loire Valley in France (UNESCO, 2000), the Lake District in England (UNESCO,

2017), the Upper Middle Rhine Valley in Germany (UNESCO, 2002), and the Rioja wine cultural landscape in Spain are examples of this (Fowler, 2003; ICOMOS-IFLA, 2017). The Jiufeng-Sheshan Historic Rural Area (Shanghai), ancient agricultural systems, topographic adaptation, and living cultural practices have been examined together. In these studies, spatial continuity has been analyzed using the "cultural landscape genes" approach (Li et al., 2024; Hua & Zhou, 2015).

A significant portion of the studies conducted in Türkiye on rural heritage focuses on areas such as Cumalıkızık, Safranbolu, Mardin, Cappadocia, and Bergama. These studies undoubtedly make important contributions to the preservation of traditional architectural fabric and the revelation of the characteristics of rural settlements. However, the number of studies addressing the spatial continuity of rural settlements, the interaction between topography and cultural memory, and the simultaneous evaluation of layers from different historical periods is quite limited. Similarly, the relationship between elements constituting cultural memory, such as oral history, collective memory, migration, and war memory, and the rural cultural landscape is not sufficiently examined in the literature. Existing studies generally, focus on specific heritage elements or individual periods. Systematic frameworks that evaluate the spatial relationships between different historical layers, the continuity of topography, and the different dimensions of cultural memory with a holistic approach are limited. This situation points to a significant methodological gap, in the analysis of complex rural cultural landscapes. This study aims to contribute to filling this gap by proposing an evaluation framework for measuring the continuity of multi-layered rural cultural landscapes, using the Tahtalı Neighborhood as an example.

1.2. Study Area: Tahtalı Neighborhood

Tahtalı Neighborhood is located 15 km from the city center of Bursa (Figure 1).

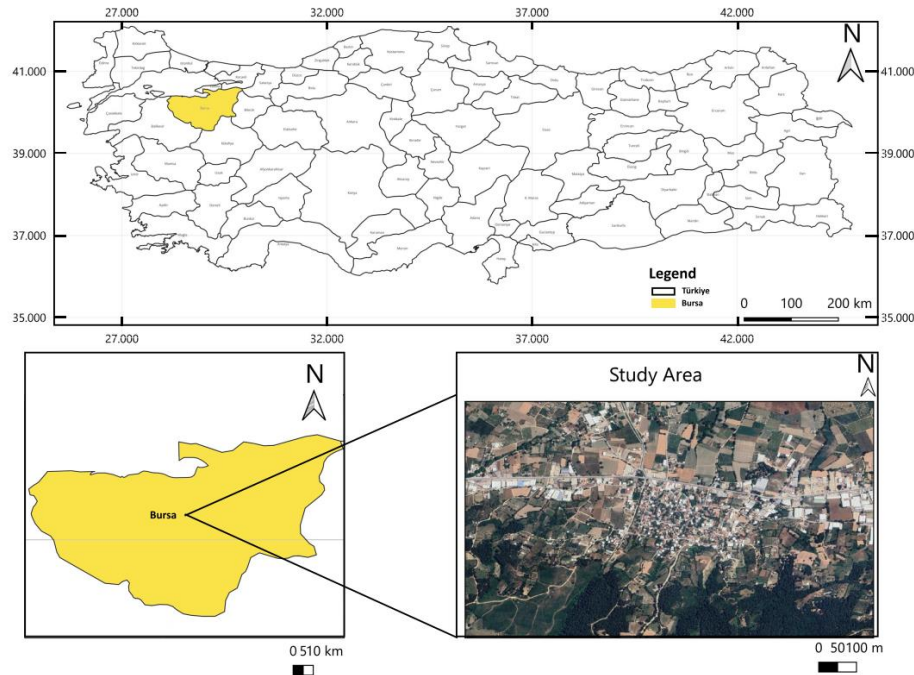


Figure 1. Location of Tahtalı Neighborhood in Bursa (adapted from Google Earth).

The Tahtalı Neighborhood, which is still inhabited today, was later established on top of an ancient settlement whose surface materials indicate a history dating back to the 2nd century BC. Necropolis areas are located in the eastern and western parts of the settlement, and on the southern part, on a strategically important hill, also known as File Tepe, which is the highest peak, there are remnants of a watchtower structure. The boundaries of the urban-archaeological, 1st, 2nd, and 3rd degree archaeological sites were determined by the decision of the Bursa Cultural and Natural Heritage Protection Board dated 10/09/1999 and numbered 7380. The urban archaeological site was transformed into an archaeological site by the decision of the Bursa Regional Board for the Protection of Cultural and Natural Heritage dated 25/08/2005 and numbered 839. By decision number 183 dated

18/11/2011 of the Bursa Regional Board for the Protection of Cultural Heritage, it was decided to register 7 monumental structures and 63 examples of civil architecture located in the village center as immovable cultural heritage requiring protection. By decision number 10768 dated 30/09/2021 of the Bursa Regional Board for the Protection of Cultural Heritage, urban site boundaries were determined around the registered structures (Bursa Regional Board for the Protection of Cultural Heritage, 2021).

The Tahtalı neighborhood in the Nilüfer district of Bursa province is partially located within the city walls of the ancient city. Today, a section of the city wall, approximately 2 meters high and 100 meters long, extending north-south, remains standing in the southern part of the village. Ceramic materials and city ruins from the ancient city were used in the construction of existing buildings by means of adobe. From ceramic materials and marble architectural fragments, it can be determined that the history of the ancient city extends back to the 2nd century BC (Bursa Regional Board for the Protection of Cultural Heritage, 2021).

2. Method

This research employed a qualitative research method. The study included literature and historical data analysis, fieldwork and on-site observation, spatial and morphological analyses, and archival cultural memory assessments.

In the first stage of the research, a literature review was conducted regarding Tahtalı Neighborhood and its surroundings. Decisions of the Regional Conservation Board, archival documents, local history studies, old maps, and relevant academic publications were evaluated. The layered historical development process of the region was investigated. In the second stage, on-site investigations were conducted. During this process, castle ruins, wall systems, necropolis areas, the ruins of the Hagios Theodoros Church, traces of the watchtower at Filetepe, the historical mosque, the traditional settlement pattern, and old Greek houses were examined on-site. The current condition of the structures, their relationships with each other, their connections with the topography, and their viewing angles were documented with photographs.

Thirdly, spatial layer analysis and morphological analysis were conducted to reveal possible continuities between the ancient defense system and the Ottoman-era rural settlement pattern. Within the scope of spatial analysis, defense structures, religious structures, necropolis areas, and settlement patterns were evaluated in terms of their relationships with the topography. In the morphological analysis, the village's street layout, building orientations, slope-based settlement patterns, and defense-oriented spatial organization were examined. Finally, in order to reveal the relationship between the physical landscape and the social memory of the region, the components of cultural memory were investigated. All data obtained from the archives, including local oral narratives, legends about the tunnel said to be between the castle and Ürünlü Castle, memories related to the War of Independence, Turkish-Greek coexistence culture, and current visitor practices, were analyzed.

Finally, within the scope of this study, a "Multilayered Rural Cultural Landscape Continuity Framework" was developed using Tahtalı Neighborhood as an example. This framework offers a systematic framework aimed at evaluating the readability of spatial layers. This layersis belonging to different historical periods in multilayered rural settlements. The framework components were created by considering the main evaluation areas that stand out in cultural landscape theory, historical environment analyses, spatial organization studies, and cultural memory literature.

The developed framework consists of five main components. These elements are followed. It is analysis framework, historical layer analysis, spatial organization analysis, topographic continuity analysis, cultural memory analysis, and spatial readability analysis. The framework, iteratively developed based on literature reviews, field studies, and spatial analyses, is applicable not only to Tahtalı Neighborhood but also to rural settlements where different historical layers coexist. The reasons for selecting these analyses are as follows:

- (I) Historical layer analysis aims to determine the continuity of different periods within the settlement.

- (II) Spatial organization analysis examines the relationships between defensive structures, religious structures, and the rural fabric.
- (III) Topographic continuity analysis aims to evaluate the impact of topography on settlement decisions.
- (IV) Cultural memory analysis investigates the spatial counterparts of oral narratives and collective memory.
- (V) Spatial readability analysis is included in the framework to reveal the extent to which historical layers are perceived today.

This evaluation approach to be applied in the research; This framework is compiled from proposals in studies that argue cultural landscapes should be read by considering spatial relationships, environmental continuity, and social memory together (Corner, 1999; Smith, 2006; Antrop, 2005; Fairclough, 2008; Taylor & Lennon, 2011; Nora, 1989). The detailed structure of the framework and its methodology are presented below (Figure 2).

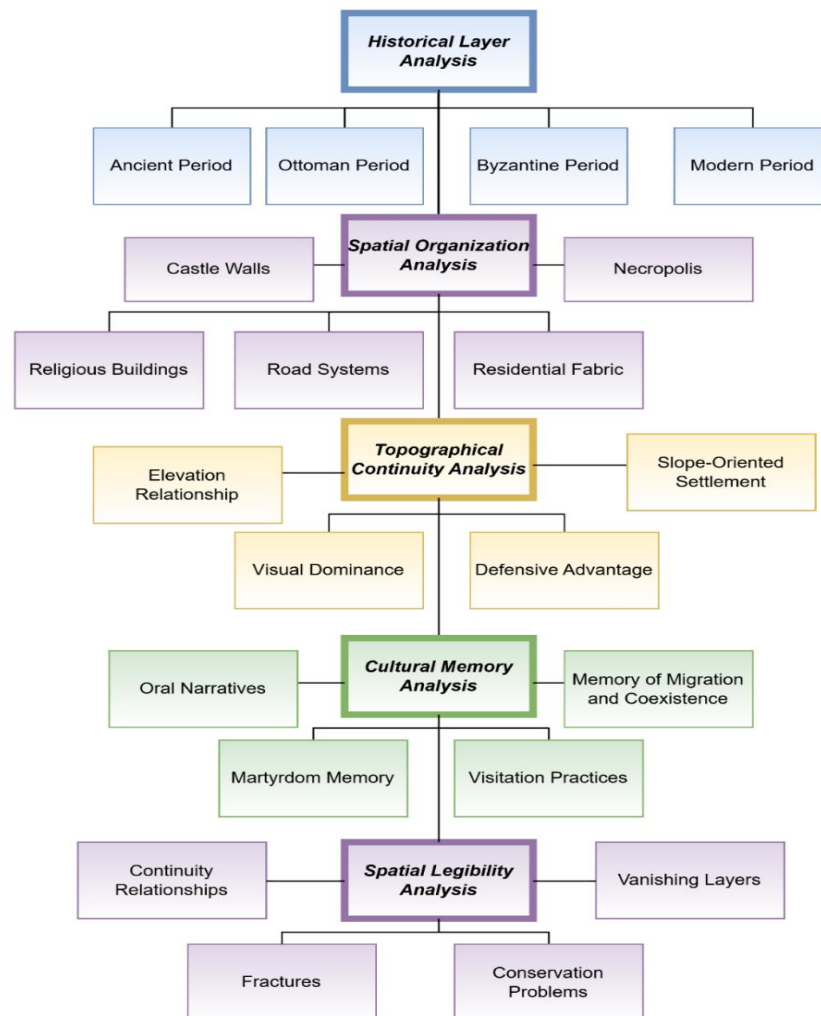


Figure 2. Sustainability Assessment Framework for Multilayered Rural Cultural Landscapes (Author, 2026)

3. Findings

In this section, Tahtalı Neighborhood was analyzed in accordance with the Multilayered Rural Cultural Landscape Continuity Framework developed within the scope of the study. The structural diagram of the model is presented in Figure 2.

3.1 Historical Layer Analysis

Bursa's Tahtalı neighborhood is considered, according to the literature, to be the earliest settlement in Bursa. Based on historical findings, experts estimate the region's history to date back to around 3000 BC. Believed to be a rural settlement with continuous habitation from antiquity to the present day, the area contains spatial traces from the Ancient, Byzantine, and Ottoman periods. The most significant historical finds include castle ruins and city walls, cemeteries, and pottery. The castle ruins and city walls indicate that the area was primarily defensive from the beginning, and architectural and archaeological findings suggest that the settlement dates back to the 2nd century BC (Bursa Regional Cultural Heritage Protection Board, 2021).

Byzantine-era remains are prominent in the area. These include the ruins of the Hagia Sophia Church and the Filetepe observation terrace. Experts believe that the Hagia Sophia Church is one of the oldest churches in Bursa that has survived from the Byzantine period to the present day. The presence and prominence of defense systems and artifacts in the region indicate that the defense system in the area continued from antiquity to the Byzantine period. The central location of religious structures in the region shows that Tahtalı Neighborhood was an important center for both defense and religious purposes during the Byzantine period (Figure 3).



Figure 3. Remains of the ancient city walls (Bursada Bugün, 2014).

Looking at another period in this region, the Ottoman period is observed. During the Ottoman period, a multicultural rural settlement structure where Turks and Greeks lived together is observed in the region. It is also known that this region was one of the settlements where the Greek population was in the majority during the Ottoman period. The main Ottoman-era artifacts in the region consist of traditional rural residential architecture and old Greek houses (Bursa Regional Cultural Heritage Protection Board, 2021; Bursa'da Kültür, 2026) (Figure 4).



Figure 4. Examples of traditional houses (Author, 2026)

Among the Ottoman-era structures in the village, there is also a historical mosque believed to have been built in the 1850s (Bursa Regional Board for the Protection of Cultural Heritage, 2021). The historical mosque, which was recently restored, is one of the finest examples of Ottoman civil architecture on a village scale (Figure 5).



Figure 5. Exterior(a) and interior (b)images of Tahtalı Village Mosque (Author, 2026)

The Tahtalı neighborhood, examined in this study, is an area that experienced the Turkish War of Independence. During this period, it suffered numerous attacks and fires. Remnants of a cemetery built for the villagers martyred by the Greeks during this time still exist. Tombstones remain as remnants in the village. In light of these historical values, the village settlement was placed under protection by the Monuments Board in 1999 (Bursa Regional Cultural Heritage Protection Board, 2021). Within this context, it is clear that the remains of the martyrs of the War of Independence constitute one of the most recent historical layers. When all this data is considered holistically, it is evident that the Tahtalı neighborhood is not merely an area consisting of individual structures from different periods. The conclusion drawn from these results is that the Tahtalı neighborhood is a region with a complex cultural landscape formed by the superposition of historical layers.

3.2 Spatial Organization Analysis

During the research process, the following findings were reached regarding the spatial structure of Tahtalı Neighborhood: The spatial structure of the area is directly related to the land and defense systems. The most important finding demonstrating this is that the castles, walls, religious structures, necropolises, and traditional settlement structures in the area developed together within the same spatial structure. The castle and wall complexes are placed on topographic elevations. The spatial arrangement in the area, taking the topography into account, shows that the defense structures were built using the natural topography. Another finding is that the wall system in the area shows a trace that defines the boundaries of the settlement. The existence of this trace clearly reveals that the spatial scheme of the neighborhood developed around this system. Another finding concerns the necropolis areas. In the area, the fact that the necropolis area is located on the east and west borders of the settlement reveals that the living and dying areas were planned within a specific organization. In the research conducted on religious structures within the spatial scheme of the area, the following findings were made. In the spatial arrangement of Tahtalı Neighborhood, religious structures such as the Hagia

Sophia Church and the historical village mosque are important focal points in the region. In other words, religious structures are central to the spatial layout of the area and occupy their place as the most important landscape elements (Antrop, 2005; Tuan, 1977; Limongiello et.al, 2026).

3.3 Topographic Continuity Analysis

The placement of buildings and cultural heritage elements in Tahtalı Neighborhood has been significantly influenced by the topography. Topography appears to be the most decisive factor in the placement of structures. Looking at the spatial settlements formed in different periods in the area, the formation of similar topographical settlements is noteworthy, indicating that topography is a compelling settlement element (Aşur et al., 2025). Elements showing that similar topographical preferences were maintained in different historical periods include. It is the settlement's location on the slopes of Uludağ, the prioritization of natural elevations providing defensive advantages, and the use of points providing visual control. The observation systems at Filetepe are particularly noteworthy. These observation systems demonstrate, that the land was used for defensive purposes. The castle and wall structures in the area, are located at points overlooking the surrounding valley. This shows that the natural topography of the area was an important part of the defense strategy. The spatial traces of the castle and wall structures in the area are evidence of a topographical continuity. This continuity is between the old defense system and the Ottoman rural settlement system (Çakan et al., 2026). Observational studies of traditional houses in the area have revealed that these architectural structures were also shaped in accordance with the topography. Traditional houses in Tahtalı Neighborhood are designed along the slopes. Looking at the street layouts in the neighborhood, the streets are also in accordance with the natural structure of the topography. The natural landscape in the area has been preserved. These findings show that the rural settlement pattern developed in harmony with the topography. When the settlement pattern that developed during the Ottoman period is examined, the same elevation systems and slope relationships are observed. This situation shows that the settlement logic has been largely preserved throughout the historical process (Figure 6).



Figure 6. In the street patterns of the neighborhood, the street weave follows the natural topography (Author, 2026)

3.4. Cultural Memory Analysis

A cultural examination of Tahtalı Neighborhood has revealed the following findings: The area's cultural memory is not solely derived from physical structures. The cultural memory of the area is also sustained through oral narratives and collective memory. Archival records show that the castle in the area is frequently mentioned in local stories. Particularly important is the legend of the tunnel said to be located between the castle and Ürünlü Castle, which is mentioned in these tales. These legends demonstrate that the cultural memory of past defense systems continues to this day. Another memory area in the region is the Cemetery of the Martyrs of the War of Independence. This area is one of the most important memory areas in the region. Here, there are the graves and tombs of villagers who fell

as martyrs in the War of Independence against the Greeks. The tombs erected for the martyrs frequently depict the weapons used to kill them. The depictions of weapons in the tombs clearly show the reflection of the war memory in the physical and spatial memory of the settlement structure where Turks and Greeks lived together during the Ottoman period. It is observed that Greek visitors still maintain their connection with the region today. The continuation of this connection shows that Tahtalı Neighborhood is an international cultural memory area. All these findings, obtained through observational methods and archival records, document that the cultural elements of Tahtalı Neighborhood are not limited to physical structures, but also include its social memory (Wang et al., 2025).

3.5. Spatial Readability Analysis

Today, different historical layers can be read together in the region. In particular, the architectural elements of the area, such as castle ruins, city walls, religious structures, traditional houses, and monumental areas, coexist within the same landscape system. However, it has been observed that the legibility of some historical layers in the area is gradually decreasing. Several reasons contribute to this, including. It is the fragmented preservation of archaeological remains. It is the fact that only the foundations of some architectural structures especially traditional ones, remain. The presence of modern interventions is in some archaeological sites due to their private ownership. All these reasons make it difficult, to read the rural cultural landscape of the region holistically. The insufficient visibility of the spatial relationships between the castle, necropolis areas, religious structures, and traditional housing fabric leads to a fragmented perception of historical layers. Therefore, the preservation of the cultural landscape of Tahtalı Neighborhood will not be possible solely through the restoration of individual buildings. The holistic preservation of the rural cultural landscape is only possible through the preservation of spatial relationships between the historical layers in the area. All these findings clearly show that the principles presented in UNESCO (1992) for the preservation of rural landscapes are not met in this respect. In this context, measures for holistic conservation should be taken as soon as possible.

4. Conclusion and Suggestions

The "Multilayered Rural Cultural Landscape Continuity Framework" proposed in this study offers a systematic approach aimed at addressing the fragmented assessment problem in the literature. The framework consists of five main components: historical layer analysis, spatial organization analysis, topographic continuity analysis, cultural memory analysis, and spatial readability analysis. Thus, archaeological, architectural, topographic, and memory-based data are evaluated together within the same analytical framework. This approach aims to provide a viable methodology for rural settlements by enabling the reading of the cultural landscape not only through period layers but also on the basis of continuity, relationality, and spatial context.

The findings obtained using the evaluation framework proposed in this study reveal that the region still contains an integrated cultural landscape system where defensive structures, religious sites, cemeteries, rural settlements, oral narratives, and collective memory coexist. These results demonstrate that there are landscape elements influencing rural heritage beyond physical structures. This supports studies explaining that restoration efforts focusing solely on physical structures are never sufficient for conservation and preservation in cultural landscape areas. Because, as seen in this region, the preservation and uncovering of heritage values in multi-layered areas requires examining the long-term relationships between people, nature, history, settlement patterns, and collective memory in the region. The study results support the need for a holistic assessment of cultural landscape areas, as stated by Sauer (1925) and UNESCO (2011). Another important finding of the study is that topography is a decisive element in the continuity of settlement. Indicators showing the importance of topography on settlements across all layers include: The settlements include defensively chosen elevations, vantage points providing visibility, slope-based settlement arrangements, and the observation system at Filetepe. These settlements demonstrate that similar spatial preferences continued in different periods. The topographical continuity between the ancient defense system and the Ottoman-era rural settlement model reveals that settlement decisions followed a similar spatial logic throughout history.

This aligns with approaches emphasized in rural landscape studies, such as "settlement-topography relationship," "development in harmony with the natural environment," and "defensive advantage" (Tuan, 1977; Limongiello et al., 2026). Research has shown that evaluating archaeological sites and historical structures separately reduces the overall readability of rural landscapes. As presented in the study in Tahtalı Neighborhood, strong spatial relationships exist between castles, city walls, necropolis and church ruins, historical mosques, traditional houses, and ancient Greek houses. However, the fact that some archaeological sites remain in private ownership and modern interventions in the region have fragmented the perception of the cultural landscape. This situation is directly related to the problems of "loss of context" and "loss of readability" highlighted in the literature (Antrop, 2005). Therefore, in all future efforts to protect rural cultural heritage, if archaeological heritage is involved, these areas should not be treated merely as isolated remnants of the past. These areas should be considered as part of the living rural landscape (Dragan et al., 2024; Yin et al., 2019).

Future research could focus on the following areas:

- Detailed archaeological surface surveys, and excavations in Tahtalı neighborhood could provide, more comprehensive data on the settlement's ancient and Byzantine periods.
- The use of digital documentation methods; such as photogrammetry, LiDAR, three-dimensional modeling, and geographic information systems could contribute to making the spatial relationships, between historical layers more visible.
- Through oral history studies and cultural memory research; data on Turkish-Greek coexistence culture, migration memory, and war memory could be documented more comprehensively.
- Applying the developed model to similar multi-layered rural settlements; such as Cumalıkızık, Tirilye, Gölyazı, Safranbolu, and Cappadocia can contribute, to evaluating the model's validity in different geographies. This would create a comparative analysis framework, for the conservation and evaluation of multi-layered rural cultural landscapes.

Acknowledgments and Information Note

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

During the preparation of this manuscript; artificial intelligence-based tools were used solely for translation, grammatical corrections, and improving the readability and clarity of the text through wording and, sentence refinement. Artificial intelligence was not used, in the design of the study, data collection, data generation, data analysis, interpretation of the results, or the production of the scientific findings. The author takes full responsibility, for the accuracy, integrity, and scientific content of the manuscript.

Author Contribution and Conflict of Interest Disclosure Information

This is a single-author study

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A Smart Support System for Renewable Energy Sharing in Small Off-Grid Facilities: Evaluating the “Stronger Together” Prototype from Design Science and Protected Area Management Perspectives

Cüneyd DİRİ^{1*} , Y. Yasef ÖZŞALOM² , Eyal KOHEN³ , Eren BEYO⁴ 
Talha KILIÇ⁵ 

ORCID 1: 0000-0001-8122-9568, ORCID 2: 0009-0000-2508-0965, ORCID 3: v,

ORCID 4: 0009-0004-1162-1395, ORCID 5: 0009-0000-6747-4663

¹ Mimar Sinan Fine Arts University, Faculty of Architecture, Department of Architecture, 34427 Istanbul, Türkiye.

² Bahçeşehir University, Graduate School, Electrical and Electronics Engineering, 34349 Istanbul, Türkiye.

³ Inholland University of App. Sciences, Tech., Design and Informatics, Aeronautical Eng., 2628 AL Delft, the Netherlands.

⁴ Student at Ulus Private Jewish Schools, 34340 Istanbul, Türkiye.

⁵ Mimar Sinan Fine Arts University, Graduate School of Natural and Applied Sciences, Istanbul, Türkiye.

* e-mail: acdiri@gmail.com

Abstract

Visitor centres, ranger stations, research units, campsites, and similar small facilities associated with protected areas often operate in locations without grid access or with frequent power outages. This study aims to develop a Smart Energy Support System to ensure energy continuity in these facilities. The system prioritizes self-consumption; when battery voltage falls below predefined thresholds, it draws support from an eligible neighbouring source and activates a backup source when local support is insufficient. The findings show that, at prototype scale, the system can demonstrate low-voltage detection, source selection, visualization of energy sharing, and source-use recording. However, sensor calibration, energy-measurement units, sender-receiver meter reconciliation, battery management, and field safety were not validated. The prototype should therefore be regarded not as a field-ready solution but as a research and educational platform requiring further development and controlled pilot testing for low-carbon and resilient energy management in small facilities associated with protected areas.

Keywords: Protected Area Management, Renewable Energy, Microgrid, Peer-To-Peer Energy Sharing, Energy Resilience

Şebekeden Bağımsız Küçük Tesislerde Yenilenebilir Enerji Paylaşımı İçin Bir Akıllı Destek Sistemi: “Birlikte Daha Güçlü” Prototipinin Tasarım Bilimi ve Korunan Alan Yönetimi Açısından Değerlendirilmesi

Öz

Korunan alanlarla ilişkili ziyaretçi merkezleri, korucu istasyonları, araştırma birimleri, kamp alanları ve benzeri küçük tesisler çoğu zaman şebekenin bulunmadığı veya sık elektrik kesintilerinin yaşandığı bölgelerde faaliyet göstermektedir. Bu çalışma, söz konusu tesislerde enerji sürekliliğini sağlayabilmek için bir Akıllı Enerji Destek Sistemi'nin geliştirilmesini amaçlamaktadır. Sistem öz tüketimi önceliklendirmekte; batarya gerilimi belirlenen eşiklerin altına düştüğünde uygun komşu kaynaktan destek almakta, yerel kaynak yetersiz kaldığında ise yedek enerji kaynağını devreye sokmaktadır. Bulgular, sistemin düşük gerilim durumunu algılama, kaynak seçme, enerji paylaşımını görünür kılma ve kaynak kullanımını kaydetme işlevlerini prototip ölçeğinde gösterebildiğini ortaya koymaktadır. Bununla birlikte sensör kalibrasyonu, enerji ölçüm birimleri, gönderen-alıcı sayaç uzlaştırmaları, batarya yönetimi ve saha güvenliği doğrulanmamıştır. Bu nedenle prototip, doğrudan saha uygulamasına hazır bir çözüm değil; korunan alanlarla ilişkili küçük tesislerde düşük karbonlu ve dayanıklı enerji yönetimi için geliştirilmesi ve kontrollü pilotlarla sınanması gereken bir araştırma ve eğitim platformu olarak değerlendirilmiştir.

Anahtar kelimeler: Korunan Alan Yönetimi, Yenilenebilir Enerji, Mikro Şebeke, Eşler Arası Enerji Paylaşımı, Enerji Dayanıklılığı

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1. Introduction

Electric power systems are changing rapidly in response to decarbonization targets, the expansion of renewable energy generation, advances in digital monitoring technologies, and the need for greater resilience to power outages. Rooftop solar systems, small wind turbines, batteries, electric vehicles, and controllable electrical appliances are transforming users from actors who only consume energy into prosumers who can generate, store, and, when necessary, share energy with others. This transition can enable more efficient use of generated energy, reduce carbon emissions and fuel-transport requirements, maintain the operation of critical equipment during outages, and ease the burden on the centralized electricity grid. However, the uncoordinated integration of distributed resources also introduces new challenges involving power quality, protection coordination, metering, data security, cost allocation, and institutional responsibility (Hirsch et al., 2018; International Energy Agency [IEA], 2022; Parag & Sovacool, 2016).

The fundamental operational challenge at the household, campus, and small-facility scales is the temporal mismatch between generation and consumption. One unit may produce more solar energy than it needs at a given moment while another nearby unit simultaneously experiences an energy deficit. When surplus energy is neither stored, shared locally, nor exported to the grid under suitable conditions, part of the renewable energy potential remains unused. Local energy sharing is therefore not merely an electrical interconnection issue; it is a sociotechnical coordination problem requiring sensing, decision-making, safe switching, protection, metering, equity, and user consent (Sousa et al., 2019; Tushar et al., 2020; Zhang et al., 2018).

Microgrids provide a strong conceptual framework for examining this coordination problem. A microgrid integrates generation resources, energy storage, and loads within a defined electrical boundary as a single controllable entity and can operate either connected to the main grid or in islanded mode. In the literature, microgrid control is generally described through primary control at the local-device level, secondary control that regulates system variables, and tertiary energy-management layers that govern economic or operational objectives (Guerrero et al., 2011; Olivares et al., 2014; Palizban et al., 2014). Peer-to-peer energy sharing and community-based energy markets, meanwhile, aim to enable neighbouring prosumers to exchange energy physically or virtually, share flexibility, and increase local benefits (Morstyn et al., 2018; Zhou et al., 2020).

This discussion is particularly important for protected area management. The principal purpose of protected areas is the long-term conservation of nature, ecosystem services, and associated cultural values; when conservation objectives conflict with other uses in management decisions, conservation should take precedence (Dudley, 2008). At the same time, managing protected areas may require energy-consuming facilities such as visitor centres, ranger stations, scientific monitoring points, communication systems, security infrastructure, campsites, mountain huts, and small service units. Some of these facilities are located in remote, seasonal, or weak-grid settings and may depend on diesel generators, long fuel-supply chains, or outage-prone electricity supplies. Although reliable energy infrastructure affects staff safety, emergency communications, cold-chain continuity, data collection, and visitor services, infrastructure installed in the wrong location or at an inappropriate scale can cause habitat loss, fragmentation, noise, light, fire, waste, and landscape impacts.

Sustainable visitor management in protected areas requires infrastructure to be assessed not only in terms of energy efficiency, but also in relation to carrying capacity, spatial planning, natural and cultural values, visitor experience, and relationships with local communities (Eagles et al., 2002; Leung et al., 2018). In this context, renewable energy cannot automatically be regarded as entirely free of environmental impacts or inherently “nature-friendly.” For solar and wind investments, direct, indirect, and cumulative biodiversity impacts should be managed through a mitigation hierarchy that first avoids impacts, then minimizes them, restores affected areas, and offsets only residual impacts (Bennun et al., 2021, 2024). In particular, using existing rooftops, parking canopies, and previously disturbed surfaces may provide a lower-conflict starting option than installations in sensitive habitats that require new roads and power lines (Kiesecker et al., 2024).

Studies of remote or conservation-oriented facilities indicate that renewable microgrids can reduce diesel consumption and operational emissions, while also showing that outcomes are sensitive to load profiles, seasonality, storage choices, maintenance capacity, and life-cycle impacts. A technical, economic, and environmental analysis conducted for a campsite in a conservation park found that photovoltaic–battery configurations could provide an alternative to diesel-dominated options (Sreenath et al., 2023). Studies of mountain huts further emphasize the need to evaluate not only operational emissions but also the life-cycle impacts of battery or hydrogen storage, including production, transport, replacement, and disposal (Mori et al., 2021, 2022). Energy resilience and nature-conservation objectives can therefore be aligned only when siting, scale, technology, and the operating model are optimized together.

The “Stronger Together” Smart Energy Support System was originally developed as an educational science project. The model represents three neighbouring houses and uses photovoltaic panels, 3.7 V Li-Po batteries, an Arduino Uno, relays, and a Python-based control interface. The prototype is neither a full-scale power-electronics controller nor a commercial microgrid; nevertheless, it makes the basic microgrid cycle tangible: measuring the status of each unit, evaluating a transparent threshold rule, selecting an eligible source, executing the switching decision, and recording source use. The use of open-source hardware in educational energy-management test benches can make complex grid concepts visible in a low-cost and modifiable environment (González & Calderón, 2019; Laayati et al., 2022).

1.1. Conceptual and Thematic Literature

This article moves beyond merely describing the original project report by reframing it at three levels. First, it examines the prototype through the design science chain of problem–requirements–artifact–demonstration–evaluation. Second, it compares the documented operating scenarios with the literature on microgrid control, shared storage, and peer-to-peer energy sharing. Third, it discusses the transferability of the residential model to small facilities associated with protected areas using technical, ecological, operational, and governance criteria. This final assessment does not claim field performance; rather, it is a conceptual suitability analysis that identifies the prerequisites and knowledge gaps relevant to future safe pilot applications.

1.1.1. Microgrid control, shared storage, and peer-to-peer energy

At the center of microgrid research is the question of how distributed generation, storage, and loads can be coordinated as a reliable whole. Hierarchical control approaches distinguish among different time scales, ranging from rapid local decisions to system-level voltage and frequency regulation and economic energy management (Guerrero et al., 2011; Li et al., 2023). IEEE Standard 2030.7, published by the Institute of Electrical and Electronics Engineers [IEEE] (2018), defines the functional specifications of microgrid controllers and establishes that a real system must satisfy requirements related to islanded operation, reconnection, protection, power quality, and safe operation. The standard is not a direct certification criterion for a low-voltage educational prototype; however, it provides a reference framework that clarifies the gap between the prototype and a field-grade controller.

Shared storage aims to use the idle capacity of individual batteries at the community level and increase the local utilization of renewable generation. Early studies of energy sharing among nearby homes showed that matching local supply and demand can reduce exchanges with the grid (Zhu et al., 2013). While shared-storage models consider economic optimization and user benefits (Taşcıkaraoğlu & Erdiñç, 2019), the P2P literature focuses on bidding, pricing, market matching, network constraints, and settlement mechanisms (International Renewable Energy Agency [IRENA], 2020; Sousa et al., 2019; Tushar et al., 2020). The “Stronger Together” prototype does not include these advanced layers; instead, it turns the underlying functional concept into a testable artifact by making source selection and exchange records visible.

1.1.2. Energy resilience and low-carbon operation in protected-area facilities

In protected area management, energy has often been treated not as a primary research subject but as a background condition for visitor services or field operations. Yet a power outage at a remote facility can directly affect critical functions such as communications, fire detection, medical devices, sample storage, water pumping, security, and scientific monitoring. Energy resilience is therefore not merely a matter of comfort or cost; it forms part of the continuity and risk management of conservation operations. Renewable energy and storage can be beneficial, particularly where transporting diesel fuel is difficult and environmentally risky; however, the system must distinguish between critical and noncritical loads, account for seasonal demand, and transition to a fail-safe state in the event of a fault.

Sustainable tourism guidelines recommend planning protected-area facilities in ways that reduce natural-resource use and environmental footprints and using energy efficiency and renewable sources where appropriate (Eagles et al., 2002; Leung et al., 2018). A low-carbon energy system, however, should not be used to legitimize uncontrolled growth in visitor capacity. It is also necessary to assess whether an increase in energy supply may encourage new construction, nighttime use, transport, or lighting pressure. This approach subjects technology to the protected area's management plan and zoning decisions, positioning energy infrastructure not as an end in itself but as a limited tool that supports conservation objectives.

1.1.3. Biodiversity, siting, and the mitigation hierarchy

Renewable energy facilities can reduce the climate and air-pollution impacts of fossil-fuel-based generation; however, they can also adversely affect biodiversity through land use, habitat loss, bird and bat collisions, changes in soil and water regimes, access roads, transmission infrastructure, and cumulative pressures. IUCN guidance recommends assessing direct, indirect, and cumulative impacts throughout the project life cycle and applying the mitigation hierarchy (Bennun et al., 2021, 2024). "Avoidance" is the most critical step, especially in protected areas; promises of technological compensation cannot justify inappropriate siting in habitats of sensitive species.

The assumption that "small means harmless" is not valid even for small-scale applications. Panels, battery enclosures, cabling, nighttime lighting, and maintenance access can affect habitat, fire risk, or visual integrity at the local scale. Priority should therefore be given to the rooftops of existing buildings, parking canopies, previously disturbed areas, and existing service corridors. Regional studies show that the advance spatial identification of low-conflict areas can reduce tensions between renewable energy targets and conservation values (Kiesecker et al., 2024). Material sourcing, manufacturing, transport, battery replacement, and end-of-life management of equipment should also be included in a life-cycle approach.

1.1.4. Governance, equity, data security, and social acceptance

In addition to technical components, community microgrids depend on institutional arrangements involving ownership, decision-making authority, allocation of costs and benefits, maintenance responsibility, and dispute resolution. Studies examining the role of institutions and social capital show that even technically suitable systems may not be sustainable without the early participation of local actors and a clear distribution of responsibilities (Warneryd et al., 2020). In protected areas, this governance dimension encompasses relationships among area management authorities, local communities, operators, visitors, researchers, electricity-distribution organizations, and conservation authorities.

Digital energy data can make it possible to infer the presence patterns of staff or users from consumption profiles (Razavi et al., 2019). Network-connected microgrids also face risks associated with authentication, access control, malicious commands, data integrity, and service continuity (Nejabatkhah et al., 2021). Logging systems should therefore be designed according to the principles of data minimization, explicit purpose specification, role-based access, secure communications, backup, and incident response. A "fair" energy-sharing rule does not merely mean allocating equal

amounts; critical duties, capacity to contribute, maintenance burdens, and the needs of vulnerable users must be considered together.

1.1.5. Design science and educational energy prototypes

Design science research is based on creating an artifact that responds to a practical problem and systematically evaluating the artifact's utility, suitability, and limitations (Hevner et al., 2004). Problem identification, definition of solution objectives, design and development, demonstration, evaluation, and communication constitute a widely used process model for this approach (Peppers et al., 2007). The academic contribution of a prototype depends not only on whether it "works," but also on explaining the class of problems it addresses, the knowledge on which it is based, the conditions under which it is valid, and the new design knowledge it generates (Gregor & Hevner, 2013).

Energy-management test benches developed with Arduino and open-source software allow measurement, communication, decision algorithms, and user interfaces to be reproduced at the student level (González & Calderón, 2019; Laayati et al., 2022). Nevertheless, the difference in scale between an educational prototype and a real facility must remain explicit. The success of a low-current, low-voltage model does not demonstrate field suitability with respect to grid voltage, short-circuit currents, electromagnetic compatibility, weather conditions, maintenance cycles, or biodiversity impacts. Rather than diminishing the prototype's value, this distinction establishes the boundaries of the scientific claim in a credible manner. Thematic synthesis of the literature and its relationship to the "Stronger Together" prototype is given in Table 1.

Table 1. Thematic synthesis of the literature and its relationship to the "Stronger Together" prototype

Theme	Main focus in the literature	Selected sources	Relationship to the prototype
Microgrid control	Safe and hierarchical coordination of generation, storage, and loads	Guerrero et al. (2011); IEEE (2018); Olivares et al. (2014)	Makes the measure–evaluate–switch cycle visible; does not include field-grade protection or islanded operation.
Shared storage and P2P energy	Local balancing, self-consumption, metering, pricing, and settlement	Sousa et al. (2019); Tushar et al. (2020); Zhu et al. (2013)	Demonstrates support between neighbouring units and source-based counters; lacks market and network-constraint layers.
Energy resilience	Continuity of critical loads during outages in remote facilities	Hirsch et al. (2018); Sreenath et al. (2023)	Makes the priority for local support tangible; reliability indicators and critical-load classification are not yet included.
Protected-area facilities	Low-impact energy needs of visitor, research, and conservation operations	Eagles et al. (2002); Leung et al. (2018); Mori et al. (2021)	Offers conceptual transfer potential for ranger, visitor, and field units; no field validation has been conducted.
Biodiversity and siting	Avoidance, minimization, restoration, and offsetting; cumulative impacts and life cycle	Bennun et al. (2021, 2024); Kiesecker et al. (2024)	Conditionally suitable for a small pilot on an existing roof or disturbed land; new installation in sensitive habitat is not recommended.
Governance and equity	Ownership, responsibility, costs and benefits, participation, and dispute resolution	Warneryd et al. (2020); Parag and Sovacool (2016)	Source records are a starting point for transparency; governance and crediting rules must be developed.
Cybersecurity and privacy	Protection of energy data, secure communication, and access control	Nejabatkhah et al. (2021); Razavi et al. (2019)	The local interface provides basic logging; a security architecture is required for a network-connected field application.
Design science and education	The artifact's problem-solving utility, demonstration, evaluation, and generalizable design knowledge	Gregor and Hevner (2013); Hevner et al. (2004); Laayati et al. (2022)	An accessible proof of concept; results are limited to prototype scale.

1.2. Research Gap, Aim, Questions, and Contribution

The existing microgrid and P2P energy literature largely focuses on optimization, market design, communications, and grid constraints. Although the protected-area literature addresses visitor management, environmental impacts, and sustainable infrastructure, it rarely discusses the transferability of low-cost educational energy-sharing prototypes to conservation facilities. There is a need for intermediate-scale design research that makes technical operation visible to nonexpert stakeholders while clearly defining ecological and governance boundaries.

This study aims to systematically analyse the documented functions of the “Stronger Together” prototype, compare its strengths and weaknesses with the literature on microgrids, P2P sharing, and design science, and identify the technical, ecological, operational, and governance conditions required for transfer to small facilities associated with protected areas.

The study addresses the following research questions:

- RQ1. Through what hardware and software logic does the prototype demonstrate self-consumption, neighbouring support, and backup-source selection among three units?
- RQ2. Which design requirements are met or only partially met by the documented operating states, and what validation gaps remain?
- RQ3. Under what conditions can the prototype be transferred to small off-grid facilities associated with protected areas, and which biodiversity, safety, life cycle, and governance safeguards are essential for such transfer?

The study makes three contributions. First, it restructures the original student project as a design science artifact, making its problem, requirements, architecture, algorithm, evaluation, and limitations traceable. Second, it situates the source-based counters and threshold-based decision logic within the energy-sharing literature while clearly distinguishing issues involving measurement units, energy accounting, and battery safety. Third, rather than adding the protected-area context merely as an application example, it proposes a structural transferability framework based on the mitigation hierarchy, low-conflict siting, critical loads, fire and data security, local participation, and life-cycle criteria.

2. Materials and Methods

2.1. Research Design

The study is a prototype-based case analysis grounded in a design science approach. The artifact examined is a Smart Energy Support System representing three neighbouring units, each with separate renewable-energy inputs, batteries, and loads. For this study, the design science process was interpreted in six stages: (i) identifying the problem of a local renewable-energy surplus occurring simultaneously with an energy deficit; (ii) defining the objective of an understandable, low-cost solution that prioritizes self-consumption and local support; (iii) developing the hardware, software, and threshold rules; (iv) demonstrating the prototype through scenarios; (v) evaluating functional outcomes and limitations; and (vi) transferring the design knowledge to the contexts of microgrids and protected area management (Hevner et al., 2004; Peffers et al., 2007).

The analysis draws on two groups of data. The first comprises the component list, control logic, threshold values, interface images, and source counters contained in the original project documentation. The second comprises peer-reviewed studies and institutional guidance on microgrids, P2P energy, design science, sustainable infrastructure in protected areas, the biodiversity mitigation hierarchy, battery management, cybersecurity, and field energy systems. The prototype was not reconstructed and subjected to an independent laboratory experiment; therefore, the findings are limited to an analysis of the documented demonstration states and are not intended for statistical generalization.

2.2. Design Objectives and Evaluation Criteria

The objective of the original project was not to mathematically determine the least-cost power flow, but to demonstrate that when a unit's battery becomes insufficient, support can be routed from an eligible neighbouring source or the backup source according to a transparent rule. In design science terminology, this objective was translated into the following requirements. Design requirements and validation indicators defined for the prototype are given in table 2.

Table 2. Design requirements and validation indicators defined for the prototype

Code	Design requirement	Evaluation indicator
DR1	Monitor the electrical status of each unit	Separate display of voltage and power values for each unit
DR2	Prioritize self-consumption	The unit uses its own source when the battery level is sufficient
DR3	Protect a low battery	External support is selected below the specified threshold, and energy export is prevented
DR4	Prioritize local sharing	Neighbouring support is selected before the backup source when an eligible neighbour is available
DR5	Safe recovery/hysteresis	Support continues until the recovery threshold is reached, reducing frequent switching
DR6	Make source selection visible	Self-source, neighbouring, and backup-source states are distinguished in the interface
DR7	Record exchanges	Source-based counters are available for each unit
DR8	Provide a reproducible educational environment	Low-cost, accessible hardware and modifiable software
DR9	Scalability to field safety	A development pathway for calibrated measurement, BMS, protection, suitable switching, and standards compliance
DR10	Protected-area compatibility	Compliance with criteria for low-conflict siting, ecological impacts, maintenance, fire, data, and governance

2.3. System Architecture and Operational Flow

The architecture represents three users or units located in the same local environment. Each unit has a photovoltaic input, a 3.7 V lithium-polymer (Li-Po) battery, and a load represented by a lamp. The central control layer consists of a computer running the Python program and an Arduino Uno communicating through a USB/serial connection. The Arduino sends measurement signals to the computer and activates relays in response to commands from the computer. The Python layer is responsible for decision logic, power calculation, counter updates, and the user interface.

The operational priority has three stages: (1) if the battery voltage is sufficient, the unit uses its own battery; (2) if the voltage is low and an eligible neighbour can provide support, the neighbouring source is selected; and (3) if no eligible local source is available, the backup source is used. This sequence embodies the principle of self-consumption–community support–backup source. In the prototype, “grid” refers to an experimental backup supply; the system does not operate in parallel with a real distribution grid and cannot export energy to it. Architecture of the three-unit Smart Energy Support System is shown in Figure 1.

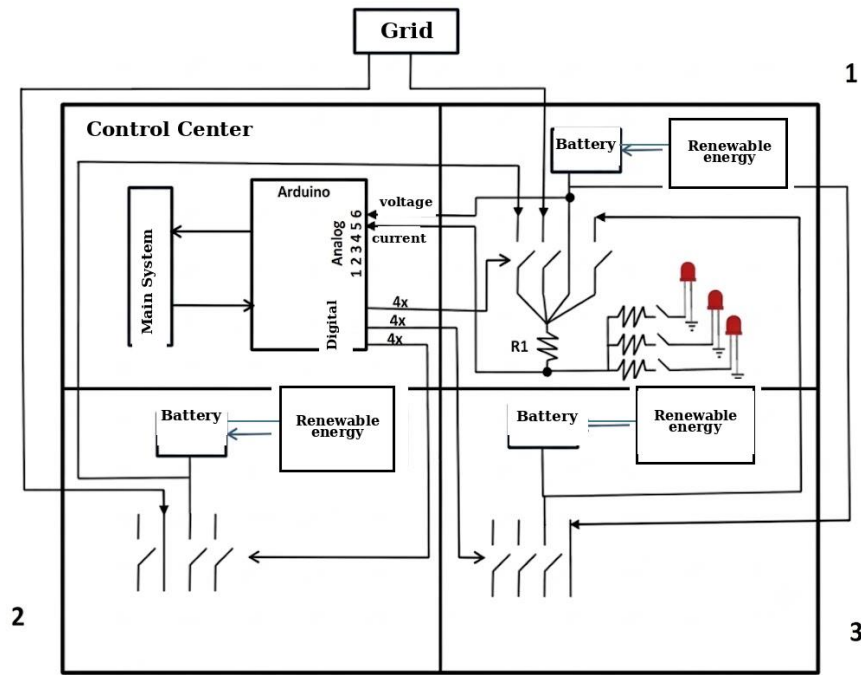


Figure 1. Architecture of the three-unit Smart Energy Support System, adapted from the original project report: renewable-energy inputs, batteries, relay-based switching, and the central control layer.

2.4. Prototype Components

The components were selected with a focus on accessibility and reproducibility in an educational setting rather than industrial-scale performance. This choice facilitates understanding of the concept while limiting its direct transfer to field applications in terms of voltage, current, protection, and environmental durability. Materials and components used in the prototype are given in table 3. Three-unit physical prototype is shown in figure 1.

Table 3. Materials and components used in the prototype

No.	Material/component	Quantity
1	Laptop/PC control interface	1
2	Arduino Uno	1
3	5 V relay	12
4	3 W, 0.33 Ω resistor	3
5	On/off switch	3
6	6 V mini solar panel, 500 mA	6
7	4.5–6 V solar charger	3
8	150 mAh 1S 3.7 V Li-Po battery	3
9	3 A buck converter	2
10	0.25 W, 9 k Ω resistors	3
11	3 V, 1.2 W lamp	3



Figure 2. Three-unit physical prototype. The house models make renewable generation, storage, and load use visible.

2.5. Software Structure, Measurement, and Control Algorithm

The software is divided between the Arduino and computer-based Python control. Acting as the physical input–output layer, the Arduino transmits measurement data and executes relay-switching commands. Locating the primary decision logic in Python makes the rule easier to read, modify, display in the interface, and discuss in an educational setting. While one concurrent task reads voltage and current data, other tasks perform source selection, counter updating, and screen refreshing.

Instantaneous power can theoretically be calculated as $P_i(t) = V_i(t) \times I_i(t)$. For calibrated energy measurement, power values must be integrated over the sampling intervals: $E_i \approx \sum_k P_i(t_k) \Delta t / 3600$ (Wh). The original interface counters were labelled in “watt-minutes”; sensor calibration, sampling duration, uncertainty, and loss calculations were not documented. The counters are therefore treated in this study not as validated energy measurements, but as relative indicators of source use.

The control rule is based on battery-voltage thresholds. The original report defined 3.3 V as the lower threshold requiring external support, 3.5 V as the recovery/hysteresis threshold, and 3.7 V as the threshold at which a unit may provide energy to a neighbour. Hysteresis is intended to reduce unstable switching by preventing a unit emerging from a low-voltage state from changing sources immediately. In lithium-ion batteries, however, voltage alone is not a reliable indicator of state of charge because it is affected by load, temperature, cell chemistry, and aging. A field system requires a battery-management system supported by current and temperature measurements, cell balancing, state-of-health monitoring, and an appropriate state-of-charge estimate (Zhao et al., 2024). Threshold-based operational logic is given in table 4.

Table 4. Threshold-based operational logic

Battery-voltage range	Energy use by the unit	Support to other units
Below 3.3 V	Support is requested from the eligible neighbour with the highest voltage; if no eligible neighbour is available, the backup source is selected.	Energy export is disabled.
3.3–3.5 V	If recovering from a low-voltage state, external support continues until 3.5 V; otherwise, the unit may use its own battery.	Energy export is disabled.
3.5–3.7 V	Under normal conditions, the unit operates from its own battery.	If recovering, it does not provide support until 3.7 V; under normal conditions, support may be possible depending on the rule set.
Above 3.7 V	The unit uses its own battery.	The unit may supply energy to a neighbouring unit.

2.6. Evaluation Scenarios and Analysis Method

The functional evaluation was conducted using the two interface states and source counters documented in the original report. The scenarios are examples illustrating possible system states rather than controlled experiments repeated under different initial conditions. Accordingly, the results were not interpreted as a success rate, efficiency value, or probability of reliability. Documented demonstration scenarios and expected functions are given in Table 5.

Table 5. Documented demonstration scenarios and expected functions

Evaluation	Initial condition/context	Expected behaviour	Feature examined
S1: Local support	Houses 1 and 2 have energy deficits; House 3 is eligible to provide support	House 3 is selected as the source; two receivers and one provider are distinguished in the interface	Local sharing and source visibility
S2: Backup source	No eligible local support is available for Houses 1 and 2; House 3 uses its own battery	Houses 1 and 2 are supplied by the backup source, while House 3 is supplied by its own battery	Backup selection when no local source is available and simultaneous display of different states
Counter review	Records for own battery, neighbouring support, backup source, and energy supplied	Comparison of totals and consistency by source type	Strengths and weaknesses of energy accounting

2.7. Transferability Assessment Framework for Protected Areas

Rather than through field testing, the transfer of the residential prototype to facilities associated with protected areas was assessed using a four-dimensional criteria matrix. The “technical” dimension covers energy balance, critical loads, measurement, protection, maintenance, and fault behaviour; the “ecological” dimension covers siting, habitat, cumulative impacts, visual, light, and noise impacts, and the life cycle; the “operational” dimension covers seasonality, logistics, staff capacity, and spare-parts management; and the “governance” dimension covers authority, participation, data, costs and benefits, permits, and monitoring. For each criterion, the available prototype evidence was classified as “demonstrated,” “partially demonstrated,” or “not demonstrated/field development required.” This classification does not generate a quantitative suitability score; it is used as a preliminary screening tool that enables decision-makers to identify evidence gaps.

2.8. Validity, Ethics, and Study Limitations

The primary limitation regarding internal validity is that the prototype was not reconstructed and tested with independent measurements in this study. The numerical values and screen states shown in the interface were obtained from the original documentation, and sensor accuracy, sampling rate, and experimental repetitions could not be verified. Regarding construct validity, voltage was used as an approximate indicator of state of charge, while actual energy and battery health were not measured. Regarding external validity, direct generalization from a low-voltage desktop model to a residence or protected-area facility is not possible.

Because the laboratory prototype involved no human participants, personal data, or interventions involving living organisms, the study did not require ethics committee approval. However, if future research examines the energy behavior, opinions, or location data of actual users, informed consent, data-protection measures, and the necessary ethical approvals must be obtained. Every pilot in a protected area must also comply with the area management plan, zoning requirements, environmental assessment, fire and electrical safety regulations, and relevant permit procedures.

3. Results

3.1. Documented Operating States

In the first interface image, Houses 1 and 2 receive support from the battery of House 3. The interface shows 3.52 V for all three houses and reports power values of 6.33 W for House 1, 4.90 W for House

2, and 3.15 W for House 3. The on-screen status indicators show that one unit can serve as a source for two neighbours simultaneously and that the user can monitor receiver/provider roles. However, because the same voltage value appears for all three houses and the current/measurement chain is not documented, this screen is interpreted as a functional demonstration of the control state rather than a quantitative validation of the physical energy balance.

In the second interface image, Houses 1 and 2 are supplied by the backup source while House 3 continues to use its own battery. The displayed voltages are 4.15 V for Houses 1 and 2 and 3.35 V for House 3. The colours and labels show that two different source states can be distinguished simultaneously. Considered together, the two scenarios indicate that the system can logically distinguish among self-consumption, local support, and backup-source states. Interface images adapted from the original report are shown in figure 3.

INSTANTANEOUS ENERGY VALUES		
House 1	House 2	House 3
3.52 V	3.52 V	3.52 V
Power 1	Power 2	Power 3
6.33 W	4.90 W	3.15 W
		Consumption

INSTANTANEOUS ENERGY VALUES		
House 1	House 2	House 3
4.15 V	4.15 V	3.35 V
Power 1	Power 2	Power 3
6.33 W	4.90 W	3.15 W
		Consumption

Figure 3. Interface images adapted from the original report. Top: Houses 1 and 2 are supported by House 3. Bottom: Houses 1 and 2 are supplied by the backup source while House 3 uses its own battery.

3.2. Source-Based Counters and Energy Accounting

The counters report 11.74 units of use from the units' own batteries, 5.79 units from neighbouring support, and 6.18 units from the backup source. Within the sum of these three consumption sources, the relative distribution is approximately 49.5% self-supply, 24.4% neighbouring support, and 26.1% backup-source supply. Because no calibrated energy unit or controlled experiment is available, these ratios are not indicators of actual efficiency or emissions reduction. Nevertheless, the records show that neighbouring support is represented in the interface as a separate source category rather than merely as a theoretical state (Table 6).

Table 6. Source-based prototype counters reported by the interface

Unit	Own battery	Neighbouring support	Backup source	Supplied to neighbour
1	2.11	5.38	2.95	0.00
2	5.37	0.41	2.28	0.00
3	4.26	0.00	0.95	2.68
Total	11.74	5.79	6.18	2.68

There is a difference of 3.11 units between the 5.79 units recorded as received from neighbours and the 2.68 units recorded as supplied to neighbours. In physical energy accounting, sender and receiver

meters should be reconciled while accounting for conversion and transmission losses and measurement uncertainty. The discrepancy may be related to the counter-update logic, time windows, sensor calibration, or the use of units intended only for the interface. This finding shows that the prototype demonstrates the concept of recording exchanges but does not yet provide sufficient accuracy for financial settlement or environmental-performance reporting. Source-based prototype counters reported by the interface are given in Table 6.

3.3. Degree to Which the Design Requirements Were Met

Evidence assessment for the design requirements is given Table 7.

Table 7. Evidence assessment for the design requirements

Code	Level	Evidence	Missing evidence/requirement
DR1	Demonstrated	Voltage and power indicators are available for each unit.	Sensor calibration and uncertainty are not reported.
DR2	Demonstrated	A state in which House 3 uses its own battery is visible.	The long-term self-consumption rate was not measured.
DR3	Partially demonstrated	The low threshold and no-export rule are defined.	No BMS, temperature monitoring, or overcurrent protection is included.
DR4	Demonstrated	In S1, neighbouring support is selected before the backup source.	No repeated testing was performed with different load and generation profiles.
DR5	Partially demonstrated	The 3.3–3.5–3.7 V thresholds embody the concept of hysteresis.	Switching frequency and stability were not measured.
DR6	Demonstrated	Source states are distinguished by colours and labels.	Accessibility and alarm design were not assessed.
DR7	Partially demonstrated	Source-based counters are available.	Sender–receiver reconciliation and Wh or kWh calibration are absent.
DR8	Demonstrated	Arduino, relays, and Python provide an accessible setup.	A complete schematic and code repository for reproduction were not assessed.
DR9	Not demonstrated	—	Field-grade power electronics, protection, standards compliance, and certification are required.
DR10	Not demonstrated / conceptual	Criteria for protected areas were defined in this study.	Siting, environmental assessment, and pilot monitoring have not been conducted.

3.4. Transferability Findings for Facilities Associated with Protected Areas

The criteria matrix indicates that the prototype’s strongest transferable feature is its role as a “small and modifiable educational/research platform that makes the operating logic visible.” Its weakest features are field safety, quantitative energy measurement, evidence for ecologically appropriate siting, and institutional governance. Transferability was therefore assessed not as “unconditional suitability,” but as conceptual potential contingent on specific development measures and conservation safeguards. Transferability matrix for the protected-area context is given in table 8.

Table 8. Transferability matrix for the protected-area context

Dimension	Potential contribution	Required safeguard/evidence	Conclusion
Energy resilience	Local resource sharing and backup-source sequencing can be adapted to maintain critical loads.	A critical-load inventory, reliability target, seasonal generation and load profiles, and islanded-mode testing are required.	Conditional potential
Siting and habitat	Small-scale and rooftop applications may reduce the need for new land.	Existing or disturbed surfaces must be prioritized, and sensitive-species and habitat screening, zoning, and cumulative-impact assessment are required.	Mandatory before field deployment

Dimension	Potential contribution	Required safeguard/evidence	Conclusion
Carbon and local pollution	The system has the potential to reduce diesel use.	The magnitude cannot be quantified without a baseline scenario, fuel-logistics data, life-cycle emissions, and actual generation data.	Evidence required
Battery and fire safety	The low-voltage model can be kept within a safe range for education.	At field scale, a BMS, appropriate battery chemistry, enclosure, ventilation, detection, suppression, and an emergency plan are required.	Critical gap
Visual, light, and noise impacts	Distributed and building-integrated installation may limit visual impacts.	Landscape character, glare, nighttime lighting, and equipment noise must be assessed.	Site-dependent
Maintenance and logistics	A modular architecture may facilitate local fault detection.	Spare parts, trained personnel, remote support, weather resistance, and an end-of-life plan are required.	Further development required
Data and cybersecurity	Source records may provide management transparency.	Secure communication, access roles, data minimization, a safe offline mode, and log integrity are required.	Critical gap
Governance and participation	The sharing rule can be discussed explicitly.	A model for decisions, costs, benefits, and responsibilities must be established with area management, local communities, and operators.	Mandatory precondition
Education and interpretation	The physical model can show visitors the trade-offs between renewable energy and conservation.	The message must not imply that “renewable energy is harmless everywhere” and must include biodiversity safeguards.	High educational value

4. Discussion

4.1. Comparison with the Microgrid and P2P Energy Literature

The prototype’s algorithm is intentionally simple compared with advanced microgrid energy-management systems. It does not forecast generation, optimize battery degradation or cost, solve AC/DC power flows, or establish prices. Instead, it ranks the unit’s own source, an eligible neighbour, and the backup source according to a transparent set of rules. The explainability of this rule-based approach is advantageous in education and early-stage design; however, the system does not define which load should be prioritized in situations involving multiple receivers, limited provider capacity, prolonged cloud cover, or a faulty sensor. A real system requires critical-load prioritization, a battery reserve, and a safe load-shedding rule.

In the P2P energy-trading literature, energy and monetary settlement are expected to rely on accurate measurement, time stamps, network constraints, and explicit market rules (Sousa et al., 2019; Tushar et al., 2020). Although the prototype counters demonstrate the technical concept of recording exchanges, the mismatch between sender and receiver totals shows that the system cannot yet be used for crediting or settlement. A future version should include calibrated bidirectional current and voltage measurements at every connection point, a common time base, and an energy-conservation check. Losses should be reported as a separate category, and acceptance limits should be defined for meter error.

The centralized Python controller is easy to understand because it consolidates the decision logic on one screen, but it also creates a single point of failure. A more resilient field architecture would provide safe local control at each unit, a fail-safe state that protects the system when communications are lost, and a higher-level coordinator authorized to issue commands only within permitted limits. The choice between centralized and distributed control should be based on the distances among facilities, communications infrastructure, maintenance capacity, and the class of critical loads.

4.2. Energy Resilience for Protected-Area Operations

The strongest rationale for energy sharing among facilities associated with protected areas is the ability to use idle renewable capacity across nearby units for critical tasks. For example, a visitor centre, ranger station, and field laboratory within the same compound may have different daily load profiles. Local sharing can help use a common reserve instead of installing oversized batteries at every facility. However, designing energy sharing with the objective of “supplying every load without interruption” may increase both cost and environmental footprint. In a conservation context, energy demand should first be reduced, critical loads should be defined, passive design and efficient equipment should be used, and generation and storage should be sized according to the remaining need.

The study of a conservation park by Sreenath et al. (2023) and the analyses of mountain huts by Mori et al. (2021, 2022) show that solutions for remote facilities cannot be reduced to a single technology. Solar resources, seasonal closure, access, fuel-transport distance, battery-replacement frequency, and the need for a backup generator all affect outcomes. The prototype examined in this article does not model these variables; nevertheless, by physically making visible the question of “which unit supports whom, and when,” it can help users understand a more detailed energy model.

4.3. Biodiversity and Life-Cycle Safeguards

In the protected-area context, low-carbon and biodiversity objectives are not interchangeable. A system may reduce emissions during operation while causing habitat loss because of inappropriate siting or generating significant impacts in the battery and panel supply chains. Energy options should therefore be compared with alternatives such as no installation or demand reduction, improved grid connection, efficiency measures, building-integrated renewables, shared storage, and new greenfield development. Under the avoidance principle, new infrastructure should be avoided in areas of high conservation value, and the existing developed footprint should be used wherever possible (Bennun et al., 2021).

A cumulative-impact assessment should consider not only a single panel or battery enclosure, but also the combined effects of access roads, power lines, communications antennas, nighttime lighting, increased visitation, and future expansion (Bennun et al., 2024). The multiplication of small pilots over time can aggregate impacts that appear insignificant individually. Monitoring indicators should include habitat area, observations of sensitive species, light levels, noise, fire incidents, waste and battery recovery, and changes in visitor use.

A life-cycle assessment should cover the production, transport, maintenance, and end-of-life stages of photovoltaic panels, batteries, power electronics, and cabling, in addition to the transport and combustion of diesel fuel. Transporting heavy batteries to a remote facility or replacing them at short intervals may reduce the expected environmental benefit. Modularity, repairability, long service life, reversible installation, and producer responsibility should therefore be treated as design criteria.

4.4. Electrical Safety, Battery Management, and Fire Risk

The prototype, which operates with low-capacity 3.7 V cells, does not represent the risks of a real high-voltage facility. At field scale, short-circuit currents, DC arcing, insulation faults, reverse polarity, overcurrent, overheating, water and humidity, lightning, and electromagnetic compatibility must be assessed. The relays’ voltage and current ratings, breaking capacity, and suitability for DC use must be verified, and fuses, disconnectors, grounding, residual-current or insulation monitoring, and emergency-stop systems must be provided.

Although battery-voltage thresholds are intuitive for educational purposes, they are insufficient for the safe management of lithium cells. State of charge cannot be measured directly; it is affected by voltage, current, temperature, aging, and usage history (Zhao et al., 2024). A real system requires a certified BMS, cell balancing, temperature monitoring, charge and discharge limits, thermal-runaway detection, and an appropriate fire-response plan. Because fire-response capacity may be limited in protected areas, battery location, surrounding combustible loads, ventilation, detection, and suppression strategies must be integrated into the site’s fire-management plan.

4.5. Governance, Data, and Equity

A decision for one facility to supply energy to another is a decision about responsibility and priorities, not merely a technical relay command. A ranger station performing a critical conservation function may receive priority over a commercial visitor service, but this priority must be grounded in an explicit management plan and stakeholder agreement. The loads considered essential, the share of reserves that may be transferred, who bears maintenance costs, and who is responsible in the event of failure should be defined in advance.

Source-based records are valuable for transparency and learning; however, the ability of energy data to reveal information about staff movements or facility use creates privacy risks (Razavi et al., 2019). If online control is introduced, authentication, encryption, software updates, log integrity, and a safe offline mode are required (Nejabatkhah et al., 2021). Data should be retained only at the level of detail necessary, and sensitive locations or patrol patterns that could compromise conservation security should not be displayed on public interfaces.

The distribution of benefits from energy infrastructure is also important in protected areas where local communities or concession holders are present. Social legitimacy is weakened if the system strengthens only visitor facilities while increasing the energy burden on nearby communities or excluding them from decision-making. Participatory needs assessment, local employment and maintenance training, a grievance mechanism, and regular sharing of performance information should be integral parts of the technical design (Warneryd et al., 2020).

4.6. Potential for Education, Environmental Interpretation, and Citizen Science

The prototype's most distinctive contribution is its transformation of abstract energy flows into a physical and visual system. Visitors or students can observe how one unit's surplus generation supports another unit's critical load, when the backup source is activated because storage is insufficient, and how energy use is recorded. In this respect, the system can serve as an interdisciplinary environmental-education tool that brings together renewable energy, electronics, programming, climate change, biodiversity, and common-resource management.

An interpretation program, however, should not present only the benefits of technology; it should also address trade-offs such as reducing energy demand, siting, battery raw materials, end-of-life waste, fire risk, and conservation priorities. In a real pilot, the interface could display environmental data such as habitat monitoring or weather conditions alongside generation and consumption data. Such an approach could move visitors from passive observation toward data literacy and citizen-science activities, provided that scientific quality control is applied and sensitive species information is protected.

4.7. Study Limitations

The first limitation of the study is that the original prototype was not revalidated through new and repeatable experiments. Although the screenshots demonstrate the system's state selection, sensor accuracy, response time, switching stability, energy losses, and fault behaviour were not measured. The second limitation is that the energy counters lack standard units and traceable calibration. The third limitation concerns the differences in scale, climate, access, safety, and institutional setting between the residential model and a protected-area facility.

Fourth, the protected-area transferability matrix is an expert assessment framework based on the literature; it has not been applied using the management plan, species and habitat data, load profile, or stakeholder views of a specific park. The study therefore does not provide a siting or investment decision. Fifth, no economic analysis, life-cycle cost assessment, emissions inventory, or comparison of alternative technologies was conducted. Future research should address these limitations through controlled laboratory testing, pre-field multicriteria assessment, and phased pilot monitoring.

5. Conclusion and Recommendations

This study re-evaluated the “Stronger Together” Smart Energy Support System as an Arduino- and Python-based design science artifact that makes renewable-energy support among three neighbouring units visible. The documented states indicate that the prototype can distinguish among self-consumption, neighbouring support, and backup-source options; display voltage and power information in the interface; and maintain source-based counters. These functions provide a practical starting point for understanding complex microgrid and P2P energy concepts in an educational setting.

Nevertheless, the prototype is not a real residential or protected-area microgrid. Voltage-based battery assessment, uncalibrated counters, discrepancies between sender and receiver records, relay-based switching, a single centralized control point, and the absence of field-grade electrical protection and independent testing prevent direct implementation. Transfer to facilities associated with protected areas could be considered only if the energy-resilience objective remains subordinate to conservation priorities; existing built or disturbed surfaces are preferred; the biodiversity mitigation hierarchy, cumulative-impact assessment, and life-cycle assessment are applied; and fire, battery, data, and governance safeguards are established.

A phased roadmap is proposed for developing the prototype. In the first stage, the laboratory setup should be strengthened with calibrated bidirectional measurement, a common time base, energy-balance verification, current and temperature monitoring, a BMS, suitable DC switching, and fail-safe local control. Scenarios involving different solar conditions, loads, communication interruptions, and sensor failures should be evaluated through repeated tests. In the second stage, a load inventory, energy-efficiency measures, critical-load analysis, technical-risk assessment, and life-cycle alternatives should be prepared for a very small pilot on an existing building or disturbed surface outside sensitive habitats.

In the third stage, the pilot should be implemented only after completion of the area management plan requirements, permits, ecological baseline data, fire plan, stakeholder participation, and data-governance arrangements. Performance should be monitored not only through technical indicators such as the renewable-energy share, critical-load availability, reduction in diesel/backup-source use, battery health, faults, and maintenance time, but also through indicators covering habitat, species, light, noise, waste, and visitor pressure. In the fourth stage, any decision to scale up should be based on a joint assessment of the pilot’s verified benefits and its total ecological and social costs.

In conclusion, “Stronger Together” is less a ready-to-deploy infrastructure solution than a research and educational platform that makes local renewable-energy sharing understandable and opens the relationship among technology, nature, and society in protected areas to discussion. Its scientific value lies not in portraying a simple prototype as more capable than it is, but in transparently identifying which functions it demonstrates, which evidence is missing, and which conditions must be met before progressing to a safe and nature-positive field application.

Acknowledgements and Information Note

This article is based on the academic development of the “Stronger Together” Smart Energy Support System project report. The prototype photographs and interface records used in the study were adapted from the original project documentation. The laboratory prototype involved no human participants, collected no personal data, and included no intervention involving living organisms. In future studies involving actual users or protected-area sites, all necessary ethical, privacy, environmental, safety, and legal permissions must be obtained before implementation.

Author Contributions, Conflict of Interest, Funding, and Data Availability

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

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All authors contributed equally to the article. There is no conflict of interest.

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HBIM-Based Cultural Heritage Information Management and Sustainability Framework for Monumental Mosques: The Case of Konya

Neriman Gül ÇELEBİ ^{1*} , Ümit ARPACIOĞLU ² 

ORCID 1: 0000-0003-0478-0449, ORCID 2: 0000-0001-8858-7499

¹ Mimar Sinan Fine Arts University, Graduate School, Department of Architecture, 34427, İstanbul, Türkiye.

² Mimar Sinan Fine Arts University, Faculty of Architecture, Department of Architecture, 34427, İstanbul, Türkiye.

* e-mail: ngcelebi@gmail.com

Abstract

The inventorying and documentation of monumental and historical mosques, which are valuable elements of cultural, religious, and architectural heritage, is of great importance. Additionally, monumental mosques, with their traditional and climate-adapted design properties, are inspiring for contemporary designers. Historical Building Information Modeling (HBIM) is the application of traditional building information modeling to heritage buildings. In this context, this study develops an HBIM-based sustainability framework to create a systematic inventory of data and develop a physical environment model. Following the proposed framework, the Sahip Ata Mosque, built in Konya during the Anatolian Seljuk period and one of the most important centers of Turkish-Islamic culture and art, was examined. The findings demonstrate the applicability of the proposed framework by holistically addressing the documentation, information management, and evaluation of the physical environment performance of monumental religious buildings. Furthermore, this study offers an approach to evaluating the relationship between the architectural design properties and environmental performance of mosques.

Keywords: Monumental and Historical Mosques, Historic Building Information Modelling, Monumental Mosques Sustainability Assessment.

Anıtsal Camiler için HBIM Tabanlı Kültürel Miras Bilgi Yönetimi ve Sürdürülebilirlik Çerçevesi: Konya Örneği

Öz

Kültürel, dini ve mimari mirasın değerli öğeleri olan anıtsal ve tarihi camilerin envanterinin oluşturulması ve belgelenmesi büyük bir öneme sahiptir. Ek olarak, anıtsal camiler, geleneksel ve iklimle uyumlu tasarım özellikleri ile günümüz tasarımcılarına ilham verici niteliktedir. Tarihi Yapı Bilgi Modellemesi (HBIM), geleneksel yapı bilgi modellemesinin miras yapılarına uygulanmasıdır. Bu bağlamda çalışmada, verilerin sistematik bir envanterinin oluşturulması ve fiziksel çevre modelinin geliştirilmesi amacıyla HBIM tabanlı bir sürdürülebilirlik çerçevesi geliştirilmiştir. Önerilen çerçeve doğrultusunda, Türk-İslam kültür ve sanatının en önemli ana merkezlerinden biri olan Konya’da Anadolu Selçuklu Dönemi’nde inşa edilen Sahip Ata Camii ele alınmıştır. Elde edilen bulgular, önerilen çerçevenin, anıtsal dini yapıların belgelenmesi, bilgi yönetimi ve fiziksel çevre performansının değerlendirilmesini bütüncül bir şekilde ele alarak uygulanabilirliğini göstermiştir. Ayrıca çalışma, camilerin mimari tasarım özellikleri ile çevresel performansı arasındaki ilişkinin değerlendirilmesine yönelik bir yaklaşımdır.

Anahtar kelimeler: Anıtsal ve Tarihi Camiler, Tarihi Yapı Bilgi Modellemesi, Anıtsal Camilerin Sürdürülebilirlik Değerlendirmesi.

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1. Introduction

The built environment is responsible for a significant portion of global energy consumption and carbon emissions and has a major impact on the environment (Azmi & Kandar, 2019). The operating of mosques, characterized by their unique operational plans, affects the energy demand of mosques depending on the climate zones (Al-Homoud et al., 2005). Climate-dependent design properties of mosques affect comfort conditions in the interior and the thermal performance of the mosque (Abdou et al., 2005). In their study, Al-Homoud et al. (2009) stated that the energy efficiency of a mosque largely depends on the overall thermal performance of building components such as walls, roof, and windows, which work together as a system. Studies also indicate that historical mosques, particularly those featuring characteristics such as the use of traditional methods, local materials, and environmentally friendly design principles, are inspiring for contemporary designers who want to design sustainable and eco-friendly buildings (Naghipour et al., 2025). In this context, documenting the architectural design properties of monumental mosques, which are valuable elements of cultural and architectural heritage, and evaluating them in terms of environmental sustainability is of great importance.

Historic Building Information Modelling (HBIM) is the application of BIM, an information management and digital modeling approach for building sustainable environments, to historically significant buildings defined as cultural heritage (Lovell et al., 2023). The HBIM concept has been used since the early 2010s for the documentation, preservation and effective modeling of historical architectural buildings (Khan et al., 2022). It is a current concept that extends traditional building information modeling (BIM) towards the preservation, management and analysis of heritage structures (Ávila et al., 2024). Data management is important for geometric and non-geometric (historical or architectural) information in historical buildings. Ávila et al. (2024) stated in their study that the HBIM methodology can be handled in three basic stages: data collection, data processing, and modeling and management. During the data collection phase, geometric and non-geometric data (historical context, architectural details, material properties, etc.) are collected. The documentation process plays a crucial role in systematically creating an inventory of the data and collecting all the information necessary for the development of the model. HBIM is an approach that can provide documentation of historical buildings and improve decision-making processes throughout the life cycle of these buildings (Puerto et al., 2024). However, due to deficiencies in the difficult integrated data collection and modeling process, the use of HBIM and studies in this field are limited.

This study aims to propose an HBIM-based information management and sustainability framework for monumental religious buildings, which are valuable elements of cultural and architectural heritage. Before 3D modeling of historical buildings, systematic definition and management of the information inventory is necessary. Systematic documentation and management of the inventory is crucial in terms of the characteristic design properties of monumental mosques, and information management is a key focus of this study. Furthermore, the study aims to investigate the relationship between the architectural design properties and environmental performance of monumental mosque buildings, and to develop a guide evaluating the design principles of monumental mosques in terms of environmental sustainability. Konya was chosen as the case study area because it is a city that has maintained its importance for many years as the capital of the Anatolian Seljuk State and one of the important provincial centers of the Ottoman Empire, hosting many civilizations and possessing valuable elements of Turkish Islamic architecture. Studies in this area are limited, and the proposed framework will contribute to filling the gap in the literature for an HBIM-based sustainability assessment system.

2. Material and Method

The HBIM-based information management and sustainability assessment framework proposed in this study for monumental historical mosques is shown in Figure 1.

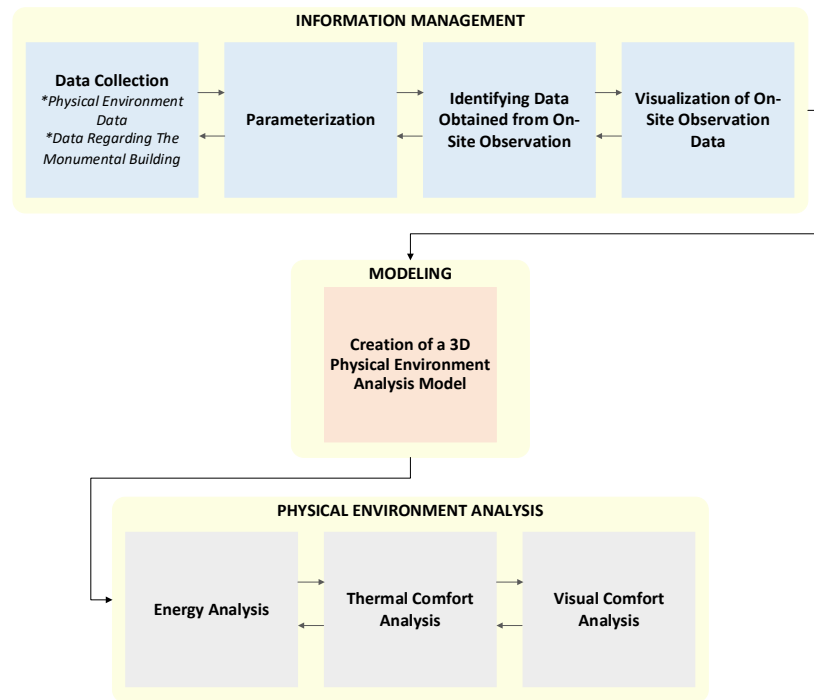


Figure 1. HBIM-based information management and sustainability assessment framework for monumental religious buildings (created by the authors)

The proposed framework consists of three basic modules: Information Management, 3D Modeling, and Physical Environment Analysis. The Information Management module includes sub-modules such as data collection, parameterization, identifying data obtained from site observation, and visualization of on-site observation data. The data collection sub-module refers to the data collection related to the physical environment and monumental religious buildings. This study focuses on the information management and sustainability framework. The proposed framework is designed not to be dependent on a specific digital platform and has a structure that can be applied in alternative (digital or non-digital) information management environments. The case study demonstrates the applicability of the proposed methodology through a systematic workflow independent of any specific digital HBIM platform.

Climate, as a physical environmental factor, is a significant element determining the energy and thermal performance of a building and is considered during the data collection phase. Data regarding the monumental mosque structure will serve as input for later stages of the proposed framework and will determine the entire evaluation process. Parameterization, which will provide the classification of data related to monumental religious buildings with characteristic design properties, is an important sub-module of data management and will provide for the systematic identification of the building's characteristics. The parameter system developed for data management is shown in Table 1.

Table 1. Parameterization systematics

Design Typology	Period
	Building Form
	Plan Organization
	Top Cover
	Building Order
	Entrance-Garden/Street Relation
	Total Area of Mosque (m ²)
	Total Height of Mosque (h)

Construction Techniques and Materials	Wall Properties	Bond Technique
		Material
		Wall Thickness (cm)
		Openings
		Windows--Wall Ratios (%) (South-North-East-West)
	Flooring Properties	Material
	Top Cover Properties	Bond Technique
		Material
		Dimensions (Diameter/Thickness)
		Openings
	Minaret Properties	Bond Technique
		Material

The parameter system is defined to provide the identification and systematic classification of architectural properties, as well as sustainability assessments, particularly focusing on passive design strategies. In line with the parameter system, the identification and visualization of field data based on on-site measurements and observations constitute other sub-modules forming the information management module. In addition to on-site observations or measurements, literature is used as a source for data related to the historical building. The information inventory obtained through this approach is transformed into a standardized and reusable information structure that can be used in the modeling process. The architectural properties defined in the information management module a basis and framework for the 3D model. In the Model basic module, a three-dimensional (3D) physical environment analysis model is being developed. Physical environment analyses include energy, thermal, and visual comfort analyses. In this study, DesignBuilder software, integrated with BIM, was used to provide the integrated performance of energy, thermal, and visual comfort analyses, as well as geometric modeling for physical environment analyses, and to support comprehensive building performance analyses.

2.1. Case Study Description

Konya is a city that has maintained its importance for many years due to its location on the caravan routes of the Silk Road in Anatolia, its geographical properties and as the capital of the Anatolian Seljuk State and one of the important provincial centers of the Ottoman Empire. It has been one of the most important main centers of Turkish-Islamic culture and art in Anatolia (Baykara, 2002). Konya, which has hosted many civilizations throughout its history and where multi-layered culture and architectural elements of these cultures coexist, has gained a valuable identity throughout history. In this respect, Konya was chosen as the study area. In order to demonstrate the applicability of the HBIM-based sustainability framework proposed in the study, the Sahip Ata Mosque, built in the Anatolian Seljuk Period in the 13th century, was taken as a case study. Additionally, thermal performance data of the monumental mosque was included in the evaluation process.

3. Findings and Discussion

In accordance with the HBIM-based cultural heritage information management and sustainability assessment framework proposed in this study, the Monumental Erdemşah Mosque was analyzed. The evaluation systematic is shown in Figure 2.



Figure 2. Sahip Ata Mosque evaluation systematic (created by the authors)

In the data collection phase, information regarding Konya's climate data was first defined. Thermal comfort is achieved by balancing heat gains and losses in the human body and controlling environmental conditions such as temperature and humidity. In this respect, environmental or climatic data such as air temperature, air humidity (relative humidity), mean radiant heat, and air velocity are of great importance. Data regarding the Sahip Ata Mosque, built in the 13th century during the Anatolian Seljuk period, were collected through literature review and on-site observation. On-site imaging of the buildings was provided using a drone, and photographs and properties were documented. After on-site observations, the electronic drawings obtained from the Konya Regional Directorate of Foundations were colored, and the current situation and its relationships with the immediate surroundings were plotted on the drawings based on the on-site observations. The documented data was classified according to the parameterization system proposed in the study. The architectural design properties of the monumental religious buildings, which were documented and visualized, were prepared for a 3D physical environment analysis model. Models have developed specific to mosque buildings with characteristic features, taking into account occupancy rates and usage times, using the DesignBuilder simulation program.

The climate-related design characteristics of mosques, which affect the thermal performance and indoor comfort conditions of the building, can be evaluated in line with passive design strategies. These strategies, also defined as energy-efficient design strategies, consider the building's location, orientation, distance from other buildings, building form, optical and thermophysical properties of the building envelope, solar control, and natural ventilation layout. In their study, Ahriz et al. (2021) identified the mosque building components affecting thermal comfort conditions as the building's orientation, the surrounding area, the building's size and geometric shape, architectural form, roof shape, prayer halls, the height of the prayer hall, openings, building materials, and surface colors. In addition to passive design strategies, the characteristic properties of the mosques should be considered as factors to be evaluated. The orientation of the mosque building is towards the qibla. The mihrab, one of the important characteristic properties of the mosque, is located in the direction of the qibla. The direction in which these characteristic properties affect passive design strategies should be defined in terms of sustainability assessment.

When the thermal comfort graphs were examined, it was seen that the outdoor air temperature, radiant temperature and indoor air temperature values for the Sahip Ata Mosque were generally close to each other. The main reason for this situation can be stated as phase shift. Phase shift is a condition that supports thermal comfort, and the wall thickness and material properties of the structure examined provide this situation. In terms of results regarding heat balance, heat leakage occurs especially in cold periods when heating is required. It can be stated that the main reason for this is the openings in the building envelope. It is seen that indoor fresh air rates are higher between June and September compared to other months. The main reason for this is natural ventilation, which is an important factor in indoor air circulation.

The findings show that the proposed HBIM-based information management and sustainability assessment system is applicable in evaluating the physical environmental performance of monumental religious buildings. With the proposed framework, monumental mosque buildings, which are valuable elements of architectural heritage, are documented and a systematic input is created for physical environmental analysis. Managing this data is as critical as collecting data about heritage buildings that are important to document. Additionally, the proposed framework provides an evaluation mechanism for the basic design and environmental performance of monumental religious buildings. The traditional design properties of the Anatolian Seljuk Period Konya monumental mosque and its importance in terms of thermal comfort and sustainability are other important achievements of the study.

4. Conclusion and Suggestions

Creating an inventory and documenting of mosques, which are important elements of religious and cultural heritage, is crucial. Furthermore, providing sustainable comfort conditions within mosque interiors, where the sense of sacred worship is of great importance, is essential. The harmonious architectural design properties of monumental religious buildings are inspiring for contemporary

designers. In this context, this study proposes an HBIM-based sustainability assessment framework for monumental mosque buildings. HBIM is an approach that aims to coordinate the storage of semantic and historical information while targeting geometric accuracy. In this study, an HBIM-based framework has been developed.

The HBIM-based information management and parameterization system proposed in this study provided the integrated management of on-site observation data, visual documents, technical documents, and physical environment data, and provided for the development of a physical environment analysis model based on this data. In this respect, the proposed system offers a significant approach in terms of information management and data quality. Focusing on developing a basic methodological framework, the proposed framework was developed independently of digital platforms. In future studies, the developed framework can be applied in BIM-compatible digital and shared data environments. The study aimed to demonstrate the applicability of the proposed framework and analyzed the Sahip Ata Mosque in terms of thermal comfort. Furthermore, the proposed framework also provides for performance analysis in terms of energy performance and visual comfort. In conclusion, this study presents an HBIM-based sustainability assessment approach, serves as a guide for climate-friendly sustainable mosque design, and provides a foundation for further studies.

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

Author Contribution and Conflict of Interest Disclosure Information

All authors contributed equally to the article. There is no conflict of interest.

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Assessment of the Quantitative Analysis of Urban Open and Green Spaces in the Case of Eğirdir Urban Centre

Hüseyin Batuhan DÜNDAR ^{1*} , Murat AKTEN ² 

ORCID 1: 0009-0003-7341-970X

ORCID 2: 0000-0003-4255-926X

¹ Süleyman Demirel University, Institute of Science, Department of Landscape Architecture, 32200, Isparta, Türkiye.

² Süleyman Demirel University Faculty of Architecture, Department of Architecture, 32200, Isparta, Türkiye.

* e-mail: hbatuhandundar@gmail.com

Abstract

This study uses GIS-based quantitative analysis to evaluate the status and spatial distribution of public open and green spaces across the 24 neighbourhoods of Eğirdir District, Isparta-Türkiye, assessing active and passive green space typologies against the 10 m² per capita standard set by Turkish planning legislation. A total of 270,341.70 m² of active green space was identified, yielding 17.07 m² per capita district-wide apparently exceeding the standard. However, neighbourhood-scale analysis reveals pronounced spatial inequality: 61.43% of this total is concentrated in a single, largely derelict space, without which per capita provision falls to 6.83 m², and ten neighbourhoods have none at all. Aggregate standards can thus conceal significant local disparities, underscoring the need for equity- and accessibility-based planning.

Keywords: Urban Open and Green Spaces, Geographic Information Systems (GIS), Spatial Equity, Active and Passive Green Spaces, Urban Planning and Design.

Kentsel Açık ve Yeşil Alanların Niceliksel Analizinin Eğirdir Kent Merkezi Örneğinde İrdelenmesi

Öz

Bu çalışma, Eğirdir ilçesi (Isparta-Türkiye) kent sınırlarını oluşturan 24 mahalledeki kamusal açık ve yeşil alanların mevcut durumunu ve mekânsal dağılımını, aktif ve pasif yeşil alan tipolojilerini Mekânsal Planlar Yapım Yönetmeliği'nde belirlenen 10 m²/kişi standardına göre değerlendirerek, GIS tabanlı niceliksel analizle ortaya koymaktadır. Araştırma alanı genelinde toplam 270341,70 m² aktif yeşil alan tespit edilmiş, kişi başına 17,07 m² değeriyle kent geneli standardın üzerinde bir sonuç ortaya çıkmıştır. Ancak mahalle ölçeğinde incelendiğinde ciddi bir mekânsal dengesizlik görülmektedir: bu toplamın %61,43'ü atıl durumdaki tek bir alanda yoğunlaşmakta, bu alan çıkarıldığında kişi başına düşen miktar 6,83 m²'ye gerilemekte, 10 mahallede ise hiç yeşil alan bulunmamaktadır. Bu durum, kent geneli ortalamaların mekânsal eşitsizlikleri gizleyebileceğini; planlamanın eşitlik ve erişilebilirlik ilkeleri odağında ele alınması gerektiğini ortaya koymaktadır.

Anahtar kelimeler: Kentsel Açık ve Yeşil Alan, Coğrafi Bilgi Sistemleri (CBS), Mekânsal Eşitlik, Aktif ve Pasif Yeşil Alanlar, Kentsel Planlama ve Tasarım.

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1. Introduction

Open and green spaces, one of the most fundamental elements maintaining balance between the individual, nature and society, hold critical importance within our rapidly developing, consumption-oriented urban areas. The fundamental components that constitute urban areas can be considered as built structures, open and green spaces, and transportation networks (Gül & Küçük, 2009; Gezer & Gül, 2009). Open and green spaces are used by society primarily to meet recreational needs; however, these spaces do not merely satisfy recreational demands but also constitute components that support the tangible cultural and spatial values of the urban area and reflect local identity (Gül et al., 2019). Recognising the physical, social and psychological harm brought about by rapidly and haphazardly developing living environments, urban residents, to the extent their circumstances allow, distance themselves from urban life and turn to nature as a place to catch their breath (Özen Öztürk & Gül, 2020; Akten, 2025). Most people living in urban areas are under psychological stress, and this stress intensifies under the pressure of urban life; the provision of open and green spaces is therefore important for meeting recreational needs such as sitting and resting, exercising, and participating in socio-cultural activities (Gezer & Gül, 2009; Çetin, 2015). In its 2016 report entitled 'Urban Green Spaces and Health', the World Health Organization (WHO) summarises the benefits that urban open and green spaces provide for human health; the analyses in the report reveal that open and green spaces improve mental health and pregnancy outcomes, while reducing the risks of cardiovascular disease, mortality, obesity and type 2 diabetes. The report emphasises that these positive outcomes arise through factors such as psychological relaxation and stress reduction, increased physical activity, and reduced exposure to air pollution, noise and excessive heat. Beyond their effects on recreational needs and human health, the most fundamental role of urban open and green spaces in building resilience against the global climate crisis whose impacts have accelerated throughout the 21st Century lies in their forming one of the main backbones of sustainable land use and management within planning strategies and nature-based solutions. By functioning as carbon sinks, open and green spaces contribute to the reduction of urban emissions, and, through their capacity to create cooler microclimates and mitigate the urban heat island effect, they form part of climate adaptation strategies (Akten & Gül, 2024). The multifaceted benefits of the vegetation naturally associated with urban open and green spaces including the provision of biodiversity, erosion prevention, improved air quality, urban beautification and the support of emotional wellbeing — contribute to the sustainability of the urban ecosystem while also harbouring strategic potential for conversion into economic value (Saphores & Li, 2012; Akten & Gül, 2024). Urban green spaces, which support ecosystem services, comprise a variety of elements with different ownership structures (Breuste et al., 2013). In Turkish planning legislation, the definition and scope of urban open and green spaces are set out within the framework of two separate regulations: the Development Regulation for Planned Areas (Planlı Alanlar İmar Yönetmeliği) and the Spatial Plans Preparation Regulation (Mekânsal Planlar Yapım Yönetmeliği). According to the the Development Regulation for Planned Areas (Planlı Alanlar İmar Yönetmeliği, 2017), green spaces comprise children's playgrounds, parks, picnic and leisure (recreation) areas, and national gardens allocated for public use. In the Spatial Plans Preparation Regulation (Mekânsal Planlar Yapım Yönetmeliği, 2014), by contrast, the concept of green space is addressed under the heading of 'Social Infrastructure Areas', with open and green spaces defined as the general term given to areas meeting the cultural, social and recreational needs of individuals and society including educational, health, religious, cultural and administrative facilities built by the public or private sector, indoor and outdoor sports facilities, and parks, children's playgrounds, play areas, squares and recreation areas. From the past to the present, urban green space standards have repeatedly been redefined through various legal regulations.

The Spatial Plans Preparation Regulation, which entered into force in 2014 (Article 11 and Annex 2, Table), set the amount of green space per capita at 10 m² and defined it under the heading of 'Social Infrastructure Areas' (Mekânsal Planlar Yapım Yönetmeliği, 2014). These standards have continued to be developed and revised over time; under the heading of 'Yaşanabilir Şehirler ve Çevre' (Liveable Cities and Environment) in the 65. Hükümet Programı (65th Government Programme) of 2016, raising the green space standard in newly developing urban areas from 10 m² per capita to 15 m² per capita was adopted as a policy target (T.C. Başbakanlık, 2016).

Previous studies have noted that standards determined on a purely quantitative basis, disregarding the socio-cultural, physical and economic structures of urban areas, can produce misleading results within planning processes; this highlights the need for both the qualitative and quantitative dimensions of open and green spaces to be addressed together in their entirety (Gedikli, 2002; Gül et al., 2020; Bilgili et al., 2011; Türker & Gül, 2022).

The 'urban'-'rural' distinction underpinning urban open and green space planning in Türkiye acquired a new administrative structure through Law No. 6360 (6360 sayılı Kanun), published in 2012, which extended metropolitan municipal boundaries to coincide with provincial administrative boundaries and abolished the legal personality of villages, converting them into 'neighbourhoods' (mahalle) (6360 Sayılı Kanun, 2012).

According to the 2025 data published by Turkish Statistical Institute (Turkish Statistical Institute, 2026), the proportion of the population residing in provincial and district centres, which stood at 93.4% in 2024, rose to 93.6% in 2025, while the proportion living in towns and villages fell from 6.6% to 6.4%. With the introduction of the Mekansal Adres Kayıt Sistemi (MAKS), a new classification has been established, under which 67.5% of Türkiye's population is defined as living in areas classified as 'densely urban', 15.8% in 'moderately urban' areas, and 16.8% in 'rural' areas (Turkish Statistical Institute, 2026). Under the Rural Neighbourhood and Rural Settlement Area Regulation, which entered into force in 2021, areas within a neighbourhood that possess rural characteristics and are no smaller than 10,000 m² are defined as a 'rural settlement area' (Kırsal Mahalle ve Kırsal Yerleşik Alan Yönetmeliği, 2021).

This makes it essential, from the standpoint of planning practice, to clarify the urban-rural distinction and to establish precise definitions and classifications for open and green spaces. In current practice, the failure to address green space systems through a higher-scale, holistic approach across the urban, rural and regional whole has prevented the formation of spatial linkages between green fabric inside and outside the urban area, thereby fragmenting green space systems. These shortcomings in the literature and in legislation necessitate a quantitative and qualitative analysis of the existing provision of open and green spaces. In this context, Eğirdir District, selected as the study area, stands out as a settlement in which the planning of urban open and green space systems carries particular importance, owing to its endangered lake ecosystem, rich biodiversity, status as a tourism destination, wealth of natural and cultural heritage, and its inclusion in the Cittaslow network in 2017.

This study aims to reveal the current status and spatial distribution of open and green space provision in Eğirdir urban centre through Geographic Information Systems (GIS)-based analyses. Accordingly, the urban area's existing green space systems have been analysed against the 10 m² per capita standard specified in Annex Table 2 of the Mekânsal Planlar Yapım Yönetmeliği, with the aim of formulating strategic action recommendations for the future.

2. Material and Method

2.1. Research Area and Geographical Location

Eğirdir District is located in the Lakes Region (Göller Yöresi) of the Mediterranean Region, 34 km east of Isparta provincial centre. The study area encompasses the 24 neighbourhoods that constitute Eğırdır district urban centre (Table 1). The total surface area of the study area is 48.88 km², situated at 030° 51' 09.25" longitude and 37° 52' 32.36" latitude. Eğırdır district has an elevation of 918 metres and, since the 2000s BC, has retained its character as a settlement area to this day (Isparta Eğırdır İlçe Milli Eğitim Müdürlüğü, 2020). According to the meteorological data for Eğırdır district, the annual mean, maximum and minimum temperature values are recorded as 12.7 °C, 17.6 °C and 7.1 °C respectively, while the annual average total precipitation of 781 mm is observed to peak at 146 mm in December and reach its lowest value of 9 mm in August (Berber & Şahin, 2020).



Figure 1. Eğırdır District, research area location map (Yeşilada Neighbourhood), (Authors' Archive, 2024)

According to TURKSTAT data, the population of Eğırdır district stood at 31632 in 2019, declining to 29200 by 2025. This indicates that the district's population decreased by a total of 2432 people (7.69%) over the past seven years. The population data for the 24 neighbourhoods examined within the scope of the study are presented in Table 1, comprising the most recent population figures published in 2025 by the TURKSTAT Adrese Dayalı Nüfus Kayıt Sistemi (Address-Based Population Registration System).

Table 1. Population data for the 24 Neighbourhoods located within the urban boundaries of Eğırdır District, within the scope of the research area (TURKSTAT, 2025)

Name of Neighbourhood	Total Population of the Neighbourhood	Percentage of the Total Population of the District of Eğırdır
Pınar Pazarı Neighbourhood	1876	6.42%
Kızılcubuk Neighbourhood	799	2.74%
Bağlar Neighbourhood	289	0.99%
Sanayi Neighbourhood	603	2.07%
Konya Bucağı Neighbourhood	572	1.96%
Bağbuyan Neighbourhood	34	0.12%
Menderes Neighbourhood	1266	4.34%
Yeni Neighbourhood	798	2.73%
Sekibağ Neighbourhood	767	2.63%
İmarat Neighbourhood	585	2.00%
Katip Neighbourhood	226	0.77%
Ağa Neighbourhood	265	0.91%
Poyraz Neighbourhood	292	1.00%
Demirkapı Neighbourhood	145	0.50%
Hacışeyh Neighbourhood	166	0.57%
Camii Neighbourhood	285	0.98%
Hamam Neighbourhood	179	0.61%
Kale Neighbourhood	106	0.36%
Yeşilada Neighbourhood	335	1.15%
İstasyon Neighbourhood	2604	8.92%
Altinkum Neighbourhood	1952	6.68%
Yazla Neighbourhood	1311	4.49%
Seydim Neighbourhood	264	0.90%
Kubbeli Neighbourhood	113	0.39%
TOTAL	15832	54.2%

When the population distribution of the 24 neighbourhoods constituting the urban boundaries of Eğırdır district is examined according to 2025 TURKSTAT data, the neighbourhood with the highest population across the district is İstasyon Neighbourhood, with a population of 2604 people, constituting 8.92% of the district's total population. This neighbourhood is followed by Altinkum Neighbourhood with 1952 people (6.68%) and Pınar Pazarı Neighbourhood with 1876 people (6.42%). These three neighbourhoods together account for approximately 22% of the district's population. By contrast, Bağbuyan Neighbourhood, with a population of 34 people, constitutes 0.12% of the district's

total population, representing a limited demographic weight (Table 1). Upon examination of Table 1, the total population of the 24 neighbourhoods constituting the urban boundaries of Eğirdir district is 15832 people, corresponding to 54.2% of the district's total 2025 population of 29200 people. The remaining 45.8% of the district's population is understood, in terms of status, to reside in rural areas. The available data indicate that the population is not homogeneously distributed among the neighbourhoods comprising the study area.

2.2. Method

In this study, the current status of the public open and green space provision of the 24 neighbourhoods constituting the urban boundaries of Eğirdir district has been established through a quantitative analysis. Within this scope, the study area has been divided into two sub-headings: active green spaces and passive green spaces. According to the Development Regulation for Planned Areas (Planlı Alanlar İmar Yönetmeliği, 2017), active green spaces have been addressed under 4 typologies: children's playgrounds, parks, national gardens, and picnic and recreation areas. Under the passive green spaces category, 3 typologies have been addressed: central reservations, cemeteries, and roadside planting. As the focus of the study is 'public' open and green spaces, semi-private green spaces belonging to hospitals, schools, military areas and public buildings — which contribute to urban ecology but are not open to general public use — as well as residential gardens and similar areas, have been excluded from the scope of assessment. In addition, data not accessible through official administrative plans have been completed and included in the quantitative analysis through the identification, during field studies, of public open and green spaces (both active and passive) used by urban residents. Within the context of the research, the relevant literature has been reviewed to establish a conceptual framework for the subject. In the process of compiling a digital inventory of the study area's existing urban open and green spaces, Google Earth Pro satellite imagery has been utilised, supported by data from the kent rehberi (urban guide) available on the official website of Eğirdir Municipality and parcel data obtained from the Tapu Kadastro Genel Müdürlüğü (General Directorate of Land Registry and Cadastre). Field studies were carried out within the study area in order to verify the accuracy of the data obtained and to identify details not observable otherwise. Within this scope, the current physical condition of the open and green space provision was established using ground-level photographs and UAV aerial photographs, and a comprehensive visual archive was obtained. The integration and digitisation of the data obtained were carried out using ArcGIS Pro software, generating an up-to-date digital base map for the study area. In the process of determining the boundaries of the study area, the neighbourhoods affiliated with Eğirdir Municipality were first identified on the basis of TURKSTAT data, after which the boundaries of these neighbourhoods were digitised via the HGMKüre application of the Harita Genel Müdürlüğü (General Directorate of Mapping) and transferred into the geographic information system. By overlaying the neighbourhood-based digital boundaries with the open and green space inventory, the open and green space inventory data for each neighbourhood were obtained. In the final stage, a quantitative analysis of the data obtained was carried out, whereby the amount of green space per capita (m^2 per capita) at both the district urban boundary and neighbourhood scale was calculated, enabling a comparison of the existing situation with the relevant standards. Based on the results of this analysis and comparison, strategic action recommendations were developed for the neighbourhoods within the urban boundaries of Eğirdir.

3. Findings and Discussion

3.1. Analysis of the Active Open and Green Space Provision Within the Urban Boundaries of Eğirdir

As a result of the quantitative analysis of the public open and green spaces of the 24 central neighbourhoods constituting the urban boundaries of Eğirdir, the number, areal values and coordinates of the open and green spaces within the study area are shown in Table 2. As a result of field studies and GIS-based analyses, a total active green space of 270341.70 m^2 has been identified across the study area. According to 2025 TURKSTAT data, the total population of the 24 neighbourhoods is 15832 people. When the total population of these neighbourhoods is taken into account, the provision of active open and green space per capita has been calculated as 17.07 m^2 per capita. This value is found to lie approximately 70.7% above the minimum standard of 10 m^2 per capita

set out in the Spatial Plans Preparation Regulation (Mekânsal Planlar Yapım Yönetmeliği, 2014). It has accordingly been concluded that the provision of active open and green space in Eğirdir urban centre exceeds the minimum standard of 10 m² per capita in meeting the recreational and green space needs of the population residing within the urban boundaries, presenting a favourable picture in terms of the provision of public active open and green space per capita.



Figure 2. Active Open and Green Spaces Within the Urban Boundaries of Eğirdir (Authors' Archive, 2024)

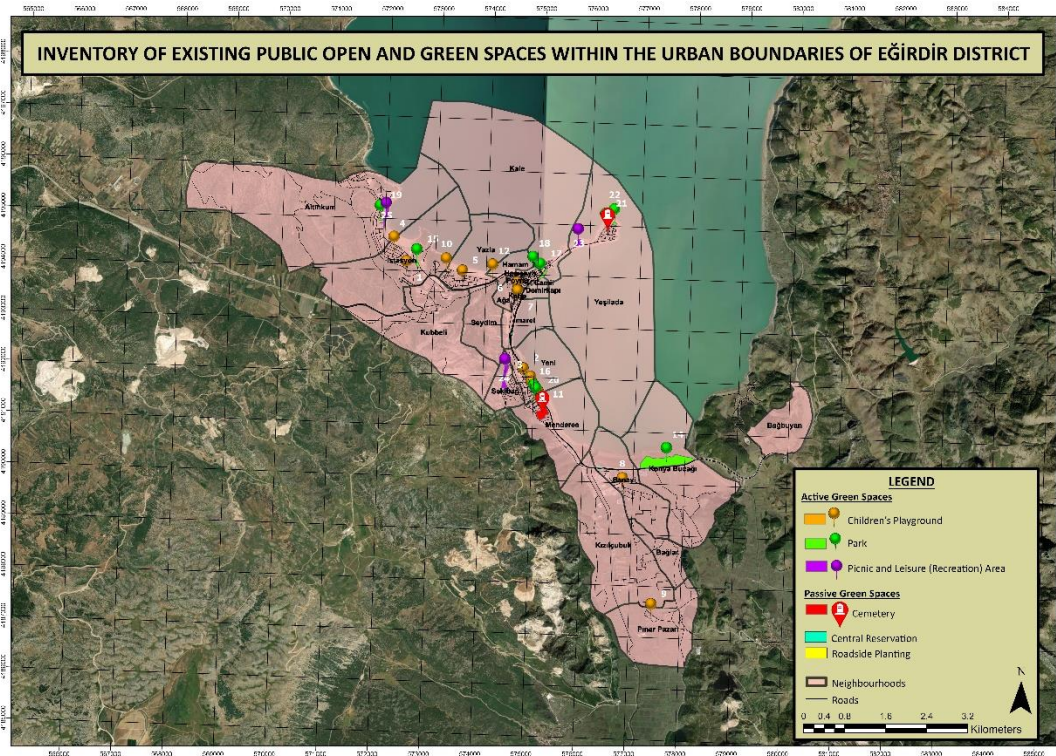


Figure 3. Inventory of existing public open and green spaces within the urban boundaries of Eğirdir District

When the numerical and areal status of the active open and green spaces within the neighbourhoods is examined: Altinkum Neighbourhood contains 1 park and 1 picnic and leisure (recreation) area (No: 19, 25); İstasyon Neighbourhood contains 1 park and 2 children's playgrounds (No: 1, 4, 15); Yazla Neighbourhood contains 3 children's playgrounds (No: 5, 10, 12); Yeşilada Neighbourhood contains 2 parks and 1 picnic and leisure (recreation) area (No: 21, 22, 23); Katip Neighbourhood contains 1 children's playground (No: 6); İmaret Neighbourhood contains 1 children's playground (No: 7); Sekibağ Neighbourhood contains 3 children's playgrounds, 1 park and 1 picnic and leisure (recreation) area (No: 2, 3, 13, 16, 24); Menderes Neighbourhood contains 1 children's playground and 1 park (No: 11, 20); Sanayi Neighbourhood contains 1 children's playground (No: 8); Konya Bucağı Neighbourhood contains 1 park (No: 14); Pınar Pazarı Neighbourhood contains 1 children's playground (No: 9); Camii Neighbourhood contains a section of Liman Park (No: 17) and Poyraz Park (No: 18); Demirkapı Neighbourhood contains a section of Liman Park (No: 17); and finally, Kale Neighbourhood contains the remaining section of Liman Park (No: 17) (Figure 2 and Table 2).

Table 2. The presence of active open and green spaces within the urban boundaries of Eğirdir

No.	Active Open and Green Spaces	Area (m ²)	Coordinates
1	İstasyon Children's Playground	198.00	030° 49' 24.49" E 37° 52' 28.75" N
2	Yeni Neighbourhood Children's Playground 2	120.66	030° 50' 59.5" E 37° 51' 22.92" N
3	Yeni Neighbourhood Children's Playground	289.67	030° 51' 5.71" E 37° 51' 17.66" N
4	Gazi Children's Playground	613.68	030° 49' 14.01" E 37° 52' 44.0" N
5	Yazla Children's Playground	359.43	030° 50' 9.2" E 37° 52' 23.71" N
6	Children's Playground	198.41	030° 50' 53.07" E 37° 52' 17.03" N
7	Children's Playground	554.93	030° 50' 53.49" E 37° 52' 11.98" N
8	Sanayi Neighbourhood Children's Playground	1810.10	030° 52' 20.94" E 37° 50' 15.0" N
9	Taştepe Children's Playground	184.93	030° 52' 46.28" E 37° 48' 55.72" N
10	Eski Yazla Children's Playground	147.61	030° 49' 56.14" E 37° 52' 31.1" N
11	Kanal Children's Playground 1	110.51	030° 51' 12.03" E 37° 51' 8.65" N
12	Children's Playground	125.82	030° 50' 33.25" E 37° 52' 28.04" N
13	Yeni Neighbourhood Children's Playground 2	57.57	030° 51' 6.41" E 37° 51' 14.7" N
14	Rüya Park	166080.76	030° 52' 55.51" E 37° 50' 34.76" N
15	Sıfır Atık Park	7030.60	030° 49' 32.42" E 37° 52' 36.4" N
16	Kanal Park 3	3208.40	030° 51' 8.28" E 37° 51' 12.6" N
17	Liman Park	11270.60	030° 51' 11.11" E 37° 52' 29.27" N
18	Poyraz Park	2699.52	030° 51' 5.35" E 37° 52' 33.54" N
19	Şelale Park	3351.07	030° 49' 2.38" E 37° 53' 3.66" N
20	Kanal Park 2	1219.33	030° 51' 10.17" E 37° 51' 10.51" N
21	Yeşilada Eski İskele Park	1492.37	030° 52' 2.24" E 37° 53' 1.97" N
22	Felekabad Park	3511.88	030° 52' 9.23" E 37° 53' 4.89" N
23	Eğirdir Can Ada Picnic and Recreation Area	15906.93	030° 51' 40.74" E 37° 52' 51.79" N
24	Eğirdir Urban Forest	32940.68	030° 50' 44.99" E 37° 51' 28.37" N
25	Eğirdir Municipality Public Picnic Area	16858.26	030° 49' 6.99" E 37° 53' 5.32" N
TOTAL		270341.70	

When the findings obtained are examined at the neighbourhood scale, a pronounced imbalance is evident. 61.43% of the total active open and green space provision in the urban area is located in Konya Bucağı Neighbourhood alone. This is attributable to the open and green space named Rüya Park located within the neighbourhood, and, given the neighbourhood's population of 572, this yields a value of 290.35 m² per capita — far in excess of the minimum standards. Konya Bucağı, Sekibağ, Yeşilada and Altinkum Neighbourhoods together account for 90.19% of the total active open and green space provision in the urban area (Table 3). By contrast, Ağa, Bağbuyan, Bağlar, Hacışeyh, Hamam, Kızılçubuk, Kubbeli, Poyraz, Seydim and Yeni Neighbourhoods have no active open and green space provision whatsoever. These 10 neighbourhoods without active open and green space provision constitute 20.21% of the urban population and have no direct access to any active open and green space. 'Rüya Park', located in Konya Bucağı Neighbourhood, is the sole active open and green space within that neighbourhood. When the active green space per capita of the remaining 23 neighbourhoods within the urban boundaries of Eğirdir is calculated excluding this space, the amount of active green space per capita falls to 6.83 m² per capita, markedly below the minimum standard of 10 m² per capita. This demonstrates that, in evaluating active open and green spaces in urban areas, planning decisions should be made taking into account not only quantitative data but also the distribution and accessibility of such spaces at the neighbourhood scale. As a result of the surveys carried out across the 24 neighbourhoods within the study area, a total of 25 active open and green spaces have been physically identified, comprising 13 children's playgrounds, 9 parks and 3 picnic and recreation areas. However, owing to the boundary characteristics of the neighbourhoods, Liman Park (No: 17) extends across the administrative boundaries of Camii, Demirkapı and Kale Neighbourhoods, and has therefore been defined as a separate park within each neighbourhood in the spatial (numerical) analyses, with its areal size recorded accordingly. Owing to this overlap, the total active open and green space provision has been processed as 27 in the neighbourhood-based distribution table (Table 3).

Table 3. Neighbourhood-based distribution of active open and green spaces within the urban boundaries of Eğirdir

No.	Neighbourhoods	Children's Playgrounds	Park	Picnic and Leisure (Recreation) Area	Total Number of Active Open and Green Spaces	Total Open and Green Space (m ²)	Amount of Green Space per Capita (m ²)	Total Active Green Space Percentage (%)
1	Ağa	-	-	-	0	-	-	0.00
2	Altinkum	-	1	1	2	20209.33	10.35	7.48
3	Bağbuyan	-	-	-	0	-	-	0.00
4	Bağlar	-	-	-	0	-	-	0.00
5	Camii	-	1	-	1	7339.10	25.75	2.71
6	Demirkapı	-	1	-	1	1707.68	11.77	0.63
7	Hacıseyh	-	-	-	0	-	-	0.00
8	Hamam	-	-	-	0	-	-	0.00
9	İmaret	1	-	-	1	554.93	0.95	0.21
10	İstasyon	2	1	-	3	7842.27	3.01	2.90
11	Kale	-	2	-	2	4923.34	46.45	1.82
12	Katip	1	-	-	1	198.41	0.88	0.07
13	Kızılçubuk	-	-	-	0	-	-	0.00
14	Konya Bucağı	-	1	-	1	166080.76	290.35	61.43
15	Kubbeli	-	-	-	0	-	-	0.00
16	Menderes	1	1	-	2	1329.84	1.05	0.49
17	Pınar Pazarı	1	-	-	1	184.93	0.1	0.07
18	Poyraz	-	-	-	0	-	-	0.00
19	Sanayi	1	-	-	1	1810.10	3.00	0.67
20	Sekibağ	3	1	1	5	36616.98	47.74	13.54
21	Seydim	-	-	-	0	-	-	0.00
22	Yazla	3	-	-	3	632.86	0.48	0.23
23	Yeni	-	-	-	0	-	-	0.00
24	Yeşilada	-	2	1	3	20911.17	62.42	7.74
TOTAL		13	11	3	27	270341.70		100.00

When the demographic structure of the neighbourhoods is weighed against their existing green space provision, the region with the highest value — both in terms of areal size and in terms of the amount per capita — is Konya Bucağı Neighbourhood, with 290.35 m². With values of 10.35 m² for Altinkum, 25.75 m² for Camii, 11.77 m² for Demirkapı, 62.42 m² for Yeşilada, 47.74 m² for Sekibağ and 46.45 m² for Kale, these neighbourhoods present a value above the standards in terms of active open and green space per capita. By contrast, with existing values of 0.10 m² for Pınar Pazarı, 0.95 m² for İmaret and 1.05 m² for Menderes, the amount of green space per capita in these neighbourhoods has been found to remain at or below the 1 m² level. In the remaining 10 neighbourhoods, no active open and green space provision has been identified at all.

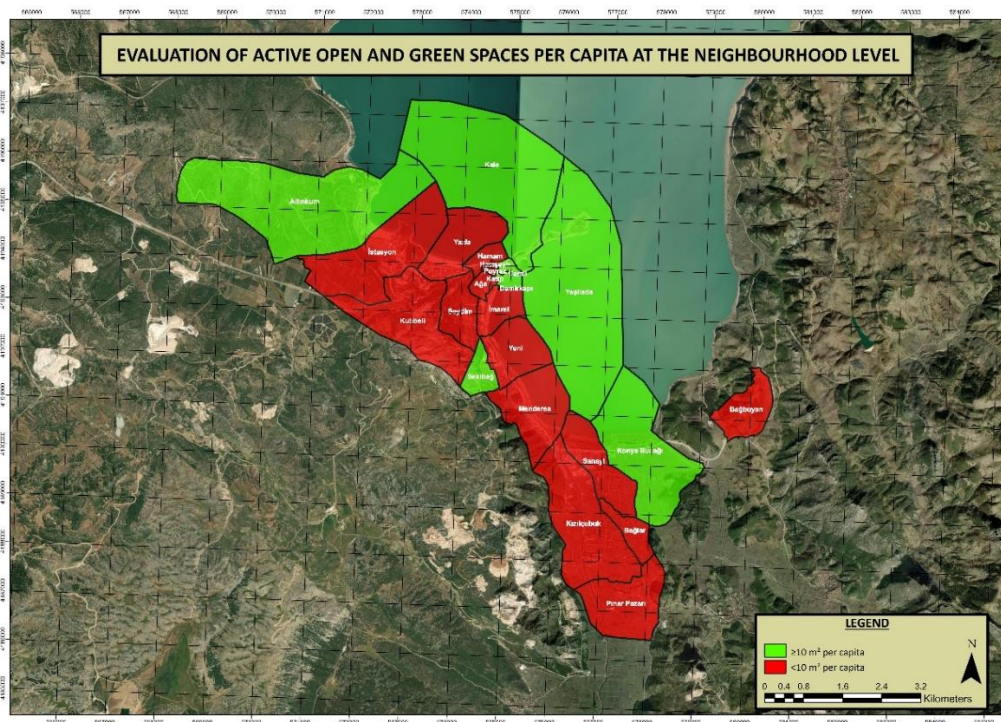


Figure 4. Evaluation of active open and green spaces per capita at the neighbourhood level

According to Figure 4., the neighbourhoods meeting the minimum standard of 10 m² per capita are Altinkum, Kale, Yeşilada, Konya Bucağı, Camii, Demirkapı and Sekibağ, while the neighbourhoods failing to meet this standard are İstasyon, Yazla, Hamam, Hacışeyh, Poyraz, Ağa, Katip, Kubbeli, Seydim, İmaret, Yeni, Menderes, Sanayi, Kızılçubuk, Bağlar, Pınar Pazarı and Bağbuyan. This indicates that, although the amount of active open and green space per capita is above the minimum standards at the urban scale, 17 neighbourhoods fail to meet the minimum standard when examined at the neighbourhood scale. On the other hand, Rüya Park which statistically holds the largest share in raising the amount of active green space above the minimum standards at the urban scale — is, in terms of its existing physical condition, effectively a derelict space. Field surveys revealed that the area is designated as a 'National Garden' on signage bearing the Eğirdir Municipality logo; however, no corresponding record of this status has been found in the official records. Although 'National Garden' is defined as a legal active green space typology in the Planlı Alanlar İmar Yönetmeliği, according to the existing official data, no area within the urban boundaries of Eğirdir has been registered under this status.

3.2. Analysis of the Passive Open and Green Space Provision Within the Urban Boundaries of Eğirdir

The passive open and green spaces within the study area have been addressed under three distinct typologies: cemeteries, central reservations and roadside planting. As a result of the spatial analyses carried out, a total passive green space of 76424.48 m² has been identified across the 24 neighbourhoods. A significant portion of these spaces is constituted by two cemeteries located within the urban boundaries; the cemetery in Yeşilada Neighbourhood, situated together with the Şeyh Muslihiddin Dede Türbesi (Şeyh Muslihiddin Dede Shrine), has an area of 3608.79 m², while the Eğirdir Kervansaray Mezarlığı (Eğirdir Caravanserai Cemetery) in Menderes Neighbourhood has an areal size of 36146.56 m². The remaining passive open and green spaces are constituted by central reservations, accompanying the intra-urban transportation network, with an area of 29429.12 m², and roadside planting covering 7240.01 m². The combined areal size of the active and passive open and green spaces within the urban boundaries of Eğirdir totals 346766.18 m². Active open and green spaces constitute 77.96% of this total area, while passive open and green spaces constitute 22.04%.

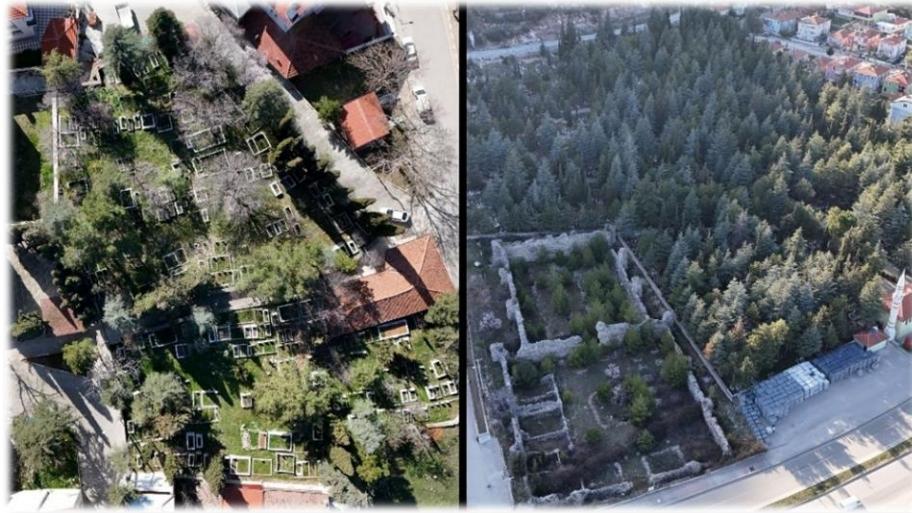


Figure 5. Aerial view of the cemeteries within the urban boundaries of Eğırdır (Authors' Archive, 2024)

3.3. Discussion of the Findings Obtained as a Result of the Open and Green Space Analysis Within the Urban Boundaries of Eğırdır

The multifaceted functions of urban open and green spaces — including public health (WHO, 2016), ecosystem services (Breuste et al., 2013) and resilience to climate change (Akten & Gül, 2024) — make it essential that the provision of these spaces within the urban area be evaluated not only in terms of their quantitative size but also in terms of their spatial distribution and accessibility. Indeed, numerous studies in the literature emphasise that standards determined on a purely quantitative basis in urban planning may produce misleading results, and that green spaces must be addressed in their entirety, including qualitative dimensions such as accessibility (Gedikli, 2002; Bilgili et al., 2011; Gül et al., 2020; Türker & Gül, 2022).

The findings obtained from the spatial analyses carried out using Geographic Information Systems (GIS) across the 24 neighbourhoods constituting Eğırdır urban centre clearly reveal the contrast between general urban statistics and local realities at the neighbourhood scale. The calculation of active open and green space per capita across the study area as 17.07 m² indicates that Eğırdır urban centre exceeds, by 70.7%, the minimum standard of 10 m² per capita set out in the Spatial Plans Preparation Regulation (Mekânsal Planlar Yapım Yönetmeliği, 2014). However, this mathematical average obtained across the urban whole does not imply that green space provision is distributed homogeneously and equitably. Indeed, the data obtained demonstrate that 61.43% of the total active open and green space provision in the urban area is attributable to a single space (Rüya Park) located in Konya Bucağı Neighbourhood alone. When this space is excluded from the equation, the fall in active green space per capita to 6.83 m² for the remaining 23 neighbourhoods demonstrates that, in current practice, green space systems have been rendered fragmented across the urban whole. This contrast, as pointed out by researchers such as Gedikli (2002) and Gül et al. (2020), gives concrete expression, in the case of Eğırdır, to the inadequacy of evaluations based solely on square metres per capita within local planning processes.

4. Conclusion and Suggestions

This research has rendered visible the spatial inequalities created by existing planning practices by addressing the provision of public open and green spaces within the urban boundaries of Eğırdır through a holistic approach, framed within quantitative and spatial standards. As a result of the study, it has been determined that the total amount of green space across the district meets the legal standard of 10 m² per capita; however, this apparent sufficiency is not distributed evenly and holistically across the urban whole. The fact that large, derelict green spaces raise the average on their own, while many neighbourhoods housing a significant share of the urban population lack quality green spaces suitable for everyday access, demonstrates that urban planning processes must be

examined from the highest scale down to the lowest, with local needs taken into account. In order for the urban ecosystem to function properly and for the quality of life of urban residents to be improved, the organisation of green space provision must be freed from purely mathematical and quantitative targets and instead structured around the principles of quality, equity, accessibility and sustainability, or prioritised in areas newly opened for development. In this context, the fundamental strategic action recommendations, aimed at supporting Eğirdir's sensitive urban ecosystem and its Cittaslow identity while remedying the spatial fragmentation and inequalities within the existing urban fabric, are set out below.

- Every neighbourhood resident within Eğirdir should be able to reach an active green space within walking distance of their home; this should be adopted as a planning principle. In neighbourhoods where no active green space currently exists, new open and green spaces should be created, with priority given to this objective.
- Spaces such as Rüya Park, which appear as large active green spaces but remain in a derelict condition, should be repurposed not merely as conventional park areas but through nature-based solutions that enhance resilience to climate change; the active participation of urban residents in the design and use processes of the space should be encouraged, revitalising the area and giving it a new image that adds both ecological and economic value to the urban area.
- Green spaces located along the lakeshore and within the interior of the urban area should cease to be fragmented spaces. The existing roadside planting and central reservations should be qualitatively improved and transformed into ecological 'green corridors' encompassing all elements constituting the urban area, linking active green spaces to one another and to the lake ecosystem in an uninterrupted manner.
- A database employing spatial analysis software should be established within Eğirdir Municipality in order to keep the inventory of open and green spaces up to date, or alternatively, the Kent Rehberi (Urban Guide) available on the official website of Eğirdir Municipality should be further developed and made publicly accessible, rendering the process transparent. Through this system, population movements and new construction should be tracked simultaneously, enabling changes in the amount of open and green space per capita to be monitored in real time.
- The demands and usage tendencies of Eğirdir residents should be identified in the processes of planning, designing and renewing open and green spaces. In addition, 'sponsorship' mechanisms should be developed for existing and future green spaces through voluntary partnerships.
- The problems of fragmented, disconnected green spaces under urbanisation pressure identified in the specific case of Eğirdir constitute a common problem shared by many cities across Türkiye. Standards for urban active open and green spaces should be established not merely in terms of areal size but also in terms of their relationship with their surroundings, quality, site selection, functionality, biodiversity, equity, accessibility, quality and user profile, and a 'Green Spaces Law' should accordingly be incorporated into the relevant regulations (Türker & Gül, 2022).
- Eğirdir Urban Forest (Eğirdir Kent Ormanı) has been included in the analysis as it is used in practice for picnicking and recreational purposes; however, this space does not have a clearly defined status under existing regulations. In order to avoid confusion within planning processes, it is essential that this and similar areas be defined within legislation, and that urban green space classifications be diversified and afforded legal protection. Without the necessary classifications and definitions being made, it is not possible to obtain clear accuracy from quantitative analyses.
- For the sustainability of urban green spaces, the processes of 'construction', 'management' and 'maintenance and repair' should be addressed as independent headings, each with its own distinct dynamics. Taking into account the neighbourhood-scale inequality demonstrated in this study (Table 3), existing resources should be directed on a priority basis not merely towards neighbourhoods whose existing active open and green space provision already meets the standards, but towards neighbourhoods with no active open and green space whatsoever, or where the amount of green space per capita falls below the standard.

- In the landscaping arrangements of the active and passive green spaces identified within the study and located along the lakeshore, plant species suited to the regional flora and with low water requirements should be preferred. Given the direct relationship of these spaces with the sensitive lake ecosystem, it is recommended that landscaping practices be planned in a manner that does not increase pressure on the urban area's water resources.
- A comprehensive 'Transportation Master Plan', addressing Eğirdir's transportation infrastructure from a holistic perspective, should be prepared. Within the scope of this plan, public transport, pedestrian and cycling route proposals should be developed in order to provide frequent and uninterrupted access to the public open and green spaces across the urban area, coordinated with their existing inventory.

In conclusion, although these 24 neighbourhoods constituting the urban boundaries of Eğirdir meet the standard for green space per capita at the urban scale, it is evident that, when examined at the neighbourhood scale, 17 neighbourhoods fall below the standards and spatial inequalities have emerged. The study clearly demonstrates that, alongside quantitative analysis, the dimensions of quality and accessibility must also be addressed in their entirety. In this context, a holistic action plan should be developed for Eğirdir regarding the future planning and design of open and green spaces.

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Author Contribution and Conflict of Interest Disclosure Information

All authors contributed equally to the article. There is no conflict of interest.

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Contributions of Biological Ponds in the Climate Change Adaptation Process and Planning/Design Principles

Şeymanur BAROL ¹ 

ORCID 1: 0009-0001-6756-4930

¹ Undergraduate Student, Süleyman Demirel University, Faculty of Architecture – Landscape Architecture, 32000, Isparta, Türkiye

* e-mail: seymabarol.375@gmail.com

Abstract

Historically, water structures and ponds have played an important role as spatial reflections of human–nature interactions. Today, biological ponds emerge as sustainable landscape components designed within ecosystem-based approaches, supporting natural water cycles and contributing to climate change adaptation. This study aims to examine the role of biological ponds in climate change adaptation and to evaluate their planning and design principles. Site selection, plant species preferences, technical requirements, and the advantages and limitations of these systems are discussed, along with their functions in sustainable water management, biodiversity enhancement, and microclimate regulation. Additionally, the integration of ecological and technical factors in the design process and its impact on long-term performance and adaptation capacity are evaluated. In conclusion, biological ponds are not only aesthetic or recreational elements but also multifunctional ecological infrastructure components, where a holistic approach in planning and design is critical.

Keywords: Biological Ponds, Climate Change, Sustainable Water Management, Landscape Planning, Landscape Design.

Biyolojik Havuzların İklim Değişikliğine Uyum Sürecine Katkıları ve Planlama/Tasarım İlkeleri

Öz

Tarihsel olarak, su yapıları ve göletler, insan-doğa etkileşimlerinin mekânsal yansımaları olarak önemli bir rol oynamıştır. Günümüzde biyolojik göletler, ekosistem temelli yaklaşımlar çerçevesinde tasarlanan, doğal su döngülerini destekleyen ve iklim değişikliğine uyum sürecine katkıda bulunan sürdürülebilir peyzaj bileşenleri olarak öne çıkmaktadır. Bu çalışma, biyolojik göletlerin iklim değişikliğine uyumdaki rolünü incelemek ve bunların planlama ve tasarım ilkelerini değerlendirmek amacıyla yapılmıştır. Sürdürülebilir su yönetimi, biyolojik çeşitliliğin artırılması ve mikroiklim düzenlemesindeki işlevlerinin yanı sıra, yer seçimi, bitki türü tercihleri, teknik gereklilikler ile bu sistemlerin avantajları ve sınırlamaları ele alınmaktadır. Ayrıca, tasarım sürecinde ekolojik ve teknik faktörlerin entegrasyonu ile bunun uzun vadeli performans ve uyum kapasitesi üzerindeki etkisi değerlendirilmektedir. Sonuç olarak, biyolojik göletler yalnızca estetik veya rekreasyonel unsurlar değil, aynı zamanda çok işlevli ekolojik altyapı bileşenleridir ve bu bağlamda planlama ve tasarımda bütüncül bir yaklaşım hayati önem taşımaktadır.

Anahtar kelimeler: Biyolojik Göletler, İklim Değişikliği, Sürdürülebilir Su Yönetimi, Peyzaj Planlaması, Peyzaj Tasarımı.

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1. Introduction

Since the Industrial Revolution and continuing to the present day—particularly over the past 50 years—at both the global and local levels, the use of fossil fuels, deforestation, changes in land use, and the multifaceted increase in industrial human activities and their impacts have led to significant increases in the levels of greenhouse gases and carbon emissions in the atmosphere. As a result, it has been observed that this leads to a rise in global average temperatures and an increase in the frequency and intensity of extreme weather events (droughts, floods, storms). In this context, climate change has brought about a range of negative consequences, including damage to natural (ecological) systems, disruption of the natural balance, increased greenhouse gas emissions, increased environmental pollution, loss of biodiversity, the drying up of wetlands, and a decline in agricultural productivity, among others (Gül et al., 2021a; WMO, 2022; Gül & Gül, 2024; Akten et al., 2025).

Today, the harmony or disharmony of the relationships between natural systems and humans' multifaceted economic activities determines and influences the future of both spheres of existence. Sustainability—the balance between meeting the needs of present-day humanity and ensuring that future generations can also meet their own needs—lies at the heart of the conflict between ecology and the economy (Gül et al., 2023).

Climate change is widely recognized as one of the most significant global challenges facing humanity today, with its environmental, social, cultural, and economic dimensions (IPCC, 2021; Gül et al., 2021a-b; Gül et al., 2025).

Today, it is widely accepted that global warming and climate change are caused by human activity. When evaluating the causes and consequences of the adverse effects of climate change, land-use practices and changes in land cover in key sectors—including energy, industry, transportation, mining, construction, and urbanization—as well as the excessive use of fossil fuels, directly impact the structure of natural ecosystems and the carbon cycle (Lal, 2019; Turner, 2020; Akten et al., 2025; Gül et al., 2026).

In areas with high levels of urbanization, these effects are felt more acutely, leading to an increase in the urban heat island effect, water management issues, and biodiversity loss. Measures aimed solely at reducing greenhouse gas emissions are insufficient in the fight against climate change. Nature-based solutions (NBS), which help adapt to inevitable climate impacts, are gaining importance as sustainable and multifunctional tools (Gül et al., 2021b; Gül & Gül, 2022).

Among these approaches, biological ponds hold great potential in terms of both water management and ecosystem services. Through functions such as retaining and delaying stormwater, reducing surface runoff, regulating the microclimate, and enhancing thermal comfort through evaporation, they can mitigate the adverse effects of climate change on a local scale. Additionally, through natural filtration processes, they improve water quality and contribute to the conservation of biodiversity by creating habitats for flora and fauna. Given these characteristics, biological ponds should be viewed not merely as aesthetic or recreational elements, but as an integral component of planning and design processes focused on adaptation to climate change. While the ecological functions of biological ponds have been extensively studied in the existing literature, a comprehensive assessment of planning and design principles in the context of climate change adaptation remains limited.

This study aims to highlight the role of biological ponds in the process of adapting to climate change and to discuss the planning and design principles necessary for their effective implementation. In this way, it introduces systems that will contribute to the conservation of natural resources and provides fundamental information for their practical application.

1.1. Climate Change, Its Environmental Dimensions, and the Adaptation Process

Climate change, which is currently being felt on a global scale, threatens the sustainability of natural and artificial ecosystems. Water resources and water-dependent ecosystems, in particular, are directly affected by this change. Biological ponds, a key component of urban green infrastructure, are systems that both support environmental sustainability and offer an adaptive solution to climate change.

The primary effects of climate change include rising temperatures, erratic precipitation patterns, drought, and a decline in water resources. Bio-ponds play a significant role in mitigating these effects and supporting the natural water cycle. While improving water quality through natural filtration, they can reduce the urban heat island effect by lowering ambient temperatures through evaporation and evapotranspiration processes (Gill et al., 2007). Additionally, they contribute to the conservation of local biodiversity by providing habitats for aquatic plants, invertebrates, birds, and other water-dependent species (Tzoulas et al., 2007).

In terms of adaptation to climate change, bio-ponds are a critical component of nature-based solutions. Compared to traditional engineering-based infrastructure, they are more flexible, self-regenerating, and resilient to environmental changes. Integrating bio-ponds into urban planning provides a sustainable approach to water management while also enhancing the community's resilience to climate change (Kabisch et al., 2016).

2. Biological Ponds

The concept of biological ponds was first introduced in Australia in the early 1980s by a researcher named Werner Gamerith. Gamerith pioneered this innovative system by first implementing it in his own garden. This approach has become increasingly widespread since the 1990s and has garnered attention particularly through studies on water systems created by mimicking the natural environment. While this method aims to protect groundwater resources, it bases this protection entirely on the principle of natural water purification. Biological ponds are natural water systems that can purify themselves and support ecological balance through the collaboration of aquatic plants and natural microorganisms, without the need for any chemical substances.

To mitigate the effects of climate change and facilitate the adaptation process, it is of great importance to integrate green-blue infrastructure systems by connecting green spaces, water resources (existing streams, rivers, etc.), and drainage systems in urban areas, and to combine these with bio-ponds. This will facilitate rainwater collection, prevent flooding, control erosion, and, in particular, contribute to the effective and rational management of water (Gül et al., 2026).

2.1. Advantages of Constructed Wetlands

- They remove organic waste and pollutants through biological processes in a more environmentally friendly and economical manner than chemical or mechanical treatment methods.
- They are mostly passive systems that operate with low energy consumption, thus offering a sustainable and environmentally friendly alternative.
- They prevent water pollution and eutrophication by reducing excess nutrients such as nitrogen and phosphorus.
- They can be used for various purposes, such as municipal wastewater treatment, stormwater management, and wetland restoration.
- They help protect groundwater levels and balance the local water cycle.
- Since no mechanical pumping is required, they maintain the necessary balance without causing water loss.

2.2. Disadvantages of Biological Ponds

- Initial investment costs are high due to the natural insulation materials, plant-based, and biological filtration systems used during the installation phase.
- Water quality, plant growth, and microbial balance must be continuously monitored; the ecological balance in the pond can be disrupted by seasonal changes (such as a slowdown in microbial activity in winter or increased evaporation in summer).
- Without proper maintenance, problems such as excessive plant growth, algae blooms, or oxygen depletion may occur.
- It creates conditions conducive to the breeding of pests such as mosquitoes.

- Minor errors made during the design phase—such as insufficient sunlight, incorrect plant species selection, or an unsuitable soil structure—negatively impact the system’s functionality.

2.3. Ecological Functions of Biological Ponds

Biological ponds are multifunctional systems that not only serve as water features that enhance landscape aesthetics but also provide significant ecological and social benefits to their surroundings. When considered as part of nature-based solutions, these structures are of strategic importance both for supporting natural life and for improving the quality of urban life.

The ecological benefits of biological ponds are multifaceted:

- **Supporting biodiversity:** Biological ponds provide a natural habitat for many species, such as amphibians, waterfowl, insects, and microorganisms. Different habitat types develop according to the zones established around the pond, thereby supporting ecological balance.
- **Improving water quality:** Thanks to their natural filtration properties, biological ponds enable the purification of water sources such as rainwater or graywater through plants and microorganisms. This process serves as an ecosystem service by providing water purification.
- **Microclimate effect:** Ponds humidify the surrounding air, create a cooling effect through evaporation, and thereby reduce the urban heat island effect. This effect provides significant benefits in terms of thermal comfort, particularly in densely built-up areas.
- **Soil and erosion control:** Aquatic plants used around the pond help ensure shoreline stability, thereby minimizing soil loss and surface runoff.

2.4. Social Functions of Biological Ponds

The social benefits provided by biological ponds serve to strengthen the relationship between humans and nature and improve quality of life:

- **Recreation and relaxation:** With their aesthetic appeal and natural surroundings, ponds provide opportunities for passive recreational activities such as relaxation, walking, and nature observation. These features help reduce stress in urban life.
- **Education and awareness:** Biological ponds integrated into areas such as schoolyards, parks, and university campuses serve as effective outdoor classrooms for environmental education. Topics such as the water cycle, ecological balance, and native species can be observed firsthand.
- **Aesthetic value and spatial identity:** Biological ponds enhance the visual quality of their surroundings and contribute to the formation of spatial identity. Water features are also valued in many cultures as symbols of harmony with nature and of life itself.

3. Current Challenges Facing Biological Ponds

Various technical, environmental, and social challenges may arise in the planning and operation of biological ponds. Accurately identifying these challenges and developing strategies to address them are critical to the success of these systems (Mitsch & Gosselink, 2015).

Technical Issues

- **Inadequate Design and Sizing:** Inadequate sizing of ponds negatively affects treatment performance. Insufficient volume means that water cannot be retained adequately and pollutants cannot be removed (Kadlec & Wallace, 2009).
- **Low Oxygen Levels:** In some wetland systems, dissolved oxygen (DO) levels may be low; this leads to the limitation of aerobic biological processes and the proliferation of anoxic/anaerobic zones (Vymazal, 2010). This situation causes aerobic processes that require oxygen to slow down in biological ponds; the breakdown of organic matter and the efficiency of nutrient cycles decrease. Furthermore, the expansion of anoxic and anaerobic zones can lead to deteriorating water quality, the formation of foul odors, and the loss of habitats for aquatic organisms.

- **Sediment Accumulation:** Sediments that accumulate over time at the bottom of the pond reduce its volume and decrease its treatment capacity (Mitsch & Gosselink, 2015). For this reason, biological ponds require regular maintenance.
- **Plant Management Issues:** The selection of inappropriate plant species or the dominance of a single, overly dominant species in biological ponds can lead to a decrease in plant diversity, excessive growth, and increased plant mortality, thereby negatively affecting biological balance and ecosystem functions; this, in turn, can compromise the pond's performance and sustainability.
- **Excessive Nutrient Load (Eutrophication):** The influx of excessive amounts of nitrogen and phosphorus into the pond leads to excessive growth of aquatic plants and algae. This reduces oxygen levels and degrades water quality.
- **Impact of Climate Conditions:** In cold climates, biological activity decreases, and treatment efficiency drops. In the summer months, however, rising water temperatures can increase water loss and evaporation.
- **Foreign Substances and Pollutants:** Heavy metals, toxic chemicals, and microplastics are pollutants that are difficult to treat in biological ponds. The accumulation of these pollutants can negatively affect the biological processes in the pond.

Social and Economic Issues

- **Lack of Space:** The lack of sufficient space in urban areas limits the design of constructed wetlands (Hassall, 2014).
- **Maintenance and Operating Costs:** Regular maintenance of ponds is necessary. In particular, weed control and sediment removal can be costly (Kadlec & Wallace, 2009).
- **Lack of Public Awareness and Participation:** The fact that the public is not sufficiently aware of the function and importance of natural ponds, combined with low stakeholder participation, makes it difficult to protect these areas and implement successful management practices.

4. Principles of Planning and Design for Biological Ponds

For biological ponds to be successful, numerous criteria must be taken into account during the planning and design phases. These phases directly affect both the treatment efficiency and the ecological and social functionality of the pond.

4.1 Site Selection

Site selection plays a critical role in the design of biological ponds from both environmental and technical perspectives; the site's topography, proximity to a water source, and distance from environmental protection zones and residential areas are among the key planning criteria (Mitsch & Gosselink, 2015).

- **Topography:** Locating reservoirs in low-elevation areas that align with natural slopes facilitates water flow by gravity and reduces energy consumption.
- **Water Source:** Being located near the water source to be treated offers both economic benefits and operational convenience. Data on the water source must be taken into account to account for the expected flow rate and water losses in the water supply.
- **Environmental Factors:** Protected natural areas must not be damaged, and biodiversity must be preserved.

Climatic Data: Precipitation and Temperature: Monthly average and extreme temperatures are essential for plant selection and water management

Vegetation: In biological ponds, vegetation is one of the key elements that determine both the functionality and aesthetic integrity of the system. Vegetation serves multiple functions, including biological water purification, habitat creation, shoreline stability, visual appeal, and user experience. Therefore, criteria such as ecological suitability, resilience,

functionality, and compatibility with local flora should be considered when selecting plant species.

Soil Properties: The functionality and sustainability of constructed wetlands depend not only on water quality or plant species selection, but also directly on the physical, chemical, and biological properties of the soil in which the system is built. Soil is one of the system's fundamental components, supporting plant growth as well as performing multifaceted functions such as water filtration, retention, and purification (Mitsch & Gosselink, 2015; Kadlec & Wallace, 2009).

Physical Properties: Soil particle size composition (clay, silt, and sand content) is a key factor that directly affects the permeability of the pond bottom and plant root growth. Clay-rich soils with low permeability can provide an advantage in terms of water retention by increasing water storage (Hammer & Hammer, 2014). Sandy soils are not recommended for the pond bottom itself due to their high water permeability, but they can be used in riparian zones to improve water drainage (Kadlec & Wallace, 2009). Although the organic matter content provides important support for plant growth, excessive organic content can degrade water quality and cause pollution; therefore, balance is crucial (Vymazal, 2010).

Chemical Properties: The soil's pH level, salinity, and nutrient content (particularly nitrogen and phosphorus levels) directly affect the growth potential of the plant species to be used. For most aquatic and riparian plants, the ideal pH range is generally considered to be 6.5–7.5 (Mitsch & Gosselink, 2015). Soils with high nutrient loads, such as those rich in phosphorus, can pose a risk of eutrophication, particularly when used in filtration zones (Kadlec & Wallace, 2009).

Biological Characteristics: Soil microbial activity plays a key role in the biological filtration process. Microorganisms contribute to the biological treatment of water by breaking down organic matter. For this reason, biologically active, living soils should be preferred around ponds (Vymazal, 2010; Hammer & Hammer, 2014).

Construction and Layering:

- In ponds, the soil is typically arranged in layered systems:
- At the very bottom, a waterproof base (clay or a membrane),
- Above that, nutrient-rich soil that retains water and supports plant root growth,
- And at the very top, decorative and erosion-preventing material (gravel, stones, organic mulch) if needed.
- These layers play a fundamental role in creating a pond system that is both aesthetically pleasing and functional.

Site Selection Criteria for Biological Ponds

- **Temperate climate:** This is the most suitable climate type. Regions that are neither too hot nor too cold, with moderate temperature fluctuations throughout the year, are preferred.
- **Temperature:** The average temperature should be between 10–25°C. This temperature range is optimal for the activity of microorganisms, aquatic plants, and other organisms.
- **Precipitation:** Regions with annual precipitation generally ranging from 600 to 1,200 mm are suitable.
- **Ground slope:** The ideal ground slope is between 0% and 2%, which balances water accumulation and surface runoff.

4.2. Definition and Scaling in the Planning Process

The planning process for biological ponds is not limited to the design of a physical water feature alone; it requires a comprehensive assessment that includes multidimensional criteria such as ecological

functions, the urban context, user needs, and environmental sustainability. In this context, the initial step of the planning process—definition—and the subsequent phasing and scaling studies are of critical importance for establishing the correct relationship between the pond and its surroundings.

During the planning phase, the physical, social, and ecological characteristics of the site where the pond will be constructed are analyzed to clearly define the system's function. At this stage, an assessment is made of whether the biological pond will serve recreational, educational, aesthetic, or purely ecological purposes; its location within the city; the target user profile; and its relationship to the site's existing infrastructure. Furthermore, involving various disciplines—such as local governments, landscape architects, and environmental engineers—in the planning process strengthens the sustainability of this system.

Hierarchical analysis refers to the process of analyzing the planning process at different scales and making decisions based on the relationships between these scales.

- On a macro scale, the relationship between the biological pond and the city's ecological networks, watersheds, natural green spaces, and climatic factors is determined.
- At the meso scale, the functional connections between the pond and the park, neighborhood, or regional open space where it is located are planned.
- At the micro level, the focus is on the details surrounding the pond (such as landscaping, water inflow and outflow, user paths, and seating areas).

During the scaling phase, an appropriate design is developed by taking into account the physical dimensions of the bio-pond, the size of the area it will serve, user density, and its ecological capacity. While small-scale ponds are typically located in neighborhood parks or schoolyards, medium- and large-scale systems can be designed for recreational areas or integrated with urban ecological corridors. As the scale increases, technical and biological details—such as integration into the natural water cycle, plant diversity, and depth-zoning to provide habitat—must also be enhanced.

This multi-layered planning approach ensures that biological ponds become not only visual elements but also active components of the urban ecosystem. Thanks to proper scaling and site selection, biological ponds provide maximum benefits in terms of both ecological functionality and user experience.

4.3. Development of the Design Concept

The functional and sustainable implementation of constructed wetlands requires not only planning but also a well-thought-out design concept. This process encompasses numerous technical and aesthetic criteria, ranging from the wetland's form to the materials used, plant selection, and water source. The key components to consider in the design of a biological pond are explained below.

Pond Shape and Dimensioning Design

The shape of the pond (organic, geometric, curved, etc.) should be determined based on its surroundings, ecological objectives, and user needs. While organic shapes provide a natural appearance, sharper geometric lines may be more compatible with modern and man-made spaces. Dimensioning includes the pond's surface area, depth zoning (shallow, medium, and deep zones), bank slopes, and shoreline length. In particular, different depth zones provide habitat diversity for various plant and animal species.

Biological ponds are typically designed in informal (natural-looking) styles that blend seamlessly with nature. This approach not only allows users to experience nature but also creates a look that harmonizes with the overall aesthetics of the landscape. Expansive water surfaces are preferred to create natural or near-natural appearances.

Materials Used in Construction

- Waterproofing Materials:
 - Clay layer (for natural waterproofing)

- EPDM or PVC membranes (flexible waterproofing materials)
- Geotextile liners (to protect the membrane and reinforce waterproofing)
- Stone and Gravel Materials
 - Used to line the bottom and edges of ponds for both decorative purposes and biological filtration.
 - Supports the roots of aquatic plants and physically cleans the water.
- Microorganism Cultures
 - Beneficial bacteria that support natural biological filtration in water (sometimes added in the form of specialized products).

The table below lists some microorganisms that can be used in biological ponds

Table 1. Microorganisms used in biological ponds and their functions.

No	Group of Microorganisms	Sample Types	Features
1	Nitrifying Bacteria	<i>Nitrosomonas</i> , <i>Nitrobacter</i>	It facilitates the conversion of ammonium (NH_4^+) and nitrite (NO_2^-) to nitrate (NO_3^-); it improves water quality (Tchobanoglous et al., 2013)
2	Denitrifying Bacteria	<i>Pseudomonas</i> , <i>Paracoccus</i>	It completes the nitrogen cycle by converting nitrate into nitrogen gas, thereby preventing the accumulation of excess nitrogen. (Ökmen & Algur, 2011)
3	Phosphate-Solubilizing Bacteria (PSB)	<i>Bacillus megaterium</i> , <i>Pseudomonas fluorescens</i>	It dissolves phosphorus, making it easier for plants to absorb, and helps prevent eutrophication. (Çakmakçı, 2005)
4	Organic Matter Degraders (Heterotrophic Bacteria)	<i>Bacillus subtilis</i> , <i>Acinetobacter</i> spp.	It breaks down organic waste, thereby improving water clarity and reducing unpleasant odors and sludge formation. (Purde, 2009)
5	Photosynthetic Microalgae	<i>Chlorella vulgaris</i> , <i>Scenedesmus obliquus</i>	It produces oxygen and improves water quality by consuming nutrients. (Ünver, 2017)

Plant Species Selection and Use

The plant species used in biological ponds must be carefully selected to support the pond's ecological functioning, improve water quality, and enhance its aesthetic value. Plants not only contribute to visual landscaping but also perform functions such as filtration, shading, oxygen production, and habitat creation. In this context, when selecting plants, their ecological functions, habitat preferences, growth habits, and regional adaptability should be taken into account. The table below lists plant species that can be used in biological ponds for various functions.

Table 2. Plant species that can be used for different functions in biological ponds (Gül & Gül, 2020)

Latin name	English Name	General Characteristics	Heavy Performances Literature	Metal in the
Azolla filiculoides Lam.	Mosquito fern, duckweed fern, fairy moss, water fern	It is an aquatic herb that closely resembles other plants. It is an invasive species that can significantly alter aquatic ecosystems such as wetlands, freshwater lakes, and ditches. It reproduces asexually by division. It floats on the water's surface via numerous small, closely overlapping scale-like leaves that hang from its roots into the water. It cannot survive winters with prolonged freezing and is not tolerant of salinity. (https://en.wikipedia.org/wiki/Azolla_ficuloides)	It can remove chromium, copper, zinc, and lead from wastewater. It can remove lead from solutions containing 1–1,000 ppm. (Irvine & Sikdar, 1998).	nickel,
Cabomba furcata Schult. & Schult.f.	Redcabomba and forked fanwort	It grows to a maximum height of 30–80 cm and is up to 8 cm wide. It has purple flowers. It is used as an aquarium plant. (https://en.wikipedia.org/wiki/Cabomba_furcata)	It reduces the concentrations of copper, cadmium, lead, and zinc in water. (Ahmad et al., 2010).	
Ceratophyllum demersum L.	Hornwort	It has trunks reaching 1–3 m in diameter and forms a dense mass with numerous lateral shoots. Each leaf is 8–40 mm long, simple, or with margins bearing spiny teeth resembling two filaments; they are stiff and brittle and can thrive in both cold and tropical freshwater environments. (https://en.wikipedia.org/wiki/Ceratophyllum_demersum)	As, Cd, Cr, Pb (Bunluesin, et. al., 2004; El Khatib, et al., 2014)	
Cyperus alternifolius Rottb.	Umbrella papyrus, umbrella sedge or umbrella palm	It is propagated by dividing the roots and requires plenty of water. It is evergreen and grows upright to a height of about 1.5 m. It has compound leaves. (https://en.wikipedia.org/wiki/Cyperus_alternifolius)	It has the capacity to treat wastewater contaminated with ethanolamine. (Dolphen and Thiravetyan, 2015).	
Echinodorus cordifolius (L.) Griseb.	Spade-leaf sword or creeping burhead	(https://en.wikipedia.org/wiki/Echinodorus_cordifolius) It blooms at the end of summer. It is a perennial. CO ₂ infusion promotes stronger growth. It requires a nutrient-rich substrate, including clay, for optimal growth. It can be grown outdoors in warm climates but is not frost-tolerant. It thrives in bright light. (https://en.wikipedia.org/wiki/Echinodorus_cordifolius)	It is effective in the reduction of three industrial glycols (triethylene glycol to diethylene glycol, diethylene glycol to 1,4-dioxane-2-one, and even to monoethylene glycol) (Teamkao & Thiravetyan, 2015).	
Egeria densa Planch.	Large flowered waterweed or Brazilian waterweed,	This species ranges in size from 20 to 30 cm and can cover an area of hundreds of hectares. Its stems and stalks are brittle. The leaves are thin, approximately 1 cm long and 2–3 mm wide. This species blooms on the water's surface with white and pale purple flowers. It is highly resilient. Colonies of this species have been found adapted to deep lake basins, even in waters with high levels of calcium and carbonate hardness. It is an aquatic plant that grows in water up to 4 m deep, has roots that are 2 m or longer, and produces roots at intervals along its stem. It is an invasive species.	It is used in wastewater treatment plants. It is effective in addressing excess nitrate levels.	
Fontinalis antipyretica Hedw.	Willow Moss	It is a submerged aquatic species found in both still and flowing freshwater. The	It is effective at accumulating cadmium	

		leaves are quite stiff and arranged in three overlapping rows. Each leaf is spear-shaped or egg-shaped, with a midrib and a pointed tip, and is approximately 4 to 9 mm long. It does not produce flowers, but occasionally produces small, smooth spores 2 to 2.6 mm long. It grows in large clusters and mats, providing shelter for fish eggs and fry.	and zinc. (Martins et al., 2004).
Heliconia psittacorum Lf	Parrot's beak, parakeet flower, parrot's flower	It is an evergreen, perennial, rhizomatous plant. It can grow up to 1.5 m tall. Its leaves are long, pointed, elliptical, lance-shaped, and bright green. The flowers are 15–55 cm long and are orange-red, sometimes pink or lilac, and last for 2–3 weeks. It is not cold-hardy. It can grow at temperatures as low as 15°C. It has high moisture requirements. It has high ornamental value.	It has the capacity to treat wastewater in terms of BOD ₅ , COD, and SST (efficiency > 70%) (Peña-Salamanca et al., 2013).
Hydrilla verticillate (L.f.) Royle	Waterthyme	In addition to containing vitamins, minerals, and antioxidants, the plant is beneficial for relieving indigestion. It is also known for its extremely high concentrations of calcium, vitamin B-12, iron, and magnesium. For this reason, it has become a "superfood."	It can be used as a phytoremediation plant for the removal of mercury, cadmium, chromium, and lead. (https://en.wikipedia.org/wiki/Hydrilla)
Juncus effuses L.	Rush or soft rush	It is an annual, flowering herbaceous plant that grows to a height of 1.5 meters. It grows in areas such as wetlands, riverbanks, and marshes. It is an invasive plant. (https://en.wikipedia.org/wiki/Juncus_effusus)	* Cd, Pb ve Zn (Leroy et al., 2015; Syranidou et al., 2017).

Water Source Characteristics

Chemical Properties:

- pH Level: In biological ponds, the water pH should generally be maintained within a neutral or slightly alkaline range (≈ 6.5 – 8.5); extremely acidic or basic values can have toxic effects on aquatic organisms and plants (U.S. Environmental Protection Agency, 2026).
- High Dissolved Oxygen (DO) Levels: These are critical to the sustainability of aquatic ecosystems; low oxygen conditions can have adverse and even lethal effects on aquatic organisms (Mitsch & Gosselink, 2015).
- Nutrient Salts (Nitrogen, Phosphorus): Nitrogen and phosphorus levels in the water should be balanced. High nutrient concentrations increase the risk of eutrophication (Vymazal, 2010).
- Heavy Metals and Toxic Substances: Substances such as lead, cadmium, mercury, and pesticides should not be present in biological ponds, as they pose a threat to aquatic life (Kadlec & Wallace, 2009).
- Salinity: Salinity should be kept low in freshwater biological ponds; this is because freshwater wetlands are generally classified as having water with a salinity of less than 0.5 ppt in order to preserve ecosystem functions and the health of aquatic organisms (Institute for Environmental Research and Education, 2025).

Physical Characteristics:

- Temperature: Water temperature should be appropriate for the regional climate; sudden increases or decreases in temperature can disrupt the biological balance (Mitsch & Gosselink, 2015).
- Turbidity: Low turbidity is ideal because suspended solids can inhibit photosynthesis and limit plant growth (Vymazal, 2010).

Biological Characteristics:

- **Microorganism Density:** Water should be free of harmful pathogens, parasites, and excessive microbial load. This is important for both public health and system stability (Kadlec & Wallace, 2009).
- **Algal and Phytoplankton Growth:** This varies depending on the nutrient load in the aquatic environment and, in the event of excessive proliferation, can have adverse effects on water quality and ecological balance (Vymazal, 2010).

a. Water Depth

Ponds may vary in shape and size, but in accordance with ecological design principles, it is beneficial to create large, shallow water areas; particularly when the water depth is maintained at approximately 20–30 cm, light reaches the bottom and the effectiveness of aquatic plant habitats increases, which supports species diversity and ecological functions. While excessive depth can increase the risk of drowning, ponds that are too shallow can lead to water loss due to evaporation.

b. Water Level Control

Water level control is achieved by balancing factors such as natural water inflows, evaporation, plant water consumption, and drainage (Kadlec & Wallace, 2009). This control is essential for the growth of aquatic plants, microbial activity, and the sustainability of aquatic habitats within the pond.

Mechanical methods, such as overflow channels, drainage channels, valve systems, and pump systems, are typically used to regulate water levels. Overflow outlets reduce the risk of flooding by allowing excess water to flow out in a controlled manner, while valve and pump systems are used to precisely manage the filling and draining of the reservoir (Vymazal, 2010). Additionally, by adjusting the water level in response to seasonal changes, oxygenation and light penetration within the reservoir are optimized.

c. Technical Design Approaches

The technical design process encompasses structural and engineering solutions that support the pond's biological functions. In this context, elements such as recirculation systems to ensure continuous water circulation, aeration units to increase oxygen levels, and waterfalls and flowing water features that provide both aesthetic and functional benefits should be integrated into the design (Kadlec & Wallace, 2009; Vymazal, 2010).

The design should aim for an appearance that harmonizes with the natural landscape while prioritizing technical functionality. Accordingly, systems that operate with low energy consumption or are entirely passive (such as flow systems that utilize natural slopes) should be preferred (Mitsch & Gosselink, 2015). In this way, the pond becomes a system that is sustainable from both an ecological and an economic perspective.

d. Infrastructure and Filtration System

One of the key requirements for maintaining long-term functionality and ecological balance in constructed wetland systems is the proper design of the infrastructure and the effectiveness of integrated filtration systems. The infrastructure includes engineering components such as geomembranes used to make the pond bottom impermeable, controls for water inlet and outlet points, drainage systems, and circulation pumps (Kadlec & Wallace, 2009). These structures manage water flow while enhancing the pond's resilience to environmental conditions.

Water treatment in constructed wetlands occurs through the interaction of multiple physical, chemical, and biological mechanisms based on natural processes. In these systems, microorganisms, aquatic plants, substrate layers, and circulation systems work together to improve water quality (Kadlec & Wallace, 2009; Vymazal, 2010).

Biological Filtration Using Microorganisms

- Beneficial bacteria in the pond break down organic pollutants in the water, thereby providing biological treatment.
- These microorganisms colonize surfaces such as gravel and stones, creating a continuous treatment cycle.
- Excess nutrients in the water, such as nitrogen and phosphorus, are absorbed by the microorganisms, thereby reducing the risk of eutrophication.

Water Purification Using Aquatic Plants (Phytoremediation)

- Aquatic and riparian plants such as water lilies (*Nymphaea* spp.), irises (*Iris* spp.), and reeds (*Phragmites* spp.) absorb nutrients (particularly nitrogen and phosphorus) from the water through their roots.
- These plants also produce oxygen, providing vital support to aquatic life.
- By shading the lake surface, they reduce algae growth.

Substrate (Base) and Stone Layers

- The layers of stone, gravel, and sand placed at the bottom of the pond help both microorganisms to attach and facilitate the physical filtration of water.
- These layers help keep the water clear by filtering out solid particles.

Natural Circulation and Waterfall Tanks

- Systems powered by high-pressure pumps circulate water through biological waterfall tanks.
- These boxes contain biofilter materials such as sponge and lava rock, which help remove harmful substances from the water.
- Continuous circulation increases oxygenation of the water, which supports the purification process.

e.Surface Cleaners (Skimmers)

- Contaminants such as leaves, pollen, oil, etc., that accumulate on the surface of a pond are collected using systems called skimmers.
- This both prevents visual pollution and stops the materials accumulating on the surface from decomposing and polluting the water

f.Rainfall and Flood Management

Areas capable of temporarily storing rainwater (such as drainage basins) should be planned around the reservoir, and spillway systems capable of discharging excess water during sudden floods should also be implemented. These measures prevent the reservoir from sustaining damage during floods.

g.Safety

The safety of bio-ponds is considered a critical factor both for protecting users and for ensuring the healthy functioning of the ecosystem. In terms of physical safety, the depth of the ponds should generally be kept below 0.5 meters, especially in areas accessible to children, and the slopes of the pond edges should be designed to be gentle and gradual. This makes it easier for users to get out of the water in the event of a fall and reduces the risk of drowning (Kadlec & Wallace, 2009; Mitsch & Gosselink, 2015).

Additionally, it is recommended that guardrails or natural barriers be installed and warning signs be placed in areas with high public traffic for safety purposes (Kadlec & Wallace, 2009).

In terms of water quality safety, the accumulation of pathogenic microorganisms and toxic chemicals in biological ponds must be prevented, and water analyses should be conducted regularly. Environmental protection measures should be implemented to prevent harmful substances such as heavy metals and pesticides from entering the pond, and sources of pollution should be minimized (Kadlec & Wallace, 2009; Vymazal, 2010). Plant management also plays an important role in

maintaining water quality; excessive vegetation and algal blooms can disrupt the oxygen balance in the water, thereby jeopardizing the stability of the ecosystem (Vymazal, 2010).

4.4. Implementation and Management

Just as important as the planning and design process for constructed wetlands is the proper implementation and sustainable management of these systems for the project's success. This phase involves translating design decisions into on-site implementation, overseeing the construction process, ensuring functionality, and establishing long-term maintenance strategies.

Implementation Process

The implementation process begins with the transfer of the plans and technical details defined in the project to the field. During this process:

- First, excavation work must be carried out to form the pond.
- Site preparation is carried out and the base is compacted.
- Materials that provide waterproofing (clay layer, membrane, natural liners) must be carefully installed.
- Filtration systems, water inlet and outlet points, and technical infrastructure (such as pumps, weirs, and overflow channels) must be constructed properly.
- Planting should be carried out in accordance with the seasonal schedule and taking into account different depth zones.

Minimizing environmental impacts during the implementation process is also a critical issue. In particular, measures to prevent habitat degradation, control erosion, and implement temporary measures that are environmentally compatible must be planned during the construction phase.

Management and Operation Process

A well-defined management model is essential for ensuring the longevity of constructed wetlands and their ability to maintain their ecological functions. The management process encompasses many different aspects, such as regular maintenance, water quality monitoring, plant health protection, and the monitoring of technical systems:

- Water levels and water quality should be monitored regularly, and water should be added or drained as needed.
- Plant maintenance (pruning, weed control, and control of excessive spread) should be performed periodically.
- Infrastructure components (filter systems, pumps, flood control structures) should be inspected periodically, and maintenance and repair work should be carried out according to a schedule.
- Measures should be taken to adapt to seasonal changes; for example, precautions against freezing during the winter months and strategies to counter evaporation during the summer months should be established.
- Public awareness and participation can contribute to the reservoir's sustainability. Raising awareness among the local community, educational programs, and volunteer monitoring groups can play an active role in this process.

In addition, managing biological ponds in accordance with the principles of integrated management—by holistically integrating them with green infrastructure systems, stormwater management, urban agriculture, and biodiversity conservation strategies—will enhance the system's success.

5. Considerations for the Design of Biological Ponds

There are certain principles that must be followed during the design phase to ensure that biological ponds are healthy, sustainable, and aesthetically pleasing. These principles are of great importance in

ensuring the pond's longevity, preserving the natural balance, and enabling it to function in harmony with its surroundings.

Growing plants using hydroponic methods ensures that nutrients are delivered in a controlled and direct manner through the water, thereby reducing the risk of nutrient excess—which can stem from organic matter in the soil—and the associated risk of algae growth; this, in turn, simplifies the maintenance and operation of the system (Clyde Smith & Campos, 2023).

If aquatic plants are not used in a biological pond, a biological filtration system must be installed to keep the water clean. This system is created using organic materials in a special area called the “regeneration zone.” Here, a biofilm layer develops where beneficial bacteria live. These bacteria naturally purify the water, taking on the role of keeping the water clean even in the absence of aquatic plants and creating a healthy aquatic environment.

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Design Parameters

- **Water Depth and Volume:** The depth of the pond affects its physical, biological, and hydrodynamic properties.
- **Surface Area and Loading Rate:** The surface organic loading rate must provide sufficient area for photosynthesis and oxygen production.
- **Hydraulic Retention Time:** This determines the time required for microorganisms to stabilize organic matter.
- **Geometry (Length-to-Width Ratio):** The length-to-width ratio affects the hydraulic regime and is an important design parameter.
- **Plant Species:** Appropriate plant species must be selected to ensure the pond's ecological balance.
- **Substrate Properties:** The permeability and particle size of the substrate are important for the growth of microorganisms.

6. Example Applications Including the Design and Details of Biological Pond Systems

Biological ponds consist of six basic systems that enable the natural treatment of water. These systems ensure that the water within the pond is purified through natural processes. Each system performs different functions to improve water quality; therefore, if any of the systems is missing or fails to function properly, the pond's overall treatment performance is negatively affected.

Biological Filter Box

- It is located at the beginning of the system. It contains biological filtration media (e.g., sponge, bioballs, lava rock).
- As water passes through this box, contaminants are biologically broken down.

Aquatic Plants

- They are found along the edges and in the shallow areas of the pond.
- They naturally purify the water by absorbing excess nutrients (especially nitrogen and phosphorus).
- They help maintain ecosystem balance and produce oxygen.

Rocks and Gravel

- Used on the bottom and along the edges of the pond.
- Their surfaces harbor beneficial bacteria, which biologically purify the water.
- They also enhance the aesthetic appeal and prevent erosion.

Fish-Friendly Plastic Lining Material

- An environmentally friendly material that lines the bottom of ponds and prevents harm to fish.

Protective Underlayment

- It is laid beneath the flooring material.
- It acts as a buffer against punctures and wear caused by soil.

High-Pressure Water Circulation Pump

- This pump circulates the pond water.
- It pumps water into the waterfall box, ensuring a continuous cycle.
- It also helps oxygenate the water and feeds the filter system.

6.1. Arcata Marsh and Wildlife Sanctuary – California, USA

Location: Arcata, Northern California, USA

Arcata Marsh is a multipurpose wetland and biological pond developed beginning in the 1980s for wastewater treatment and natural habitat creation; it was designed to serve both as a biological treatment system and as a wildlife sanctuary. Today, Arcata Marsh is recognized as a prime example of how natural systems can be successfully integrated into urban wastewater treatment. It is one of the model projects for biological treatment systems at the international level.

6.2. Sinpaş Lagoon Project

The Lagoon Project, which features Turkey's first biological pond, won the "World's Best Biological Pond" award at the 2010 Firestone Pondgard competition. It is located on the Anatolian side of Istanbul. The project features an ecological landscape design created using more than 100 different plant species and over 60,000 plants, along with a 35,000 m² biological pond.

6.3. Dülük Baba Nature Park

Dülük Baba Nature Park is located in the Şehitkamil district of Gaziantep, approximately 8 km from the city center, and, with an area of 306 hectares, is one of the region's largest green spaces. Created through afforestation efforts that began in the 1950s, the park was designated as a Type A recreational area in 2020. One of the park's most striking features is its biological pond, which covers an area of 16,000 m². A total of 11,335 plants representing 255 different species are found around this pond. These plants contribute to the pond's natural filtration system, helping to keep the water clean. Solar panels are used to generate energy for the pond's operation, aiming to promote environmentally friendly energy use. (tr.wikipedia.org, 2025) (Gaziantep Metropolitan Municipality, 2016).

6.4. Bursa Merinos Nature Park

Merinos Nature Park is an area located in the Osmangazi district of Bursa and is considered the city's second-largest urban park. It was built by the Bursa Metropolitan Municipality between 2006 and 2008 on the site of the historic Merinos Woolen Textile Factory. It covers a total area of 252,500 square meters. The biological pond within Merinos Nature Park covers an area of 4,000 square meters. This project was implemented by converting the park's former chemical pond into a biological pond using an environmentally friendly approach. As a result, a natural water ecosystem, completely free of chemical substances, was created (tr. kulturportali.gov, 2013).

7. Conclusions and Recommendations

Today, cities face numerous environmental challenges, such as climate change, ecological degradation, depletion of water resources, and loss of biodiversity. These challenges have demonstrated that traditional engineering approaches are insufficient, thereby highlighting the importance of systems that are in harmony with nature, flexible, and multifunctional. In this context, bio-ponds are not merely landscape elements; they are ecological infrastructure systems that are considered nature-based solutions and directly contribute to the climatic, environmental, and social sustainability of cities.

Biological ponds, which provide natural purification through aquatic plants and microorganisms without the use of chemicals, improve water quality by retaining pollutants such as phosphates,

nitrates, and heavy metals; support the natural water cycle; and offer economic advantages by operating without requiring energy consumption. Low long-term maintenance costs and the ability to design systems that are compatible with local climate and topography make these systems attractive for both newly developing urban areas and existing urban renewal projects.

Beyond providing environmental benefits, biological ponds enhance the quality of urban life; they support biodiversity by creating habitats for birds, amphibians, insects, and aquatic organisms. By creating ecotone zones that strengthen ecological connectivity, these structures offer urban residents spaces that are integrated with nature, aesthetically pleasing, and recreational. Incorporating social functions such as relaxation, observation, education, and raising awareness, biological ponds serve as a concrete example of sustainable urban development as a key component of green infrastructure systems.

Biological ponds play a significant role in enhancing resilience to climate change. With functions such as mitigating the urban heat island effect, regulating the microclimate through evaporation, and contributing to flood control by storing rainwater, these systems should be considered strategic components of cities' climate adaptation and ecological restoration policies. At the same time, they contribute to reducing carbon emissions by promoting water reuse and creating carbon sinks.

Given all these multifaceted contributions, biological ponds must be addressed in a more systematic, widespread, and strategic manner in spatial planning and design processes. The planning of these systems should be approached holistically, encompassing not only their physical layout but also areas such as social acceptance, education, governance, and interdisciplinary collaboration.

To ensure that biological ponds can be effectively, functionally, and sustainably integrated into urban ecosystems, a comprehensive planning and implementation process should be followed in accordance with the following recommendations:

Strategic Spatial Planning

Biological ponds should be positioned as a key component of open and green space systems in new urban development areas; pond planning should be prioritized, particularly in areas at risk of flooding, with a high proportion of impervious surfaces, and those connected to ecological corridors.

In transformation and rehabilitation projects within existing urban areas, biological ponds should be functionally integrated; these systems should be combined with multifunctional designs such as stormwater management, natural treatment, and recreation.

• Interdisciplinary Design Approach

- A design process that takes into account not only the aesthetic but also the ecological, hydrological, and sociocultural functions of biological ponds should be adopted. To this end, collaboration should be established among landscape architects, ecologists, water engineers, urban planners, and environmental scientists.
- Site selection, topography, climate data, the physical and chemical properties of water sources, and flora and fauna components should be evaluated together to develop site-specific solutions.

• Governance, Management, and Standards

- Local governments should view constructed wetlands as strategic water management tools that go beyond traditional artificial pond systems and, accordingly, should prepare technical guidelines that include design principles, maintenance protocols, and monitoring standards.
- The operation and performance of biological ponds should be monitored regularly; they should be evaluated based on criteria such as quality control, species diversity, and user experience, and interventions should be made as necessary.

- **Community Participation and Awareness**

- The success of ponds depends not only on technical expertise but also on the community's ownership of these systems. Therefore, participatory design processes should be encouraged, and the public should be involved in decision-making and maintenance processes.
- Public awareness should be raised through educational displays, outdoor classrooms, observation areas, and nature-based learning activities; biological ponds should be utilized as tools for environmental education.

- **Selection of Plants Compatible with the Local Ecology**

- Aquatic and terrestrial plant species to be used in biological ponds should be selected from native species that are suited to local ecological conditions; these choices should support the system's long-term sustainability and low maintenance requirements.

- **Financial Incentives and Implementation Support**

- Municipalities, environmental agencies, and relevant institutions should provide technical consulting, implementation grants, and maintenance support for constructed wetlands projects; these incentive mechanisms should facilitate the widespread adoption of the system.

- **Development of Landscape-Based Monitoring and Evaluation Models**

- The operational performance of biological ponds should be evaluated not only based on technical criteria but also on spatial and aesthetic quality criteria. In this context, landscape architects should play a role in developing measurement systems focused on visual quality, spatial accessibility, and user satisfaction.

- **Promotion of Best Practices**

- Catalogs and implementation guides should be prepared by compiling successful constructed wetland projects implemented in various cities; these examples should be presented as references for other cities and regions.
- The system should be evaluated through pilot projects, taking into account both its functionality and user feedback; the data obtained should inform new projects.

- **Establishment of Monitoring and Performance Evaluation Systems**

- Regular monitoring systems must be established to ensure the long-term success of constructed wetlands. Indicators should be defined for criteria such as water quality, plant growth, biodiversity, and system efficiency, and periodic data should be collected based on these indicators.
- The data collected should be published in an open data format and made accessible to researchers and the local community.

- **Resilience Planning Based on Climate Scenarios**

- Biological pond designs should be resilient to drought, sudden rainfall, and temperature fluctuations caused by climate change.
- Plant species that can withstand fluctuations in water levels should be selected, and water storage capacities should be reassessed in light of changing climate conditions.

- **Integration with Urban Agriculture and Nature-Based Production**

- They should be planned holistically in conjunction with nature-based production systems such as biological ponds, surrounding vertical gardens, and agroecological areas.
- These areas provide an environment for production and education for city dwellers and can raise their awareness of biological ponds.

- **Biodiversity Monitoring and Species Conservation Strategies**

- Local wildlife should be supported through structures such as bird-watching towers and bat roosts that will be integrated into the pond areas.
- Species observed around the ponds should be recorded to create local biodiversity databases.

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All authors contributed equally to this article. There are no conflicts of interest.

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