CLIMATIC CHANGE, CARBON MANAGEMENT AND GREEN SPACE SYSTEMS IN ARCHITECTURAL SCIENCES

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PREFACE

In the history of humanity, especially in the last few years, the pressure and intervention of humankind on natural resources has gradually increased. Primarily, due to urbanization, industrialization, and technological and digital developments, the gradual increase and diversification of production and consumption activities focused on economic growth has brought multifaceted problems and negativities. In this context, human beings have exploited, changed, shaped, and destroyed nature as a unilateral commodity in line with their needs and demands. Capitalist approaches in the pursuit of ‘maximum profit’ in economic production and consumption relations and implementing activities/investments that are incompatible with natural (ecological) systems constitute the basis of the problems.

It was widely accepted that the leading cause of climate change and its adverse effects, which is dictated as a global problem today, is the carbon cycle disruption due to multifaceted and excessive human production and consumption activities.

It is possible to say that sustainability, which is the balance between meeting the needs of humanity today while meeting the needs of future generations, is at the center of the conflict between ecology and economy. Since human beings, as a component of nature, will co-exist with nature, they should be in harmony with nature, have an ecology-centered perspective, and reflect it in their attitudes and behaviors by considering nature as a goal rather than a tool.

To mitigate the negative consequences of climate change on a global scale and for the adaptation process, the protection of natural resources and ensuring sustainability, the transformation of nature/ecological and science-based spatial use decisions and policies into action, and the dissemination of interdisciplinary joint studies in the spatial planning, design, and management process should be the primary goal.

In this context, there is an absolute need for communication and cooperation between the disciplines of Architectural Sciences in solving global problems.

The editors of this book believe that a more livable and sustainable world can be created by carrying out interdisciplinary studies of spatial planning and design disciplines together under the roof of ***Architectural Sciences***.

In this context, '***The Journal of Architectural Sciences and Applications (JASA)***,' which pioneered the collective work of related disciplines, was first published in 2016. Subsequently, JASA Editors have made significant contributions to creating various books containing original studies and bringing the latest developments in the field to the reader. This book, titled Climate Change, Carbon Management and Green Space Systems in Architectural Science, contains 16 chapters and covers precious topics.

The authors of the chapters are solely responsible for the copyrights of the figures, pictures and visuals in the book chapters, their content, the accuracy of references and citations, the proposed ideas and compliance with all the rules of publication ethics.

We want to thank the authors, the referees with their valuable contributions, İKSAD Publishing House, and Professor Atila GÜL, General Coordinator of the Architectural Sciences book series, who contributed to the completion of this book.

We hope that our book '***Climate Change, Carbon Management and Green Space Systems in Architectural Science'*** will be helpful to the readers.

Best regards.

01.10.2024

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Examining Sustainability Concepts Through LEED Platinum Certified Libraries

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1. Introduction

The impact of the Industrial Revolution in the 19th century and the rapid consumption of natural resources due to population growth in the 20th century set the stage for environmental disasters (Çakır Kiasif et al., 2020). The concept of sustainability has emerged as a response to the ecological imbalance caused by human activities, such as depletion of the ozone layer, melting of glaciers, and seasonal changes. Although there are various definitions of sustainability in the literature, each scientific discipline offers unique interpretations. Generally, sustainability can be defined as the ability to maintain productivity and diversity continuously without interruption (Tüyen, 2020, as cited in Arıcı &Arısal, 2021).

Sustainability is a complex and multifaceted concept that transcends multiple fields including education, agriculture, health, and architecture. From an environmental standpoint, sustainability involves taking present-day actions to preserve the ecological balance for the benefit of future generations (Küçükcan, 2015). In the realm of architecture, sustainable design encompasses all efforts aimed at prioritizing renewable energy sources and maximizing the efficient use of energy, water, materials, and the environment throughout the lifespan of a structure. The ultimate goal is to create environmentally conscientious buildings that safeguard human health and well-being (Sev, 2009, as cited in Küçükcan, 2015). Sustainable architecture focuses on creating buildings that are well-suited to socio-economic, cultural, and environmental factors, while also considering the long-term impact on future generations. Within this framework, it is important to minimize the overall energy usage in buildings, including during construction, operation, and demolition. To achieve this, passive design strategies should be utilized, and reliance on energy-intensive systems such as HVAC and artificial lighting should be minimized. Additionally, buildings should be designed to harmonize with the local climate of their location (Guedes et al., 2009, as cited in Tatar, 2013).

In the current context, the increase in carbon dioxide emissions from the materials and energy production systems currently in use, which contribute to global warming, has underscored the significance of sustainability. This has spurred the rapid growth of green building systems globally with a focus on promoting this concept. One of the most well-known systems is LEED certification, which originated in the USA (Somalı & Ilıcalı, 2009).

In a 2018 study conducted by Ertan, it was observed that, between 2005 and 2017, the sectors showing the least reported sustainability efforts were education, health, sports, and other social services (0.51%). By contrast, the sectors with the highest reported efforts were manufacturing (43.48%) and financial institutions (35.81%) (Arıcı & Arısal, 2021). This study emphasizes the significance of library buildings, which cater to diverse community needs and play a crucial role in education and culture by embodying sustainability principles within the LEED certification system. A comprehensive literature review also uncovered a plethora of scientific studies on the LEED certification system and sustainability.

Several studies have examined the literature on LEED certifications. These include the examination of certification efforts in educational buildings (Tavşan, Tavşan & Bahar, 2021), contributions of LEED certification to the sustainability of airports (Çelik & Görgülü, 2021), and sustainable approaches and green building certification systems in hotel buildings (Sipahi & Tavşan, 2019). Furthermore, studies have addressed the impact of LEED-certified buildings and indoor environmental quality on humans (Orhan & Kaya, 2016) and the evaluation process of LEED v4 certification. In the realm of sustainable libraries, important works in the literature include a general assessment of libraries and sustainability (Akkaya & Yıldırım, 2020), the contributions of library activities to sustainability (Topkaraoğlu, 2021), and studies aimed at presenting the concept of sustainable architecture in addition to the social dimension (Küçükcan, 2015).

After conducting a thorough review of the available literature, it is clear that there is a gap in the research concerning the evaluation of libraries with LEED Platinum certification based on their certification versions and criteria. To address this gap, this study examined platinum-certified libraries listed on the usgbc.org website. A comprehensive analysis was conducted for all certified libraries, with a particular focus on those that have achieved platinum certification.

2. Material and Method

During the research, we searched for the term "library" on the usgbc.org website and downloaded information on 975 libraries in an Excel format. After filtering out libraries with unavailable certification-level information, we left 593 libraries. These libraries were then analyzed based on their countries, certification versions, and levels. Our main focus was a detailed analysis of the LEED Platinum-certified libraries. We found 42 platinum-certified libraries on the usgbc.org website, with scorecards available for 36 libraries (Figure 1). While analyzing the libraries with accessible scorecards, we gathered information such as library names, their countries, certification versions, certification scores, and the years they received certification, and organized them into a table (Figure 2).

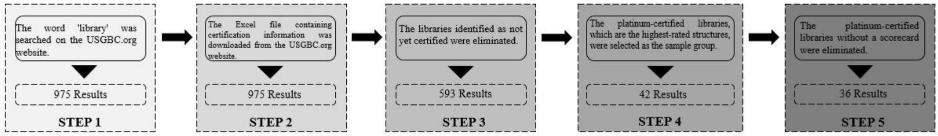

Figure 1. Selection of the Study's Sample Group

This study aims to explore the concept of sustainability in library buildings, as they serve as indicators and tools of societal and cultural development within the framework of LEED certification criteria. This research is important because it sheds light on sustainability in architectural production, specifically focusing on library buildings, and identifies the sustainability criteria that can be successfully implemented in these structures.

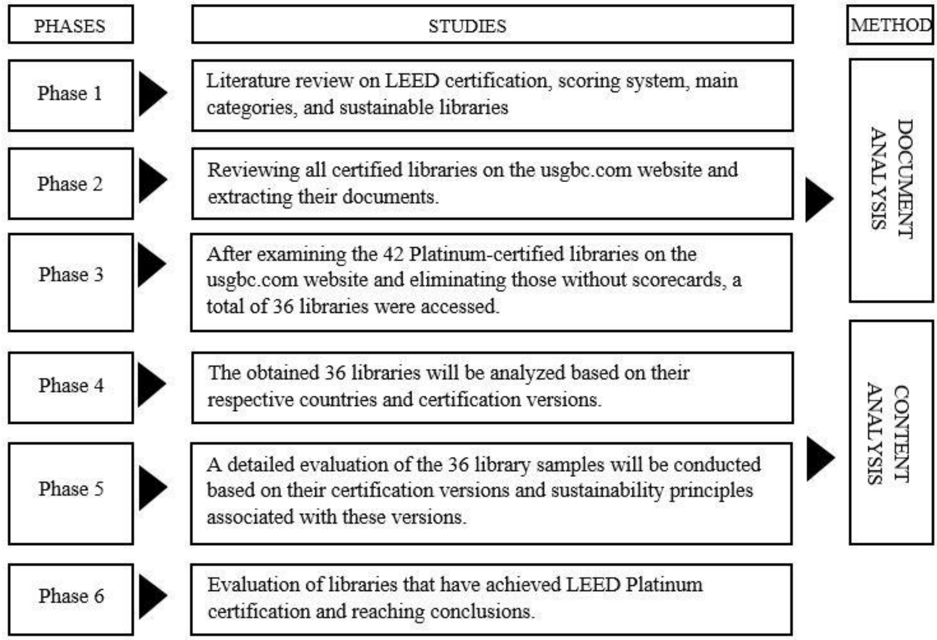

Figure 2. Methodology Diagram of the Study

2.1. Literature Review

The following passage contains general information about LEED Certification, including details of the scoring system and main categories. It also includes an analysis of libraries certified by LEED, based on their certification levels, versions, countries of origin, and years of certification, as listed on the usgbc.com website.

2.1.1. LEED Certification

The Leadership in Energy and Environmental Design (LEED) certification system, developed by the US Green Building Council (USGBC) in 1998, is a framework for evaluating and identifying green buildings in the sustainable construction industry (Sev & Canbay, 2009). LEED has emerged as an American environmental movement aimed at producing market-compatible buildings that are less harmful to the environment. It is the world's most comprehensive responsibility project, striving to provide individuals who produce environmentally friendly structures with healthy living standards, and aims to reverse climate change resulting from the damage caused by the construction sector (Orhan & Kaya, 2016).

The evaluation parameters of certifications have evolved since 1998 to cater to a wider audience and better reflect advancements in green technologies. The initial version, the v1.0-LEED New Construction, was introduced in 1998 as a pilot study. Subsequently, v2.0-LEED New Construction, v2.2-LEED New Construction, and v2009-LEED (formerly known as v3) were developed in 2005 (How to obtain a LEED certification, n.d.). Building on the success of the v2009 version, the green building standards were updated, leading to the release of v4 in 2014. Following v4, feedback on innovations was collected to ensure that the evolving needs of the users were met. This led to the introduction of v4.1 in 2020, which was designed to be more user-friendly, accessible, and collaborative (Doğru, 2020).

In versions v4 and v4.1, it is apparent that certain credits from previous versions were eliminated, whereas new credits were introduced. The LEED platform explained this as "certain credits that did not align with the revised credit objectives and the updated rating system were removed as they did not contribute to the measured outcomes" (Doğru, 2020).

2.1.2. LEED Scoring System and Main Categories

The LEED scoring system comprises three main components. Prior to certification registration, certain conditions, known as "Minimum

Program Requirements," must be met. After registration, the LEED green-building certification prerequisites and credits were addressed.

- Minimum Program Requirements (MPR)
- Prerequisites
- LEED Credits

LEED credits are divided into three main categories: project site, design phase, and construction phase credits. Project site credits pertain to the project's location and site selection, whereas design phase credits encompass all work carried out during the design stage. Construction phase credits include aspects related to construction activities such as waste management and indoor environmental quality (LEED Green Building Certificate, n.d.).

In the LEED scoring system, 110 points were divided into main categories based on the impact and area of interest. There were six main categories and two additional subcategories. The names of the main categories and their corresponding points are shown in the graph as follows (LEED Green Building Certificate, n.d.) (Figure 3):

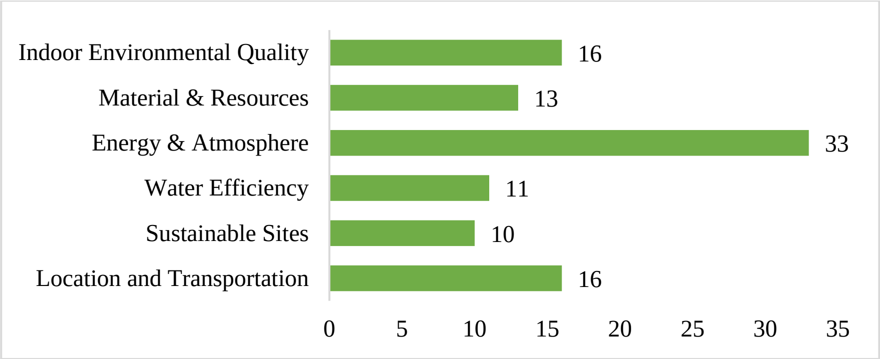

Figure 3. Names of the Main Categories and Their Corresponding Point

Upon approval of the prerequisites for certification and obtaining a minimum of 40 points, buildings are eligible for certification at one of four levels based on the points they have accumulated.

- Certified: 40+
- Silver: 50+
- Gold: 60+
- Platinum: 80-110

2.1.3. Sustainable Libraries

With the evolution of information technology, the rise of user-centered spaces since the 1900s, and shifts in architectural paradigms, concepts, such as sustainability, have gained prominence. In addition, the design of library structures in line with sustainability principles has garnered significant attention (Atınç, 2013 as cited in Arıcı & Arısal, 2021).

Library buildings incur substantial construction and operation costs and contribute significantly to waste generation. Therefore, it is imperative for library buildings to adhere to sustainability principles in their design, construction, and maintenance. Furthermore, adopting sustainable architectural practices has a notable impact on institutional and national economies (Küçükcan, 2015).

IFLA's "Libraries and the Sustainable Development Goals: A Storytelling Handbook" details the various sustainable development goals (SDGs) and discusses the ways in which libraries can contribute to these objectives. The handbook also emphasizes the importance of human activities, such as construction, trade, finance, and culture, in addition to addressing concerns about the quality and environment of the planet (Akkaya & Yıldırım, 2020).

It is crucial for libraries to uphold sustainable principles starting from the construction phase. Project planning, site selection, transportation options, material selection and usage, and energy sources play a role in adhering to sustainability principles. Transforming existing buildings in line with these principles is a common approach. Libraries, like other buildings, were assessed within different categories of the LEED certification system to benchmark these principles.

3. Findings and Discussion

On the usgbc.org website, 975 libraries were found to have LEED certification. After downloading the information about these libraries from the website in an Excel table, libraries that had not yet received certification were excluded, reducing the number of libraries to 593. These libraries were then analyzed according to the countries in which they were located, their certification levels, and their certification versions.

Table 1 presents the distribution of 593 libraries by country and certification. The data show that the majority of LEED-certified libraries (a total of 574) are situated in the United States, with the most common certification version being v2009. After the United States, China has the second highest number of certified libraries, with seven in total. Israel, Lebanon, Pakistan, Taiwan, Thailand, and the UAE each have one certified library. Among the libraries, 257 are certified in the v2009 version. On the other hand, the certification version with the fewest libraries is v2008. It is worth noting that the latest version, v4.1, is still active, with only four libraries certified under this version by 2023.

Table 1. Distribution of LEED-Certified Libraries by Countries and Versions

Name of the Countries	v2.0	v2.1	v2.2	v2007	v2008	v2009	v4	v4.1	Total
Canada	1	2	-	-	1	-	2	-	6
China	-	-	-	-	-	3	1	3	7
Israel	-	-	-	-	-	1	-	-	1
Lebanon	-	-	-	-	-	1	-	-	1
Pakistan	-	-	-	-	-	1	-	-	1
Taiwan	-	-	-	-	-	-	1	-	1
Thailand	-	-	-	-	-	1	-	-	1
UAE	-	-	-	-	-	1	-	-	1
United States	35	55	184	5	1	249	44	1	574
Total	**36**	**57**	**184**	**5**	**2**	**257**	**48**	**4**	**593**

Based on the data presented in Table 2, it is evident that the highest number of libraries have obtained gold certification, with the lowest number of libraries achieving platinum certification. The majority of gold-certified libraries are situated in the United States, while Lebanon and Pakistan each have one gold-certified library. Following gold certification, libraries most commonly receive silver certification. Notably, only one of these silver certifications is located in Canada, while 221 are located in the United States.

Table 2. Distribution of LEED-Certified Libraries by Country and Certification Level

Name of the Countries	Certified	Gold	Platinum	Silver	Total
Canada	2	3	-	1	6
China	-	4	3	-	7
Israel	-	-	1	-	1
Lebanon	-	1	-	-	1
Pakistan	-	1	-	-	1
Taiwan	-	-	1	-	1
Thailand	-	-	1	-	1
UAE	-	-	1	-	1
United States	64	254	35	221	574
Total	**66**	**263**	**42**	**222**	**593**

Table 3 shows the distribution of LEED-certified libraries by certification version and certification level. The gold certification level has the highest number of libraries, specifically the v2009 version. There are no libraries certified at the basic certification level under the v2007 and v4.1 versions. Similarly, no libraries are certified at the gold and silver levels using the v2008 version. At the platinum level, there are no libraries certified under versions v2.1 and v2007.

Table 3. Distribution of LEED-Certified Libraries by Certification Level and Version

Certification Version	Certified	Gold	Platinum	Silver	Total
v2.0	8	14	3	11	36
v2.1	18	13	-	26	57
v2.2	13	95	7	69	184
v2007	-	4	-	1	5
v2008	1	-	1	-	2
v2009	16	113	28	100	257
v4	10	23	1	14	48
v4.1	-	1	2	1	4
Total	**66**	**263**	**42**	**222**	**593**

3.1. Material of Study

This research concentrated on gathering information from 38 libraries that have achieved platinum certification. These libraries were sourced from the usgbc.org website, and those with Certified, Silver, and Gold certifications were not considered for the analysis. The collected data encompassed details such as the country, year of certification, certification version, and certification score for platinum-certified libraries, as indicated in Table 4.

Table 4. LEED Platinum-Certified Libraries

PLATINUM-CERTIFIED LIBRARIES	COUNTRY	LEED SYSTEM VERSION	POINTS ACHİEVED	CERTIFICATION YEAR
Lake View Terrace Branch Library	United States	v2.0	-	2005
Council Tree Library	United States	v2.0	43	2009
Silverlake Library	United States	v2.2	52	2010
Crossroads College Prep-Science/Library	United States	v2.2	55	2010
White Tank Branch Library	United States	v2.2	52	2011
Franklin Avenue Library Expansion	United States	v2009	86	2012
Prairie Creek Branch Library	United States	v2009	82	2012
East Rancho Dominguez Library	United States	v2009	86	2012
HSBC Green Library	Thailand	v2009	80	2013
Gutman Library - 1st and 2nd Floor	United States	v2009	83	2013
Highland Terrace	United States	v2008	-	2014
Clinton Presidential Library Recert	United States	v2009	84	2014
Cedar Rapids Public Library	United States	v2009	82	2014
Athol Public Library Renovation/Addition	United States	v2.2	54	2014
Pico Rivera Library	United States	v2009	81	2015
Billings Public Library	United States	v2009	80	2015
Pico Branch Library	United States	v2009	89	2015
Pierce College - library learning	United States	v2.2		2015
Mitchell Park Library Community Center	United States	v2009	92	2015
West Berkeley Public Library	United States	v2009	81	2016
MA Maritime Acad. Library Modernization	United States	v2.2	53	2016
South Whittier Library	United States	v2009	81	2017
Longwood Public Library	United States	v2009	85	2017
Chinatown Branch Library	United States	v2009	80	2018
New Central Library	United States	v2009	82	2018
Kunshan High School Library	China	v2009	81	2018
William J Clinton Presidential Library	United States	v2009	85	2019
Half Moon Bay Library	United States	v2009	80	2019

Library of International Campus, ZJU	China	v4.1	85	2019
ASU - Hayden Library Renovation	United States	v2009	82	2020
Long Beach Civic Center - Main Library	United States	v2009	80	2020
Southwest Library	United States	v2009	81	2021
Cleveland Avenue Library	United States	v2009	81	2021
Administration Building	United States	v2009	84	2021
Namasia Elem. School-Instruction/Library	Taiwan, China	v4	83	2021
Mohammed Bin Rashid Al Maktoum Library	United Arab Emirates	v2009	85	2021
Hayward Library / Community Learning Cen	United States	v2009	84	2022
Yangzheng Library	China	v4.1	80	2023
National Library of Israel	Israel	v2009	83	2023

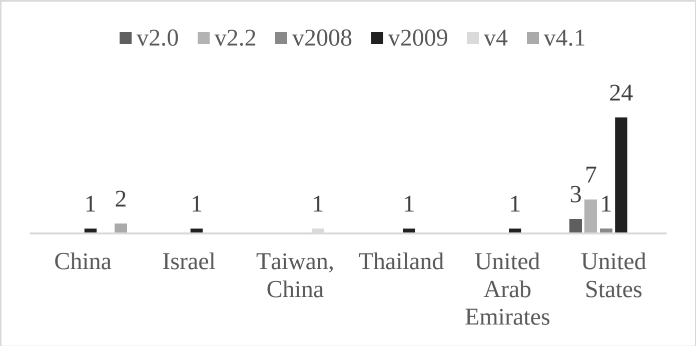

Figure 4. Distribution of Platinum-Certified Libraries by Certification Version

The distribution of the certification versions by country is presented in Table 6. The United States has the highest number of certified libraries, with v2009 being the most commonly certified version. For v2.0, there is only one certified library in the United States, and none in other countries. In the case of v2.2, there are six certified libraries in the United States and none in other countries. In the v2009 version, there are no certified libraries in Taiwan, but there is one each in China, Israel, Thailand, and the UAE, and 22 in the United States. For v4, there is one library in Taiwan and none in other countries. Similarly, for v4.1, there is one library in China and none in the other countries (Table 5).

Table 5. Distribution of LEED Platinum Certified Libraries by Certification Versions and Countries

Name of the Countries	v2.0	v2.2	v2008	v2009	v4	v4.1	Total
China	-	-	-	1	-	2	3
Israel	-	-	-	1	-	-	1
Taiwan	-	-	-	-	1	-	1
Thailand	-	-	-	1	-	-	1
UAE	-	-	-	1	-	-	1
United States	1	7	1	24	-	-	35
Total	**1**	**7**	**1**	**28**	**1**	**2**	**42**

3.2. Findings

In the findings section, we analyze the influence of the evaluated criteria on platinum-certified libraries. We assessed the number of points received by platinum-certified libraries based on criteria levels and certificate versions, calculated the percentage of points obtained, and color-coded each section based on the determined ratios.

Table 6 presents the points earned by platinum-certified libraries based on sustainability criteria in v2.0-LEED ID+C: Commercial Interiors, v2.0-LEED BD+C: New Construction, and v2.2-LEED BD+C: New Construction versions. These libraries were assessed across sustainability sites, water efficiency, energy and atmosphere, materials and resources, indoor environmental quality, and innovation categories. Notably, all libraries scored close to full marks in the innovation criteria. Furthermore, in the indoor environmental quality category, the White

Tank Branch Library and Athol Public Library Renovation/Addition, Silverlake Library and Crossroads College Prep-Science/Library, MA Maritime Acad. Library Modernization and Pierce College-Library, and Council Tree Library achieved nearly 80%, 73%, 87%, and 76%, respectively. In the Materials and Resources section, while seven library structures achieved success rates between 40-70%, Pierce College-Library's performance remained within the 0-40% range.

The data revealed that in the energy and atmosphere categories, all structures achieved success rates between 70-100%. In the water efficiency section, most library structures, with the exception of the Silverlake Library, demonstrated success rates of between 70-100%. The Silverlake Library achieved success within a 40-70% range. For sustainable sites, the White Tank Branch Library and the MA Maritime Acad. Library Modernization achieved success rates between 50-70%, whereas the other five libraries had success rates ranging between 70-100%. It is evident from the data that the most successful categories among the criteria are "innovation, energy and atmosphere, and indoor environmental quality," whereas the less successful category is "sustainable sites".

Table 6. Evaluation of Platinum-Certified Libraries According to Sustainability Principles and Certification Versions

Name of the Library's	Certification Version	Sustainability Principles and Success Percentages					
		SS	WE	EA	MR	IEQ	IN
Council Tree Library	v2.0-LEED ID+C: Commercial Interiors	7/7 %100	2/2 %100	10/12 %83	6/14 %43	13/17 %76	5/5 %100
Silverlake Library	v2.2-LEED BD+C: New Construction	11/14 %79	3/5 %60	15/17 %88	7/13 %54	11/15 %73	5/5 %100
White Tank Branch Library		9/14 %64	4/5 %80	16/17 %94	6/13 %46	12/15 %80	5/5 %100
Athol Public Library Renovation/Addition		12/14 %86	4/5 %80	14/17 %82	7/13 %54	12/15 %80	5/5 %100
MA Maritime Acad. Library Modernization		8/14 %57	4/5 %80	17/17 %100	7/13 %54	13/15 %87	5/5 %100
Crossroads College Prep-Science/Library		12/14 %86	4/5 %80	14/17 %82	9/13 %69	11/15 %73	5/5 %100
Pierce College - library learning		10/14 %71	4/5 %80	16/17 %94	5/13 %38	13/15 %87	5/5 %100

SS: Sustainable Sites *WE: Water Efficiency* *EA: Energy & Atmosphere*

MR: Material & Resources *IEQ: Indoor Environmental Quality* *IN: Innovation*

100		99-80		79-60		59-	

The following analysis examines 22 library structures that obtained LEED Platinum certification under the v2009-LEED BD+C: New Construction Version. In the sustainable land criterion, 13 out of 22 libraries achieved a success rate of 70-100%, while the remaining nine attained a success rate of 40-70%. With regard to water efficiency, the majority of the examples demonstrated success rates between 40-70%. Among the eight libraries examined, eight scored between 70-100%, while 14 scored between 40-70%. In the energy and atmosphere category, 18 out of the 22 libraries achieved success rates between 70-100%, whereas four libraries attained success rates between 40-70%.

In the Materials and Resources section, it is noted that none of the libraries achieved a score between 70-100%. Nine libraries scored between 0-40%, while 13 libraries scored between 40-70%. Regarding the Indoor Environmental Quality criteria, 11 libraries scored between 70-100%, 10 libraries scored between 40-70%, and 1 library scored between 0-40%. In the Innovation category, 18 out of the 22 libraries achieved success rates between 70-100%, while four libraries scored between 40-70%. Additionally, Table 7 shows the "Regional Priority Credit" criteria, with all 22 libraries achieving success rates between 70-100%. From the analyses, it can be concluded that the highest scores in this table are for the "energy and atmosphere, innovation, and regional priority credit" criteria, while relatively lower scores are for the "water efficiency and materials and resources" criteria.

Table 7. Evaluation of Platinum-Certified Libraries According to Sustainability Principles and Certificate Versions

Name of the Library's	Certification Version	Sustainability Principles and Success Percentages						
		S.S.	W.E.	E.A.	M.R.	I.E.Q	IN	R.P.C
East Rancho Dominguez Library	v2009-LEED BD+C: New Construction	23/26 %88	6/10 %60	34/35 %97	5/14 %36	10/15 %67	4/6 %67”	4/4 %100
Cleveland Avenue Library		17/26 %65	8/10 %80	31/35 %87	7/14 %50	9/15 %60	6/6 %100	3/4 %75
HSBC Green Library		21/26 %81	8/10 %80	25/35 %72	5/14 %36	12/15 %80	5/6 %83	4/4 %100
Prairie Creek Branch Library		23/26 %88	9/10 %90	21/35 %60	7/14 %50	11/15 %73	5/6 %83	4/4 %100
Southwest Library		23/26 %88	7/10 %70	29/35 %81	5/14 %36	9/15 %60	6/6 %100	2/4 %50
ASU - Hayden Library Renovation		18/26 %69	5/10 %50	33/35 %94	9/14 %64	7/15 %47	6/6 %100	4/4 %100
Mohammed Bin Rashid Al Maktoum Library		20/26 %77	10/10 %100	33/35 %94	4/14 %29	8/15 %53	6/6 %100	4/4 %100
National Library of Israel		24/26 %92	6/10 %60	31/35 %87	6/14 %43	6/15 %40	6/6 %100	4/4 %100
South Whittier Library		21/26 %81	5/10 %50	32/35 %91	6/14 %43	11/15 %73	4/6 %67	2/4 %50
Longwood Public Library		23/26 %88	6/10 %60	29/35 %81	8/14 %57	10/15 %67	5/6 %83	4/4 %100

Pico Branch Library		22/26 %85	8/10 %80	32/35 %91	6/14 %43	11/15 %73	6/6 %100	4/4 %100
New Central Library		22/26 %85	10/10 %100	23/35 %66	7/14 %50	10/15 %67	6/6 %100	4/4 %100
Long Beach Civic Center - Main Library		24/26 %92	4/10 %40	31/35 %87	5/14 %36	7/15 %47	6/6 %100	3/4 %75
West Berkeley Public Library		18/26 %69	6/10 %60	33/35 %94	5/14 %36	10/15 %67	6/6 %100	3/4 %75
Half Moon Bay Library		23/26 %88	6/10 %60	28/35 %80	5/14 %36	11/15 %73	3/6 %50	4/4 %100
Chinatown Branch Library		21/26 %81	6/10 %60	24/35 %69	7/14 %50	12/15 %80	6/6 %100	4/4 %100
Pico Rivera Library		17/26 %65	8/10 %80	29/35 %81	6/14 %43	13/15 %87	4/6 %67	4/4 %100
Billings Public Library		23/26 %88	5/10 %50	24/35 %69	7/14 %50	12/15 %80	6/6 %100	3/4 %75
Cedar Rapids Public Library		21/26 %81	7/10 %70	28/35 %80	6/14 %43	11/15 %73	5/6 %83	4/4 %100
Franklin Avenue Library Expansion		14/26 %54	7/10 %70	35/35 %100	9/14 %64	11/15 %73	6/6 %100	3/4 %75
Mitchell Park Library Community Center		24/26 %92	6/10 %60	35/35 %100	5/14 %36	13/15 %87	5/6 %83	4/4 %100
Hayward Library / Community Learning Cen		23/26 %88	8/10 %80	31/35 %87	4/14 %29	9/15 %60	6/6 %100	3/4 %75

S.S: Sustainable Sites *W.E: Water Efficiency* *E.A: Energy & Atmosphere*

M.R: Material & Resources *I.E.Q.: Indoor Environmental Quality* *IN: Innovation*

R.P.C.: Regional Priority Credits

100		99-80		79-60		59-	

The data in Table 8 show the performance of platinum-certified libraries based on sustainability criteria in different versions of LEED certification, such as v2009-LEED BD+C: Schools, v2009-LEED ID+C: Commercial Interiors, v2009-LEED O+M: Existing Buildings, v2009-LEED O+M: Existing Buildings, and v4-LEED O+M: Schools. In the sustainable sites criterion, all five libraries listed in the table achieved success in the 70-100% range. For water efficiency, three libraries scored in the 70-100% range, whereas two libraries achieved success in the 40-70% range. Similarly, in the energy and atmosphere category, three libraries scored in the 70-100% range, whereas two libraries achieved success in the 40-70% range. Regarding the materials and resources criterion, two libraries scored in the 70-100% range, two libraries in the 40-70% range, and one library in the 0-40% range. In terms of indoor environmental quality, two libraries achieved success in the 70-100% range, whereas three libraries achieved success in the 40-70% range. Regarding the innovation criterion, four libraries scored close to 100%, whereas one library scored in the 40-70% range. In terms of regional priority credits, all the libraries examined in the table achieved a success rate close to 100%. The inclusion of the "integrative process credit " criterion in Table 9 is evident in Table 8. Although two libraries received no points for this criterion, one library achieved a score in the range of 70-100%. According to the deductions derived from this table, the criteria of "sustainable sites and regional priority credits" appear to be the most successful, while "materials and resources and integrative process credits" are the relatively lower scoring criteria.

Table 8. Evaluation of Platinum-Certified Libraries According to Sustainability Principles and Certification Versions

Name of the Library's	Certification Version	Sustainability Principles and Success Percentages							
		S.S.	W.E.	E.A.	M.R.	I.E.Q	IN	R.P.C	I.P.C
Kunshan High School Library	v2009-LEED BD+C: Schools	19/24 %79	10/11 %91	27/33 %81	6/13 %46	11/19 %58	4/6 %67	4/4 %100	--
Gutman Library - 1st and 2nd Floor	v2009-LEED ID+C: Commercial Interiors	19/21 %90	6/11 %55	30/37 %81	9/14 %64	10/17 %59	6/6 %100	3/4 %75	--
Clinton Presidential Library Recert	v2009-LEED O+M: Existing Buildings	24/26 %92	12/14 %86	18/35 %51	8/10 %80	12/15 %80	6/6 %100	4/4 %100	0/2 %0
William J. Clinton Presidential Center	v2009-LEED O+M: Existing Buildings	24/26 %92	11/14 %79	23/35 %55	7/10 %70	11/15 %73	5/6 %83	4/4 %100	0/2 %0
Namasia Elem. School-Instruction/Library	v4-LEED O+M: Schools	7/10 %70	7/12 %58	37/38 %97	1/8 %13	7/17 %41	5/6 %83	4/4 %100	15/20 %75

S.S: Sustainable Sites *W.E: Water Efficiency* *E.A: Energy & Atmosphere*
M.R: Material & Resources *I.E.Q.: Indoor Environmental Quality* *IN: Innovation*
R.P.C.: Regional Priority Credits *I.PC.: Integrative process credits*

100		99-80		79-60		59-	

In v4.1 ID+C: Commercial Interiors version, Table 9 displays the criteria and corresponding scores for the Yangzheng Library in China. A new criterion, "Location and Transportation," has been added to the v4.1 version to evaluate the sustainability of the building's location and transportation accessibility, replacing its previous classification within the sustainable site criteria. The Yangzheng Library excelled, earning a full score in water efficiency credit and achieving a 70-100% score in energy and atmosphere credit. It also scored between 70-100% for the materials and resources and indoor environmental quality credits. For innovation credit, it received a score between 0-40%, and in the integrative process credits, it scored between 40-70%.

Table 9. Evaluation of Platinum-Certified Libraries According to Sustainability Principles and Certification Versions

Name of the Library's	Certification Version	Sustainability Principles and Success Percentages							
		W.E.	**E.A.**	**M.R.**	**I.E.Q**	**IN**	**R.P.C**	**L.T.**	**I.P.C**
Yangzheng Library	v4.1-LEED ID+C: Commercial Interior	12/12 %100	37/38 %97	8/13 %62	9/18 %50	6/6 %100	4/4 %100	2/20 %10	1/2 %50

S.S: Sustainable Sites *W.E: Water Efficiency* *E.A: Energy & Atmosphere*
M.R: Material & Resources *I.E.Q.: Indoor Environmental Quality* *IN: Innovation*
R.P.C.: Regional Priority Credits *I.PC.: Integrative process credits* *L.T.: Location & Transportation*

100		99-80		79-60		59-	

In v2.0 Commercial Interiors and v2.2 New Construction versions, buildings are evaluated based on Sustainable Sites, Water Efficiency, Energy and Atmosphere, Materials and Resources, Indoor Environmental Quality, and Innovation credits. In the v2009 New Construction, Schools, and Commercial Interiors versions, regional priority credits were incorporated alongside these credits. Furthermore, in v2009 Existing Buildings and v4 existing buildings, school versions and integrated process credits have been introduced compared to previous versions. Notably, the latest version, v4.1 Interior Design and Construction, has replaced sustainable site credit with Location and Transportation credit.

4. Conclusion and Suggestions

In today's era of consumption, preserving resources for future generations, avoiding the exploitation of our planet's resources, and embracing environmental consciousness are becoming increasingly important. This heightened awareness has brought sustainability at the forefront. Broadly speaking, sustainability encompasses an approach that prioritizes considering the future, safeguarding nature and natural resources, and promoting the production and consumption of environment-friendly products.

Architecture is one of the fields that contributes the most to the sustainability approach. Buildings, which constitute a significant portion of carbon dioxide emissions into the atmosphere, should be constructed in accordance with sustainability principles. The USGBC introduced the LEED certification system as a guideline for these principles. LEED, which certifies various building types, has established distinct classification systems. Within this scope, libraries, which are abundant worldwide and hold an important place in people's lives, have been certified. It is believed that library buildings, which can be included in educational structures, can serve as a starting point for sustainability efforts.

The examinations conducted on LEED platinum-certified libraries, which are the focus of this study, revealed that these libraries have received certification under a range of versions, including v2.0, v2.2, v2009, v4.0, and v4.1, as well as their subversions. Upon analyzing the sustainability principles of these certification versions, it becomes apparent that the principles differ across versions. With each version updated, the principles are further developed, and new evaluation criteria are introduced. These updates seek to enhance the understanding of sustainability in building design, improve standards, and align them with the current norms.

The assessment included 35 libraries that have achieved LEED platinum certification, evaluating their performance across "Sustainable Sites," "Water Efficiency," "Energy and Atmosphere," "Materials and Resources," "Indoor Environmental Quality," "Innovation," "Regional Priority Credits," "Integrative Process Credits," and "Location and Transportation" principles. These evaluations encompassed various LEED versions, including v2.0-LEED ID+C: Commercial Interiors, v2.2-LEED BD+C: New Construction, v2009-LEED BD+C: New Construction, v2009-LEED BD+C: Schools, v2009-LEED ID+C: Commercial Interiors, v2009-LEED O+M: Existing Buildings, v4-LEED O+M: Schools, and v4.1-LEED ID+C: Commercial Interior. The sustainability scores obtained in these assessments were calculated and the average scores were tabulated (Table 11).

From Table 11, it is evident that among the seven libraries assessed under the v2.0-LEED ID+C: Commercial Interiors and v2.2-LEED BD+C: New Construction versions, the "Innovation" principle achieved the highest success rate of 97%, while the lowest success rate of 51% was observed in the "Materials and Resources" principle. For the 24 libraries evaluated under the v2009-LEED BD+C: New Construction, v2009-LEED BD+C: Schools, and v2009-LEED ID+C: Commercial Interiors versions, the highest success rate was 89% in the "Regional Priority Credits" principle, and the lowest was 45% in the "Materials and Resources" principle. Among the 3 libraries assessed under the v2009-LEED O+M: Existing Buildings and v4-LEED O+M versions, the highest success rate was 100% in the "Regional Priority Credits" principle, while the lowest was 25% in the "Integrative Process Credits" principle. The single library evaluated under the v4.1-LEED ID+C: Commercial Interior version achieved a 100% success rate in the "Water Efficiency," "Innovation," and "Regional Priority Credits" principles, while the lowest rate was 10% in the "Location and Transportation" principle. Overall, the analysis of the table reveals that the sustainability principles with the highest success rates are "Regional Priority Credits," "Innovation," and "Water Efficiency," each achieving a 100% success rate. The "Location and Transportation" principle showed the lowest average success rate (Table 10).

Table 10. Average Rates of Sustainability Principles by Certification Versions

Certification Version	Number of certified libraries	Sustainability Principles	Rate
v2.0-LEED ID+C: Commercial Interiors v2.2-LEED BD+C: New Construction	7	Sustainable Sites	%78
		Water Efficiency	%80
		Energy & Atmosphere	%89
		Materials & Resources	%51
		Indoor Environmental Quality	%79
		Innovation	%97
v2009-LEED BD+C: New Construction v2009-LEED BD+C: Schools v2009-LEED ID+C: Commercial Interiors	24	Sustainable Sites	%81
		Water Efficiency	%69
		Energy & Atmosphere	%84
		Materials & Resources	%45
		Indoor Environmental Quality	%67
		Innovation	%81
		Regional Priority Credits	%89
v2009-LEED O+M: Existing Buildings v4-LEED O+M: Schools	3	Sustainable Sites	%85
		Water Efficiency	%74
		Energy & Atmosphere	%71
		Materials & Resources	%54
		Indoor Environmental Quality	%64
		Innovation	%89
		Regional Priority Credits	%100
		Integrative Process Credits	%25
v4.1-LEED ID+C-: Commercial Interior	1	Water Efficiency	%100
		Energy & Atmosphere	%97
		Materials & Resources	%62
		Indoor Environmental Quality	%50
		Innovation	%100
		Regional Priority Credits	%100
		Location & Transportation	%10
		Integrative Process Credits	%50

Based on the findings of this analysis, it is clear that the criteria for LEED platinum-certified libraries vary depending on the certification version. In the updated versions, the "Sustainable Sites' principle consistently showed an increase in average scores. The "Energy and Atmosphere," "Water Efficiency," and "Regional Priority Credits" principles consistently achieved scores within the 70-100% range in all examined versions, suggesting that library structures are designed in line with these principles. However, "Materials and Resources" and "Indoor Environmental Quality generally receive scores within the 40-70% range, indicating deficiencies in areas such as construction materials, waste management, lighting, ventilation, and interior acoustic systems. Scores for the "Location and Transportation" and "Integrative Process Credit" principles fall within the 0-40% range. This implies that these libraries may have significant shortcomings in terms of accessibility, site selection, transportation options, parking facilities, and traffic.

The LEED Certification “Sustainable Sites” criterion includes aspects such as site selection, the use of brownfields, the use of alternative transportation methods, water use, heat conservation, and prevention of light pollution. Therefore, the selection of the area where the building will be constructed in accordance with its function, the reuse of rainwater through conversion, the selection of heat sources that do not have harmful effects on the environment, and the encouragement of environmentally friendly transportation methods gain importance. The "Energy and Atmosphere" criterion aims to minimize a building's energy efficiency and environmental impact. In this case, it is recommended to prioritize the use of renewable energy sources, the reduction of greenhouse gas emissions, and energy-efficient design and performance during both the planning and construction phases of buildings.

The "Water Efficiency" criterion similarly emphasizes the importance of minimizing water consumption for all purposes, both within and around the building, and incorporates credits for the application of innovative technologies aimed at water conservation. Consequently, water usage in buildings must be carefully monitored, and advancements in water-saving technologies should be integrated into the design of structures. A critical aspect to consider in this context is the landscape design of buildings. Upon examining LEED-certified examples, one can observe the implementation of innovative systems that capture and treat non-potable water sources, such as rainwater, for reuse in garden landscaping or on rooftops. The "Regional Priority Credit" criterion serves as a mechanism that grants additional points within the LEED scoring system. This criterion emphasizes the importance of alignment with local climate and environmental conditions, the adoption and implementation of local water, energy, and land management strategies, and addressing gaps in these areas. By focusing on regional priorities, projects can enhance their sustainability performance while responding effectively to the unique challenges and opportunities presented by their specific contexts. The "Materials and Resources" criterion emphasizes the importance of the storage and use of recyclable materials, the potential for the reuse of existing buildings, the management of waste generated during the construction phase, and the utilization of materials sourced from the area where the building is constructed. In this context, it is crucial to focus on designing buildings for flexibility, using materials that can be recycled or renewed, and incorporating certified wood into the construction. These considerations are vital for enhancing the sustainability and overall performance of the structures. The "Indoor Environmental Quality" criterion highlights the significance of factors such as natural and artificial lighting, acoustic comfort, thermal control, accessibility, and flexibility within the building. This criterion emphasizes the importance of user-controlled lighting, ventilation, and climate control systems, as well as minimizing environmental pollutants. By addressing these aspects, projects can enhance their scores under this criterion, ultimately contributing to a healthier and more comfortable indoor environment for occupants. The "Location and Transportation" criterion aims to plan a building's location in a way that contributes to sustainable development goals. This criterion focuses on reducing the project's environmental impact while promoting transportation solutions and settlement strategies that enhance users' quality of life. Consequently, effective site selection, along with the facilitation of alternative transportation methods that encourage the use of public transit, cycling, and walking, plays a critical role in highlighting the buildings under this criterion.

The "Integrative Process Credit" criterion is designed to foster a multidisciplinary approach in the pursuit of sustainability objectives within projects. This credit encourages collaboration among project teams across diverse areas of expertise throughout the design, construction, and operational phases of the building lifecycle. The primary aim is to promote the efficient utilization of energy, water, and other resources while embracing a holistic framework for sustainability. In this regard, it is imperative to enhance the engagement of various disciplines in the project, conduct comprehensive analyses of water consumption and energy efficiency, and focus on the intricacies of building systems. These elements are critical for significantly enhancing a structure's performance in meeting the stipulated criteria.

When designing a library, it is crucial to prioritize the sustainability and well-being of users, as outlined by the LEED criteria. These criteria aim to minimize the environmental impact while improving the overall quality of the space. By considering the LEED criteria from the initial design phase, libraries can ensure the implementation of sustainable practices, encompassing areas, such as energy efficiency, material selection, indoor air quality, water conservation, and waste management. This approach not only creates a healthy and comfortable environment for library users, but also plays a significant role in conserving natural resources.

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This article complies with the national and international research and publication ethics.

Ethics Committee approval was not required for the study.

Author Contribution and Conflict of Interest Declaration Information

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A Bio-Cultural Architectural Approach for the Sustainability of Mediterranean Coasts

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1. Introduction

Since prehistoric times, people have established settlements in fertile areas such as coastal regions. With the development of communal living and urban systems, trade and transportation activities have concentrated in coastal areas. Tekeli (1976) defined coastal areas as transition zones between the sea and land. Coastal regions may be subjected to environmental degradation due to activities such as transportation, trade, tourism, settlement and these areas should be protected through various regulations. Many scholars indicate that regions have become more developed residential areas with population growth, which negatively affects ecosystems (Cortinovis et al., 2019; Yin et al., 2016). Protecting coastal areas through regulations can create physically and mentally beneficial living spaces (DEFRA, 2011).

Keleş (2015) noted that resources in coastal areas in Türkiye have been destroyed due to accelerated urbanization and increased construction since the 1970s. As of 1990, coastal areas in Türkiye were defined by the Coastal Law No. 3621, but international legislation has addressed coastal areas more comprehensively (Söylemez et al., 2018). International regulations by entities the UN and the European Union have developed various strategies for the protection of coastal regions. It is estimated that 40% of the world's population lives in areas close to the coast (UNEP, 2024).

The Brundtland Report “Our Common Future” was published by WCED in 1987 and defined sustainable development as a method of development that meets the needs of the present without compromising the ability of future generations to meet their own needs. The UN's Sustainable Development Goals 2030, indicate 17 goals including 169 targets and they all have the common aim of enabling a better, healthier and safer world. Reducing poverty and hunger within the scope of sustainable development; health, education, accessibility to clean water; the aim is to make ties and human settlements inclusive, safe, resilient and sustainable. In terms of architecture, Goal 11 recommends that cities be built sustainably, together with human life, cultural, biological elements and built environment. In this process cities have a big role and as Brown (2009) states cities must be meaningfully and functionally sustainable in all aspects. This means that they should be planned not only to meet the needs of the current population but also to ensure that future generations can meet their needs. In this context, cities should aim to protect natural, biological, cultural and social heritage. Protecting natural heritage involves the sustainable management of ecosystems and biodiversity, while preserving human life and cultural heritage ensures the sustainability of historical and cultural values as well as social and economic structures. Cities can support environmentally and socially sustainable development and adopt holistic and integrated approaches to achieve these goals.

Bio-cultural approaches emphasize the role of humans as creative actors shaping everyday life (Davidson-Hunt, 2006). These approaches explain how people influence and shape their environments through cultural values and practices. In this context, bio-cultural perspectives highlight the importance of local knowledge and practices, which are critical for both human and environmental sustainability.

Cities should be designed holistically, considering all dimensions of sustainability. A sustainable environment and living conditions must be ensured in coastal areas. Sustainability can be achieved in architectural projects in coastal settlements where identity and life are integrated through design principles and material choices. According to Putra et al. (2023) emphasizes the importance of coasts in terms of their richness in terms of biodiversity, geographical and cultural elements in spatial planning, economy, ecosystem and equality in life within the scope of a holistic sustainable urban development.

In this context, the aim of this study is to develop a sustainable architectural and urban design proposal with a biocultural and holistic approach to support the biological and cultural identities of the small towns and cities Mediterranean coasts. The study consists of five sections beginning with an introduction summarizing the importance of coastal areas for sustainable development goals. The second and the third sections explain the place and importance of biocultural approaches in sustainable urban development studies and a brief of coastal areas in the context of sustainability respectively. The fourth section the proposed biocultural design project that had been developed for two small towns: (1) Numana from Marche Region in Italy, (2) Kumla from Marmara Region in Türkiye, as case areas. The study concludes with recommendations derived from the proposal development process aimed at achieving sustainable urban development in coastal cities.

2. Sustainable Architecture and Bio-Cultural Approaches

The concept of sustainability encompasses a wide range of processes from the global to the local level. The word "sustainable" is derived from the Latin "subtenir," meaning to support or protect from below (Muscoe, 1995). Defined by the United Nations Development Commission in 1987, sustainability refers to the capacity to meet today's needs without compromising the ability of future generations to meet their own needs, integrating ecological, economic and social components (WCED, 1987). Ruckelshaus (1989) describes sustainability as the doctrine that economic growth and development will be achieved through mutual interaction within the broadest boundaries of ecology and maintained over time. Continuous growth, improvements in welfare levels and shared concerns about the world's natural resources are all addressed within the concept of sustainability (McDonough, 1992).

Sustainability is the ability of a society, ecosystem or any ongoing system to function indefinitely without depleting essential resources (Gilman, 1992). According to Tekeli (2001), the principle of sustainability is based on an ethical understanding that considers human-centered values while consciously using and developing environmental values with appropriate technologies without compromising human needs.

Sustainability involves the holistic preservation of nature, the biological environment, culture, the natural and built environment from the local to the global level. This preservation should be addressed within the context of environment, human beings and resources; encompassing economic, ecological and social dimensions. In the architectural context, sustainability includes a multi-dimensional approach involving local to global planning, resource conservation, material consumption, application and use.

The concept of sustainability, including the protection and development of the environment. After having been discussed firstly by the United Nations at the Stockholm Conference in 1972 various organizations and reports have focused on the goals, scope and implementation methods of the concepts of sustainability and sustainable development. The most notable among these are; 1976 Habitat I Summit, 1987 Brundtland Report (Our Common Future), 1992 UN Conference on Environment and Development in Rio de Janeiro with Agenda 21, 1996 Habitat II Summit in İstanbul with Local Agenda 21, 1997 Rio +5 Summit, 2002 Johannesburg Summit (Rio+10) and the UN Sustainable Development Goals 2030 (SDGs).

As an interdisciplinary and multi-dimensional concept, sustainability has been updated in terms of scope and conceptuality parallel to the evolving human activities over time. Consequently, many concepts have emerged such as sustainable development, ecological sustainability, social sustainability, economic sustainability, sustainable architecture, livability, resilience, biodiversity, eco-culture, ecological design and biocultural architecture; all of which encompass biological, ecological, cultural and architectural activities. Callicott & Mumford (1997), the concept of ecological sustainability is defined as the conservation that connects what the ecosystem offers with human needs.

In its ecological dimension, sustainability means living in harmony with the natural environment as much as possible and in the architectural context, it means designing in a way that ensures seamless integration with the natural environment in which the biosphere is situated (Utkutuğ, 2011). Ecological sustainability strategies encompass several critical measures. These include safeguarding the fundamental needs, products and services for both current and future generations by addressing social needs such as local employment, fair trade and the environmental characteristics of raw materials. Additionally, they aim to enhance the consumption and renewal capacity of natural resources by promoting the use of renewable resources. Improving product efficiency through reuse, recycling and waste management is also emphasized. Furthermore, these strategies focus on limiting the use of non-renewable resources and reducing waste production, alongside protecting energy resources and biodiversity (Morelli, 2011).

Biocultural architecture based on ecological sustainability, as highlighted by Hanspach, Jamila Haider & Oteros-Rozas et al. (2020), requires biocultural approaches that incorporate a majority of worldviews on the interaction of humans, nature and culture; in addition to the sustainability dimension. While sustainability science acknowledges the close connection between humans and their environment within a complex and adaptive system (Folke, 2006), biocultural approaches recognize cultural diversity and focus on understanding the interrelationships between humans and nature. This approach provides a valuable framework (Maffi, 2005). Biocultural approaches, which first emerged in anthropology and then spread to other fields, offer ways to simultaneously represent, interpret and shape the human and cultural dimensions of complex social-ecological systems (Merçon et al., 2019). Adopting a social-ecological system perspective, biocultural approaches are defined as the diversity of biological, cultural and linguistic life, which are interconnected and possibly co-evolved within a complex system of socio-ecological adaptation (Maffi, 2007). The Convention on Biological Diversity (CBD, 1992) recommends respecting, protecting and sustaining the knowledge, practices and innovations of indigenous and local communities regarding the sustainable use of biological resources. Biocultural architecture emphasizes the vital role of integrating diverse cultural perspectives and ecological practices to enhance the sustainability of social-ecological systems.

3. The Mediterranean Coastal Zone and Sustainability

Coastal areas are significant urban spaces where land and water intersect. Coastal cities are regions where water is shaped according to physical conditions, creating a natural formation. Water is utilized as a resource, contributing to the city through functions such as trade or transportation and there is a mutual interaction between water and the city. These cities establish a relationship with the outside world and have a distinct impact on the city's perception by contributing to its silhouette. Additionally, they are a significant factor and influence in the formation of coastal culture (Erkök, 2002). According to Timmerman & White (1997), coasts act as the interface between water and the city. Due to their water and land components, the concept of coastal cities is bipolar and is limited to the last point where the coastal ecosystem extends inland. Furthermore, Konvitz (1997) states that coastal areas, regarded as the most critical factor in forming new urban structures, have the potential to alter cityscapes through developments focused on functional, cultural, social and economic relations. Today, construction activities in coastal areas are highly intense, leading to the destruction of regional characteristics from cultural, ecological and biological perspectives.

Ecological approaches should be designed in accordance with the principles of sensitive land use within the framework of the human-nature relationship and applied to environmental values through natural and social processes (Markhzoumi & Pungetti, 1999). On the other hand, the sustainability of the built environment encompasses not only energy efficiency, water usage and waste control but also represents abstract and tangible heritage data or indicators that must be understood and experienced contextually (Díaz López et al., 2019; Guzmán, Roders & Colenbrander, 2017; Daoudi et al., 2019). In this context, sustainability in coastal areas should be addressed multi-dimensionally with ecological and cultural dimensions and biocultural approaches. When considering that coastal settlements are not only physical areas where land and water intersect but also cultural heritage sites where a culture of living near and with water has developed, this necessity becomes clear. Shepherd & Burian (2003) put stress on this necessity explaining the crucial role of protecting the uniqueness and fragility of the natural coastal environment, as well as preserving the character of existing settlements in the growth process of coastal settlements.

As ecological balance deteriorates, environmental pressures related to the continuity of natural ecosystems, biological environments and resource sustainability increase. Ecosystems and their processes are directly and indirectly affected. Indirect effects include changes on a global scale due to shifts in population density, economic activities, socio-political factors, cultural influences and technological changes. According to Reid et al. (2005), direct effects include those that lead to negative changes in biodiversity and climate.

Blue-green development involves the use of natural systems in the region to structure the future. It includes the composition of blue, green and grey networks for the continuity of human settlements in the structuring of urban spaces (Bacchin et al., 2014). As Yücel Gier et al. (2019) state, due to structural degradation and increasing pollution, people have become alienated from their environment and lost their sense of belonging in coasts which have an inseparable bond with their surroundings. To be able to prevent this, within the framework of innovative and integrated urban practices, ecological, economic and cultural networks should be developed that aim to develop the Mediterranean perspective in the basic parameters of blue-green development by preparing a memory for ecosystems in the sensitive land-sea interface. In this sense, blue-green growth, which is widespread throughout the Mediterranean region, should be implemented with sustainable materials within the framework of integrated coastal design, environmentally friendly planning and innovative approaches with interrelated projects that connect marine networks with other thematic networks. If in the formation of coastal areas, sea-land relations as well as coast and city are provided with a physical plan and governance framework in principle, the right goals can be achieved in the joint development of coastal areas and in meeting the quality of life and democratic demands of the city.

The Mediterranean climate, building typology, local materials, culture and community lifestyle have distinct regional characteristics. Mediterranean cities have specific characteristic features with their natural-built environments and are connected by urban-coastal relations through corridors, walkways and squares with a holistic design approach (Sala, Alcamo & Ceccherini Nelli, 2020). Mediterranean life includes certain habits stemming from geography, routine activities in daily life and culture. When examined from the three different dimensions of sustainability, these cities possess a particular identity in terms of social traditions and culture. Previously more sustainable, Mediterranean coastal regions have become unable to provide sustainable living with the rise of technology and population growth. In this context, projects that can solve local problems should be carried out on the Mediterranean coasts, including sustainable and biocultural approaches that establish the relationships between society, material, living, settlement and built environment. In this study, an architectural and urban design proposal for Mediterranean coast towns is presented. This proposal is developed with a biocultural approach and considering sustainable architecture criteria. In the following section the project proposed for two coastal towns as cases is presented.

The Mediterranean Sea surrounded by 22 countries located in Europe, Africa and Asia; also connects the Atlantic Ocean with the Indian Ocean (Figure 1). With these characteristics, the Mediterranean Sea is subject to heavy maritime traffic and is also significantly impacted by tourism due to hosting many countries with natural beauties and connecting different cultures. This situation leads to urbanization problems in countries bordering the Mediterranean, particularly in coastal settlements, due to rapid population growth. As a result, the unique characteristics of these settlements are increasingly disrupted.

Figure 1. Mediterranean Coastline and Countries (Graphic maps, 2010)

In this study, two similar samples located in the Mediterranean coastal region are selected as cases, Numana in Marche Region-Italy, Kumla in Marmara Region-Türkiye (Figure 2).

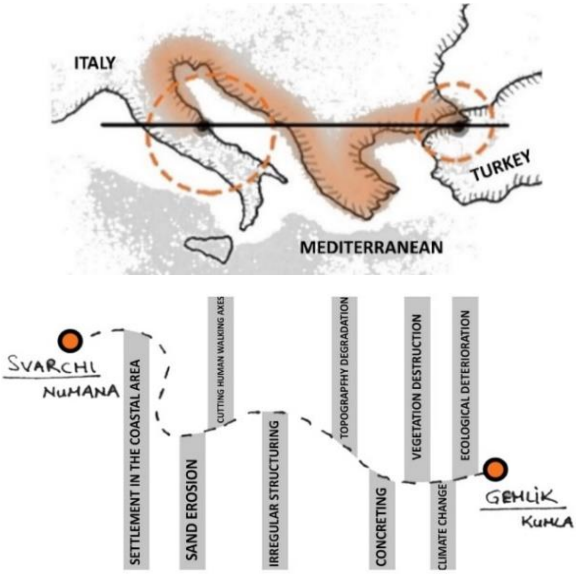

Figure 2. Numana and Kumla on the Mediterranean Coast and Their Major Problems

These two towns were selected for this study due to several compelling reasons: their location on the Mediterranean coast within an olive grove region, their positioning on a mountain slope, the excessive construction activities in their coastal areas and the resultant destruction of the natural ecosystem in these coastal zones. Both towns have comparable populations (approximately 100,000) and settlement areas, the influence of Mediterranean culture is evident in their daily life (Figure 3).

(a)

(b)

Figure 3. a. Numana Case Study (Napolitano, 2019) **b.** Kumla Case Study (Gemlik Municipality, 2018)

Solutions for ecological sustainability and environmental problems have been proposed through a bio-cultural architectural approach. The method of the study involves literature and archival reviews with analysis of the two towns. The design process of the proposal developed for the coastal areas of two towns has been supported by bio-cultural architectural approach. While developing proposals to address the identified problems, the UNEP's 2006 report on "Priority Environmental Issues in the Mediterranean Region" was utilized. This project has been designed in line with the 2030 Sustainable Development Goals, specifically considering Goal 11 Sustainable Cities and Communities, Goal 13

Climate Action, Goal 14 Life Below Water and Goal 15 Life on Land. Figure 4, summarizes the theoretical framework of the proposal.

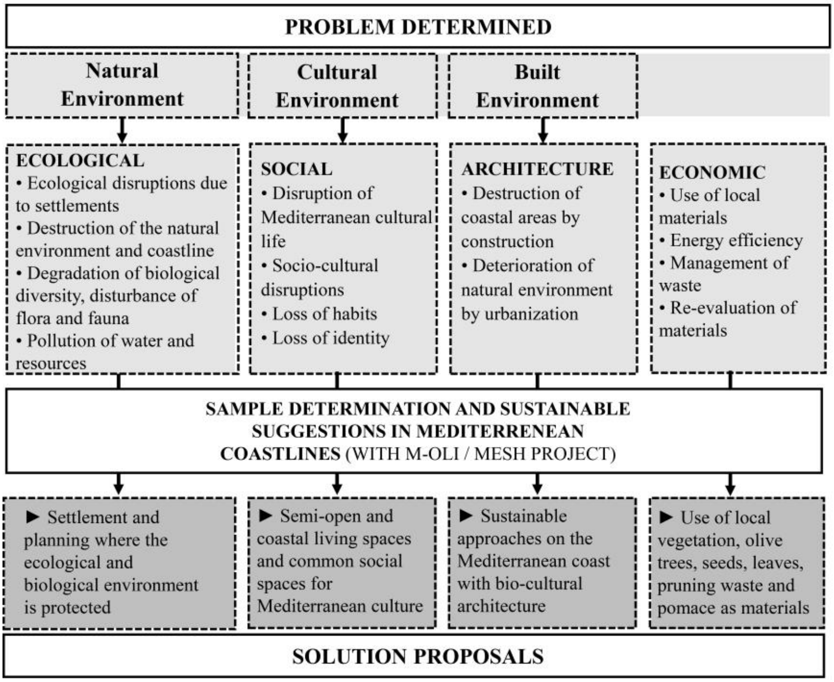

Figure 4. Theoretical Framework

4. M-Oli / Mesh Project

Determination of the Problems

Deteriorations observed along the Mediterranean coasts have been documented in various reports Priority Environmental Problems of the Mediterranean Region, Mediterranean Strategy for Sustainable Development-MSSD, Sustainable Development in the Mediterranean-SDSN, Sustainable Development Goals 2030 are some of them. According to the "Priority Environmental Problems of the Mediterranean Region" report (UNEP, 2006), environmental issues in this region are attributed to both land-based and marine-based anthropogenic activities, which result in significant environmental degradation. These issues pose a substantial threat to the Mediterranean coasts and can potentially be mitigated through sustainable development and design practices. Urbanization throughout the Mediterranean basin contributes to a range of environmental challenges, including the generation of waste. Historically, there has been significant deterioration of the natural interface between sea, beach and built environment in coastal areas, characterized by overbuilding with the degradation of biological - ecological systems. These deteriorations along the Mediterranean coast are illustrated in Figure 5.

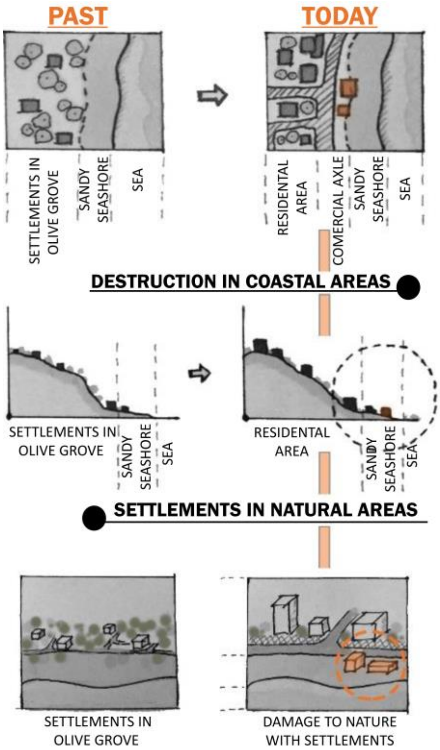

Figure 5. Deteriorations on the Mediterranean Coast

Figure 6 shows the identified issues in both Numana and Kumla. They include the destruction of natural olive groves, the intersection of beach areas with settlements of the coastline such as concrete-coast-beach, sea-beach-settlement area interactions and in the elements of coastal regulations-settlements-beach relationships.

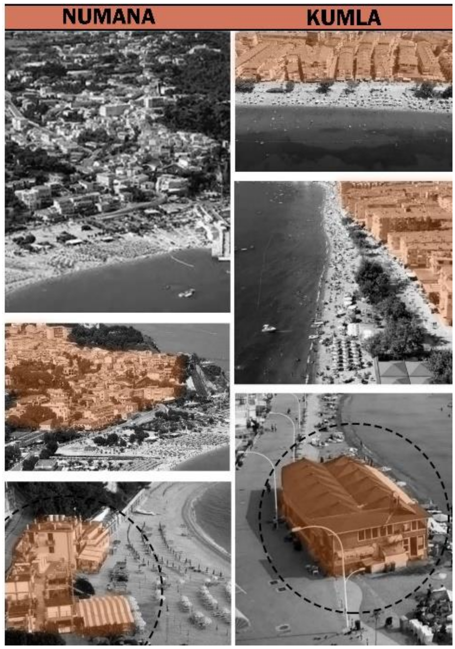

Figure 6. Numana and Kumla Settlements Problems

The intersection of pedestrian and vehicular roads with buildings has led to the obliteration of natural axes in sandy and green areas. The prevalence of intensive construction has significantly altered topography and natural elevation, resulting in considerable environmental damage. The built environment has disrupted natural features, thereby severing the connection between humans and their surroundings. If these issues in coastal settlements are not addressed, they are likely to cause irreversible ecological disturbances. These problems are commonly observed in the small coastal towns of the Mediterranean region, where environmental degradation, construction and urban development adversely affect the natural environment. Specific issues include settlement construction, water pollution, sea level rise, climate change, coastal retreat due to water extraction, pollution and damage caused by urban infrastructure, traffic, transportation, sand erosion, inadequate design of human-nature interfaces, destruction of olive groves and forested areas, irregular construction practices, topographical modifications, destruction of flora, fauna and biodiversity. These challenges can only be effectively mitigated through the implementation of sustainable solutions and a biocultural architecture approach.

Development of the Design Proposal

Humans and nature have a reciprocal relationship. Humans create a space for themselves within nature to live, but as they develop new urban environments, they often begin to feel alienated from their surroundings due to the deterioration of these spaces. During the construction process, as built environments transform and interact with people, individuals can become estranged from the spaces they create. Considering the similarity between tree rings and human fingerprints (Figure 7), it becomes evident that humans and nature form an inseparable whole.

Figure 7. Similarity of Tree Stump and Human Fingerprint

The preservation of natural resources and the creation of a productive future are secured through the relationship between resource use, waste materials and architectural production. Therefore, built environments and urban spaces should be created by integrating these criteria into architectural design. The development of the design proposal is based on these thoughts. The proposal includes three main modules. The planning of these three main modules within the framework and their different interconnected combinations positioned on road and passage networks, involves the use of materials produced from olive waste. For this reason the name of the project is M(editerranean)-Oli/Mesh. It consists of a main axis parallel to the coastline and secondary axes perpendicular to it, used to gather people. At the intersections of these perpendicular axes, all units designed to meet social and functional needs are located and resolved with modules. This flexible design approach allows for adaptation and transformation over time. The construction proposal, which aims to protect the natural environment through a network of walkways developed to address identified coastal issues is shown in Figure 8.

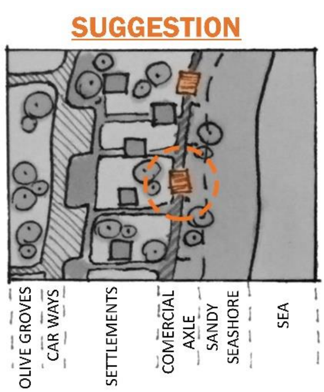

Figure 8. Architectural Approach Proposal on The Mediterranean Coast

Three distinct modules are proposed within the scope of the M-Oli / Mesh project. These modules can be combined in various configurations. They are designed to be easily assembled and disassembled on natural topography without causing harm to the environment. This flexibility allows communities to create spaces tailored to their specific needs through different combinations. The modules are constructed from bamboo reed-like components and panels, shells or cage systems made from olive waste. They are arranged along curves on natural axes, extending from residential areas to the coast, with dimensions adjustable according to their intended use and function. These units can serve various functions based on different needs. Additionally, the modules act as transitional elements, strategically positioned along roads and paths, as well as at intersections, to connect different axes (Figure 9).

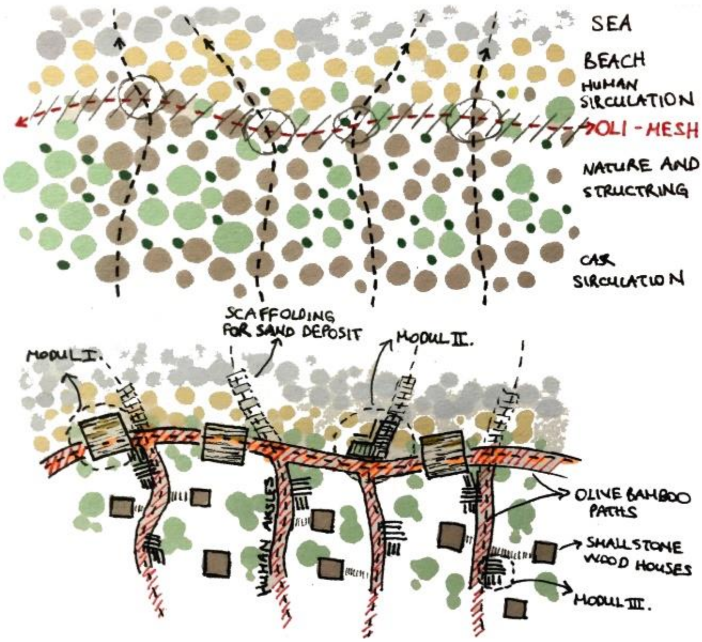

Figure 9. M-Oli / Mesh Project Planning Proposal

Module I. serves multiple functional purposes, including as a socialization area, recreational space, seating unit and transitional element (Figure 10). This unit is designed with adaptability in mind, allowing it to be transformed according to specific needs. It can be repurposed for various functions, such as a commercial unit, sales department, cafe or library. To enhance its versatility, a shell structure composed of olive bamboo and shading panels can be integrated to provide shelter and mitigate exposure to sunlight. Additionally, the natural pathways and roads within the settlement can be accommodated by suspending these shells, ensuring minimal disruption to the existing topography.

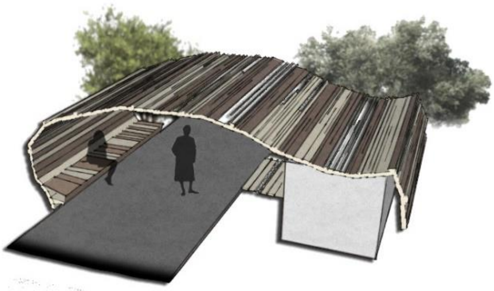

Figure 10. M-Oli / Mesh Project Module I.

Module II. can be strategically positioned along the constructed roadways and pathways, as shown Figure 11. This module is designed with flexibility in mind, allowing it to be integrated with Module I to serve multiple functions. Constructed from olive rod elements, Module II functions as a frame system that can be adapted for various uses. By incorporating panel elements, it can also serve as a shading device. The module can be employed in diverse capacities such as a seating area, a commercial unit or a recreational space. This versatility ensures that it not only maintains the continuity of road axes but also integrates essential community functions into the area. It addresses the identified issue of discontinuity between the beach-coastal zone and human-commercial interactions by aligning with the coastline and the pedestrian pathways originating from the settlement.

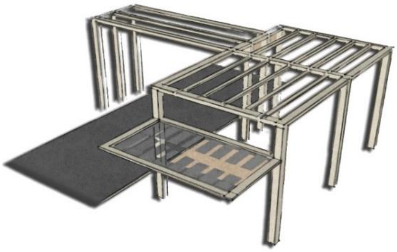

Figure 11. M-Oli / Mesh Project Module II.

Module I. + II. can be combined in various configurations to suit different needs (Figure 12). This approach is particularly effective at intersections, along pathway edges or where coastal and residential zones converge. By integrating shading elements from both modules, spaces are created that support residential living and recreational activities. These multifunctional areas enhance both practical community needs and social interaction.

Figure 12. M-Oli / Mesh Project Module I.+ Module II.

Module III addresses issues at the coastal and sandy areas interface (Figure 13) by recommending architectural interventions to improve pedestrian pathways in this area. It suggests obstructing these pathways with buildings and increasing development density within the coastal region. The proposal includes extending pedestrian axes into the coastal-sandy area to create a pier structure, which integrates pedestrian pathways with the beach and helps mitigate sand erosion. For sandy substrates, the design features a gradual descent to the beach using the natural slope, providing both access and seating. Additionally, the architectural shell offers shaded areas and promotes social interaction along the pedestrian pathways.

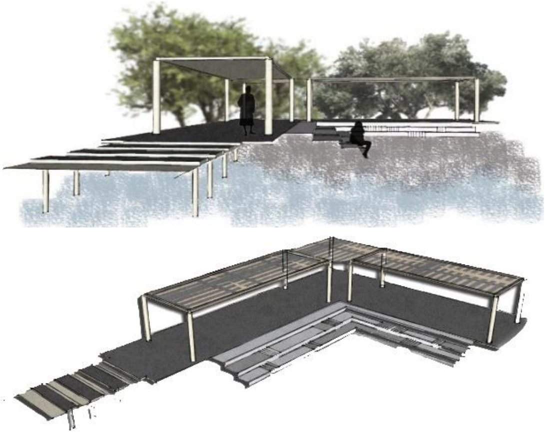

Figure 13. M-Oli / Mesh Project Module III.

The modules developed within the scope of the project will be placed along the coastline without disturbing the natural environment and will create a walking axis. Places where residents can socialize and experience the natural environment can be created. A simulation of the placement of project modules on Kumla beach is shown in Figure 14 below.

Figure 14. M-Oli / Mesh Project Modules to be Displayed at Kumla

Historically, coastal areas have served as pivotal centers for trade, facilitating the establishment of early settlements and linking cities with external regions. As a result, growing populations have often concentrated in these coastal zones. Over time, such areas have experienced significant challenges, including environmental degradation, pollution and increased urban density. Addressing these issues necessitates an approach grounded in sustainable biocultural architectural design. The adverse effects of construction activities are particularly pronounced along the Mediterranean coast. In response to these challenges, the M-Oli / Mesh project has been conceived. This initiative aims to tackle architectural and environmental concerns on the Mediterranean coast thereby creating a network-like structure that integrates sustainable practices into coastal development by building materials from olive waste products.

Material Selection: Waste Olive Products

Local architectural examples have been integrated in a highly appropriate manner with the knowledge accumulated over the years and the specific data of the region. This integration illustrates that even before concepts like sustainability were articulated, ancient societies were striving to ensure continuity within nature while creating artificial environments. Architectural characteristics vary by region in terms of materials used, plan types, functions of spaces, priorities of use and settlement patterns. These differences are rooted in the instinct to harmonize with nature, strengthen local identity and thereby enhance human comfort and health. Today, efforts are being made to create structures sustainable by reinterpreting materials (Güleryüz & Dostoğlu, 2011). Material selection in architecture is critically important for sustainability. Jones (2008) proposes three strategies in this context: reducing, which aims to minimize the use of materials and resources; reusing, which involves the reuse of products with minimal energy consumption; and recycling, which entails repurposing waste materials. Within the scope of this project, suggestions have been developed, such as reusing used olive products, transforming them into new products by creating plates, producing insulation materials through chemical recycling processes, reducing transportation and costs by using local materials. In this way, the use of building elements made from locally sourced materials significantly contributes to sustainability.

The M-Oli / Mesh project aims to provide economic and ecological benefits to the environment and society by utilizing waste materials such as olive branches, leaves, seeds and olive pomace (Figure 15) sourced from local olive groves. The abundant olive raw material in the region can be transformed and used as building material. This approach supports environmental sustainability and contributes to the local economy.

Figure 15. Olive Trees and it's Products

Using parts of olive trees, branches and leaves obtained during the pruning season, panel and stick elements called olive-bamboo are produced. These elements can be utilized in the production of modules in urban and coastal areas within temperate Mediterranean climate regions. In a project supported by Balıkesir University and TÜBİTAK (Balcıkoca, 2019), building materials were developed from olive waste. In this context, a polymeric composite product was created from olive pits. According to AnadOlive (2020-2021) "Impact Report" 30 million tons of waste is produced globally each year as a result of olive and olive product production activities. Türkiye covers 8% of this waste. By utilizing these olive trees, an insulation material capable of blocking water, sound, radiation, toxic gases and bad odors has been developed. This material is recommended for use within the scope of the M-Oli / Mesh project. Additionally, the waste resulting from olive cultivation and olive oil production is processed into pomace blocks. These blocks are proposed as an alternative to fossil fuels such as coal and wood for use in Mediterranean coastal regions. Pomace blocks have five times the calorific value of coal and wood derivatives, and they produce less ash, making them an environmentally friendly fuel.

5. Conclusion and Suggestions

Contemporary urban areas, particularly along the Mediterranean coast, face multifaceted challenges including rapid population growth, dense construction, inadequate transportation infrastructure, traffic congestion, environmental pollution and extensive concretization. These issues exacerbate environmental degradation and ecological damage, notably in coastal regions, leading to uninhabitable conditions due to sand erosion, water scarcity, pollution, climate change and the deterioration of natural habitats. Additionally, these challenges contribute to a growing sense of disconnection among individuals from their built environment, diminishing their sense of belonging.

Addressing these challenges requires a comprehensive approach to sustainable development that integrates ecological, social and economic dimensions. The study underscores the necessity for solutions grounded in sustainable development principles to mitigate the destruction of olive groves, coastal areas and forests, as well as the degradation of the built environment. Coastal areas must be designed with a focus on sustainability, ensuring environmental compatibility while preserving local identities with the social and cultural life of communities.

The M-Oli / Mesh project presents a sustainable construction and design framework by proposing the integration of coastal towns into a cohesive network to mitigate environmental and ecological degradation. This project advocates for the use of modular components that can be adapted to various regional contexts, emphasizing the utilization of recycled materials from olive trees such as branches, seeds and leaves which offers both environmental and economic advantages. In the context of sustainability and biocultural architectural approaches, it is suggested to construct structures by reducing the destruction of the environment, to establish a natural connection as a network between sandy areas and settlement, to create social spaces where culture can be shared, to reuse olive waste and to solve the ecological, social and economic dimensions of the degradation in the natural and cultural environment. In the next step of this study, prototypes of the proposed modules can be developed, followed by an on-site pilot application study. Determining how the proposed solutions are received, adopted and utilized by the local population, as well as measuring their satisfaction and expectations, is crucial for ensuring the success and sustainability of the applications.

Urban and architectural designs and built environment regulations in Mediterranean coastal areas often result in ecological and social detriment. Therefore urban planning, architectural design and construction in these regions should adopt a holistic perspective of sustainability, ensuring development that harmonizes with local ecosystems while preserving unique characteristics and fostering sustainable living conditions. Comprehensive sustainability principles should guide the design of urban spaces, integrating ecological, social and economic aspects along with bio-cultural approaches. Such strategies will support the preservation of biological and cultural diversity in coastal areas and ensure its transmission to future generations.

Acknowledgements and Information Note

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 Declaration Information

All authors contributed equally to the article.

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Afforestation and Reforestation (AR) Project Design Stages for Carbon Storage, Carbon Calculation Methods and Estimation

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1. Introduction

In the history of humanity, especially since the last 30 years, the pressure and intervention of human beings on natural resources has gradually increased. Especially as a result of urbanization, industrialization, technological and digital developments, economic growth-oriented production and consumption activities have gradually increased and diversified, bringing multifaceted problems and negativities. In this context, human beings have exploited, changed, shaped and destroyed nature as a unilateral commodity in line with their own needs and demands. In fact, rent-seeking approaches in the pursuit of "maximum profit" in economic production and consumption relations and the realization of investments that are not compatible with natural (ecological) systems constitute the basis of the problems (Gül & Kurdoğlu, 2021; Gül & Akten, 2022; Gül et al., 2023).

Human beings, who have damaged nature by intervening in the physical dimension until today, have been working to change the content, genetics, magnetics and frequency of the natural system, especially in recent years, and although it is not yet clear what the effects will be on nature and human life, it is thought that it will bring serious vital problems (Gül et al., 2021; Gül & Kurdoğlu, 2021).

It is accepted that the main cause of the climate change and its negative impacts, which is dictated as a global problem today, is the result of the disruption of the carbon cycle, in particular of greenhouse gases released into the atmosphere as a result of multifaceted and excessive human production and consumption activities.

It is possible to say that sustainability, the balance between meeting the needs of humankind today while ensuring that future generations can meet their own needs, is at the center of the conflict between ecology and economy (Gül & Akten, 2022; Gül et al., 2023).

For a sustainable life on a global scale and to mitigate the negative consequences of climate change and for the adaptation process, it is a priority to put forward nature-based solutions in ecological discourse and action. In fact, the basic approach is to prevent and/or reduce greenhouse gas emissions into the atmosphere and to protect and/or increase greenhouse gas sinks (forests, oceans, lakes, etc.).

The underlying Kyoto Protocol Mechanisms, and in particular Article 5/1 of the “Paris Climate Agreement”: “Parties shall, as appropriate, take action to protect and enhance greenhouse gas sinks and reserves, including forests.”, while Article 5/2 states: “incentives for reducing emissions from deforestation and forest degradation, the role of conservation, sustainable management of forests and strengthening forest carbon stocks” (UNFCC, 2015).

In the “Sustainable Carbon Cycle” statement adopted by the EU in 2021 within the scope of the “Green Deal”, it was stated that it is critical to produce ecosystem-based solutions to offset carbon emissions and increase carbon sequestration, and it was recommended to promote “carbon agriculture” and related industrial solutions. In this context, trees and forests, in particular, are one of the most important strategic actions as their vital multifaceted services and contributions are becoming increasingly important (Gül et al., 2009).

Greenhouse gas emissions/sequestration caused by anthropogenic impacts can be calculated in units of CO_2; therefore, the impact of these impacts on the environment is presented as a “carbon footprint” (Akten & Akyol, 2018). In order to reduce the carbon footprint and/or maximize carbon sequestration, afforestation of private or public areas and the calculation of a certain carbon sequestration on a national basis and the establishment of a carbon standard have become a priority in order to achieve the global net zero emission target coming from the Paris Agreement.

Project preparation, design, carbon calculation methods and estimation will play an important role in the carbon market for carbon sequestration and storage, ecosystem services production, carbon crediting and certification of voluntary carbon sequestration afforestation and reforestation projects.

In this study, the importance and processes of voluntary carbon sequestration afforestation and reforestation projects, carbon calculation methods and estimation are discussed and discussed, and suggestions are made under the conditions of our country.

2. Material and Method

The relationship between climate change and the carbon cycle, which is becoming increasingly important today, the importance of carbon sequestration and storage, carbon certification and carbon calculation methods for reducing carbon emissions are presented based on literature data. In this context, a general framework that can be a guide on the importance, processes and contents of voluntary carbon sequestration afforestation and reforestation projects has been determined and suggestions for implementation in our country have been made.

3. Findings and Discussion

3.1. Carbon Cycle and Climate Change

The carbon cycle is a vital cycle that underpins all organic compounds in the universe, from the smallest vitamin molecule to the long polymer chains of proteins and DNA. Carbon also has a multifaceted impact on the physical environment and climate. In the carbon cycle, carbon is mostly in the form of gas, carbon dioxide, but can also be found in compounds such as methane and carbon monoxide. In the form of carbon dioxide, carbon is released as a residue during the combustion of fossil fuels and the respiration of organisms. Carbon dioxide can be removed from the atmosphere through photosynthesis in plants, which convert carbon into a solid form (sugars) that can be stored or returned to the air during respiration. It can also be removed from the atmosphere by being absorbed by water, where it becomes available to aquatic plants for photosynthesis and can be used to form compounds such as calcium carbonate (chalk) or returned to the atmosphere when the water is heated (Kennesaw State University, 2024).

The total amount of carbon atoms available on Earth is constant due to the law of thermodynamics. The total carbon follows a certain process, moving from one sink to another in short- and long-term cycles. This holistic cycle is called the “carbon cycle”. In other words, it is the movement of carbon from a carbon source to a carbon store and back again (Pamukçu Albers et al., 2018). For example, every year 120 giga¬tonnes of carbon passes from the atmosphere to plants through photosynthesis, but in the same year, just as much carbon enters the atmosphere again from plants and animals through decay and respiration. In other words, carbon is in constant motion between sinks.

In a carbon cycle that has reached equilibrium, the rate at which carbon is removed from storage is equal to the amount taken up from the atmosphere (Kennesaw State University, 2024).

It is also known that climate change is caused by a "carbon cycle" problem. Climate change is caused by the imbalance in the cycles between these sinks due to human intervention, with some sinks becoming carbon deficient while others are becoming carbon surplus. The best-known example of this is the release of carbon from these sinks into the atmosphere when humans burn fossil fuels found beneath the earth and oceans for energy production. Some of this carbon "swelling" in the atmosphere is absorbed by the oceans, another carbon sink, and the increased carbon in the oceans creates acidification problems. Another example of human disruption of the carbon cycle is deforestation. Here again, carbon in the form of trees/woody plants on the ground is released into the atmosphere through burning and/or reduction of forest areas.

As a result, the balance between carbon emissions from ecosystems to the atmosphere and carbon sequestration in ecosystems directly or indirectly affects climate change in a positive or negative way. Therefore, climate change is considered as the most important environmental problem of our time.

Climate change can be perceived as a result of the use and management of natural resources, production and consumption activities since it is caused by human impact. It is also tried to be managed with different methods and approaches. Moreover, although the methods of struggle are quite clear, it is seen as the main reason that managers and decision makers and multinational companies are not willing enough to change the way of life dependent on fossil fuels and do not envision solutions compatible with nature.

According to the Synthesis Report (SYR) published by the Intergovernmental Panel on Climate Change (IPCC, 2023), anthropogenic emissions are damaging the planet due to dependence on fossil fuels, but a resilient and livable future is still possible with rapid action on renewable energy sources and other mitigation actions, and that climate impacts are hitting much harder than previously known, even at lower temperatures, and that it is vital that governments follow the 1.5°C target in the Paris Agreement. Global surface temperature rose 1.1°C above industrial temperatures between 2011 and 2020. In the report; 48% CO_2 reduction in 2030, 65% CO_2 reduction in 2035, 80% CO_2 reduction in 2040, 99% CO_2 reduction in 2050 were envisaged (IPCC, 2023).

3.2. The Carbon Market

It is envisaged that market mechanisms can play an important role in reducing greenhouse gases, particularly carbon. In this framework, a carbon market that will operate according to market rules and a price for carbon dioxide subject to trade is seen as an important instrument in reducing emissions. Mandatory and voluntary project and market-based flexibility mechanisms are envisaged in the Kyoto Protocol to achieve greenhouse gas reduction and limitation targets and to reduce the cost of emission reduction practices (Ülgen & Günes, 2016).

I. Mandatory mechanisms: (Quotas, carbon capture and storage - mandatory market)

a. Project-based mechanisms

- Clean Development Mechanism (CDM)

- Joint Execution Mechanism (JEM)

b. Market-based mechanism

- Emissions Trading System (ETS)

II. Voluntary Mechanisms: (Voluntary reductions are not covered by countries' mandatory mitigation obligations. There is no restriction on market entry).

a. Project-based

- Voluntary Carbon Market

b. Market Based!

- Chicago Climate Exchange (CCX)

The carbon market is a market created to facilitate the voluntary reduction and offsetting of greenhouse gas emissions resulting from the activities of individuals, institutions and organizations, private companies, non-governmental organizations and events. Carbon market consists of the following features (Ecer, 2010);

- It can be project and market based.

- There is no limitation for participation.

- It is a process similar to the flexibility mechanisms implemented compulsorily under the Kyoto Protocol.

- In the Voluntary Carbon Market, the targets of institutions and organizations can be developed independently from the policies and targets set by the state.

- Organizations that want to be carbon neutral can calculate the greenhouse gases they create (emitted to the atmosphere) within the framework of their activities (by measuring their carbon footprint) and reduce these emissions and

They can purchase carbon credits generated by emission reduction projects in order to offset their emissions.

- There are many standards in the market regarding the standards and trading rules of carbon credits generated in voluntary carbon reduction processes (VER - Voluntary or Verified Emission Reduction).

In order to reduce greenhouse gas emissions on a global scale, and to capture and store them in the atmosphere, the legal infrastructure of a market for the production of clean and renewable energy on a project basis and the trade of emission credits earned accordingly is being established.

The basis of the "Voluntary Carbon Market", which is gaining importance in our country, is based on the principle of "carbon dioxide offsetting", which is defined as neutralizing the greenhouse gas emitted from one location by preventing the same amount of greenhouse gas to be emitted from another location or by sequestering/sequestration of the same amount of greenhouse gas in the atmosphere. In this way, projects can trade the emission reduction certificates they produce in this market. However, the Voluntary Carbon Market operates separately from the Kyoto Protocol (Ülgen & Güneş, 2016).

In this context, the implementation, implementation and management of voluntary carbon market-based afforestation or planting projects is considered an important approach. Achieving success in carbon pricing is only possible with an effective, holistic and stable policy, planning and governance organization of the market system (Gül & Akten, 2022).

3.3. The Importance and Relation of Forests and Trees in terms of Carbon

In order to reduce the imbalance in the carbon cycle, the main goal is to greatly reduce the rate of burning fossil fuels, i.e. carbon dioxide gas, or to remove carbon from the atmosphere or to increase the rate of carbon capture and storage. For this purpose, increasing the number and surface area of trees is accepted as the basic approach (Sedjo, 1989; Gül, 2024).

Trees and forests play a very important role in increasing carbon storage. Forests, which account for 92% of terrestrial biomass, store around 400 G tonnes of carbon. Trees take carbon from the atmosphere and store it in their own trunks, and then, if they are cut down, they continue to store it in the healthiest way by turning it into wood/wood, one of the most valuable products.

During photosynthesis, trees convert carbon dioxide and water into sugar molecules and oxygen through a series of oxidation and reduction reactions. The general equation for the photosynthetic process can be expressed as follows (Kennesaw State University, 2024).

$$6\ CO_2 + 6\ H_2O + \text{sunlight} \dashrightarrow C_6H_{12}O_6 + 6\ O_2$$

While some of this sugar is stored, most is used by the tree for other purposes, such as energy and structure. For example, much of the sugar binds together to form cellulose, which provides the structure of the tree. Most of this sugar by mass comes from carbon. The fact that carbon has an atomic mass of 12, hydrogen an atomic mass of 1 and oxygen an atomic mass of 16 means that 72/180 = 40% of the mass of the sugar molecule comes from carbon. Taking into account the other types of molecules present in a tree (proteins, lipids, etc.), about 45% of the dry mass of a tree (excluding water) is composed of carbon. In other words, a 100-kilogram log of fully dried wood contains about 45 kilograms of stored carbon. Each kilogram of dried wood stores .45 kilograms of carbon, while removing more than one kilogram of carbon dioxide from the atmosphere. This is because each carbon dioxide molecule contains two oxygen atoms. Using the data above, this means that each carbon dioxide molecule has an atomic mass of 12 + 2(16) = 44, of which only 12 are bound to carbon. So for every one carbon atom stored in a tree, 44 atomic mass units of carbon dioxide are removed from the atmosphere. This means that each kilogram of dried wood corresponds to (Kennesaw State University, 2024).

(1 kg dried wood) x (.45 kg C/1 kg dried wood) x (44 amu CO_2/12 AMU C) = 1,65 kg CO_2

According to this formula, the amount of CO_2 bound in 1 kilogram of wood mass is calculated as 1,65 kg.

Such a large amount is the most important justification for using trees to remove carbon from the atmosphere. However, it should be noted that this equation also works in the opposite direction. When a tree is burned or allowed to decompose completely, the carbon in the tree is returned to the atmosphere as carbon dioxide.

The issue of the carbon storage capacity of forest ecosystems is of particular interest to researchers and policy makers because, on a global scale, forests contain 80-90% of the carbon in terrestrial plants and 30-

40% of the carbon in soils (Harvey, 2000; Landsberg & Gower, 1997). Increasing forested land (e.g. by creating plantation forests) is proposed as an effective measure to increase C storage, reduce carbon dioxide (CO_2) concentrations in the atmosphere and thus contribute to preventing global warming (Kurz et al., 1996).

The greatest potential of forest ecosystems for above-ground biomass and C storage are usually tree biomass components (roots, branches and leaves). Dead and standing dry trees also contribute significantly to above- and below-ground biomass (e.g. Whittaker & Woodwell, 1968; Long & Turner, 1975).

3.4. Proposal for Stages and Processes of Afforestation Projects for Carbon Sinks

In order to reclaim idle, eroded or degraded lands and create new carbon sinks for the development of climate change adaptation and mitigation strategies, it is considered an important approach to carry out and implement Voluntary Carbon Market-based afforestation or planting projects by considering the appropriate use of lands with a holistic approach.

Voluntary carbon-based projects can obtain carbon certificates just like renewable energy and energy saving projects. Carbon certificates are certificates given to projects that reduce carbon emissions or sequester carbon from the atmosphere within the scope of carbon trade, one of the tools developed to combat climate change. The 'carbon certificate' obtained with each ton of carbon dioxide equivalent sequestered in afforestation areas is offered for sale in international voluntary carbon markets at the current market value. However, there are no certified afforestation projects in Türkiye yet.

Afforestation and plantation projects to be carried out for carbon sequestration and storage require the preparation and sustainable management in accordance with the purpose and technique. Carbon sink area afforestation project design processes and stages to be carried out in our country can be suggested as follows;

a. General Information on the Project Owner

b. Project Type, Objectives and Content

c. Project Area General Inventory Information

d. Design Application Project and Technical Information

e. Project Implementation and Management Strategies

f. Project Carbon Accounting and Pricing

g. Project Technical Report

h. Carbon Crediting and Certification Processes

a. General Information of the Project Owner: Project Title, Name and surname of the Project Owner, ID No, Contact Information, ID No, Project partners and Sponsors, Status of rights and responsibilities of the project owner, Certificates for the project owner, carbon crediting utilization status, existence and information on other carbon projects, Compliance of the project with national regulations and laws, Approval status of relevant institutions and organizations for the project area, etc.

b. Project Type, Objectives and Content: Project title, Project responsible and team, Carbon farm project type, Carbon farm project type, Project start and end date, Estimated life of the project (years), Project crediting start date and end date, Objectives of the project, Sustainable principles of the project, Activities to be implemented in the project, Ecological services and contributions to be provided by the project, Technological tools and measures to be used in the project, Level of stakeholder participation in the project, Database and methodological approach for design implementation projects, Project summary, Additional documents etc.

c. Project Area General Information and Inventory: Site location (Province, District, Neighborhood/Village, Island/Parcel), Geographical coordinates, Site layout plan, Site size (ha), Type of land, Zoning status, Ownership status, Climatic data (Precipitation Average (mm), Temperature average (^{o}C), Temperature average (^{o}C), Temperature min (^{o}C), Temperature max (^{o}C), Humidity average rate), Elevation (m) (max, min, average), Slope status (%) (max, min, average), Available water sources, Major Soil Group (MSG) type, Land Use Capability Class (LUC), Combination of Soil Characteristics (CSC), Depth (cm), Soil Organic Carbon (SOC) (Avg. (t/ha) and total (tC)), Land Productivity Dynamics (LPD) (%), Dynamic Erosion Model and Monitoring System (Demis) (%), CORINE 2018 (%), Land Degradation Prevention Action Recommendations (%) (LDP), Intervention hierarchy (ha), Water resources, Land survey studies, etc.

d. Design Implementation Project, Concept and Technical Information: Identification of the project team and stakeholders, Objectives of the project concept, Design strategies and principles, Design implementation project preparation process (Layout Sheet" (1/500 scale), 'Concept (Proposal) Sheet', 'Landscape Design Implementation Preliminary Project (1/500 or 1/200 or 1/100 scales according to the size of the land), Landscape design implementation final project' (1/500 or 1/200 or 1/100 scales according to the size of the land), Approval process of the final project, Detail sheet (Scaled detail drawings of all plant and structural materials, reinforcement, plant pattern etc. used in the project), Plant species and characteristics used in the project, Plant pattern types, plant numbers and total areas (%) envisaged in the design, Technical specifications, Bill of quantities and Total implementation cost etc.

e. Project Implementation and Management Strategies: Defining Project Implementation processes and prioritization. Implementation management strategy, Establishment of activity work-time schedule in the management process, Sustainable Land Management (SLM) approach (Intervention Hierarchy), Structural and cultural measures, risks/threats/measures, Identification of monitoring and supervision methods and techniques for implementation and management, Methods of carbon measurement, recording, storage, collection and reporting, Defining institutional structure, responsibilities and staff competencies for management and monitoring activities, Feedback methods, Sampling approach for carbon accounting (sample area size, number, frequency) etc.

f. Project Carbon Accounting and Pricing: Tools and analysis techniques used in the method, emission/sequestration calculations, estimated values of carbon sequestration by plant species in the first year of installation, estimated annual carbon sequestration by plant species during the crediting period, leakages and plans and studies to reduce/prevent them, projections for buying and selling within the scope of the carbon exchange, etc.

g. Project Technical Report: All the information mentioned above is prepared as a file and made ready for approval by attaching the Project sheets and other documents.

3.5. Carbon Accounting Methods for Afforestation or Reforestation Projects in Voluntary Carbon Market

In voluntary carbon market-based afforestation or reforestation projects within the scope of climate change mitigation, carbon sequestration and storage amounts are generally calculated before the project is started (Ex-Ante) and the calculated amounts are evaluated for the future of the project and used in the carbon certification process (Serengil, 2018).

In the calculation of carbon sequestration and storage as a result of land use and change within the scope of the plant pattern envisaged in the project, the determination of carbon sequestration in biomass, dead wood, dead cover, soil and harvested wood products carbon pools, their spatial distribution and changes, and land use and management effects are taken into consideration.

The rate of carbon sequestration and storage in trees can vary depending on factors such as tree species, growth form and characteristics, biomass, growing conditions (climate, soil, aspect, elevation, etc.) and age. For this reason, it is of great importance to calculate and estimate the biomass of the tree by local measurements for each tree species.

Accurate estimates of tree leaf area and leaf mass are critical for assessing evapotranspiration, atmospheric deposition, biogenic volatile organic emissions, light interception and other ecosystem processes, particularly carbon accounting. Equations or ratios are often used to estimate leaf area or leaf biomass from easily measurable tree traits such as stem diameter (dbh) or sapwood cross-sectional area (Waring et al., 1982).

Various approaches are used to calculate and quantify carbon storage in vegetation. Carbon accounting methods are mostly scientifically standardized. This allows globally comparable accounting and trade supported in internationally unified and standardized systems (IPCC 2000, 2003; McPherson & Kendall, 2014; Nowak et al., 2013).

Accurate estimates of tree leaf area and leaf mass are critical for assessing evapotranspiration, atmospheric deposition, biogenic volatile organic emissions, light interception and other ecosystem processes, particularly carbon accounting. Equations or ratios are often used to estimate leaf area or leaf biomass from easily measurable tree characteristics such as stem diameter (dbh) or sapwood cross-sectional area. For this purpose, measurements of stem diameter in each tree and allometric and biomass equations are used to calculate the amount of carbon stored (Nowak et al., 1996; Pearson et al., 2007; Stoffberg et al., 2004; Stoffberg & Van Rooyen, 2012).

*Carbon stocks can be calculated in two way*s (VCS, 2015):

a. Periodic direct measurement of sampling by combining assumptions or models. In this method, carbon sequestration is calculated from the forest biomass measured in the sampled area.

b. Projection of appropriate increment models and/or carbon models for project area inventory, etc. with minimum periodic direct monitoring.

The basic principles that should be considered in the carbon calculation and reporting process in voluntary carbon market-based afforestation and reforestation projects can be summarized as follows (Serengil, 2018).

- Scientificity: Scientifically accepted and scientific methods, formulas and parameters should be used in carbon calculations.
- Permenance: Calculation and reporting processes should be designed to be carried out continuously.
- Transparency: It refers to the fact that the data, methods and assumptions used in the inventory are clearly stated. In this way, calculations should be repeatable, controllable and reviewable.
- Accuracy: Calculations should produce results in a way to reach the most accurate results possible. The results should be neither above nor below the actual values, but as close to the actual values as possible. The methods specified in IPCC guidelines should be used, national data with high reliability should be included as much as possible and the level of uncertainty in the results should be kept low.
- Consistency: Calculations should be made using the same methods for all years of the inventory. If different methods are used for some years or periods, they should be transparently explained in terms of consistency. At the national level, it is especially important to ensure that the base year and the final year are calculated using the same methodology. In project-based calculations, the same or similar methodologies should be used when comparing the situation with and without projects.

- Comparability: Inventory calculation results should be comparable with other similar ones. In national inventories, they should be comparable with inventories of other countries; in project-based inventories, they should be comparable with similar projects.
- Completeness: It means taking into account all of the greenhouse gases, sources and pools both geographically and in the calculation.

The factors to be taken into consideration in voluntary carbon market-based afforestation and reforestation projects and carbon calculations can be summarized as follows;

- Pre-feasibility and inventory (especially field survey) studies are important for carbon calculations in the project area. The carbon stock at the time the project started (t0), the increases that will occur in carbon stocks, the calculation of the carbon stock difference in the project and non-project scenarios, or the calculation of carbon stock changes resulting from human impact and natural causes definitely require a terrestrial inventory study.
- Inventory and field survey (natural, environmental, social and economic, etc.) should be made comprehensively and realistically.
- In carbon projects, measurements to be made in different time periods, time plan and silvicultural methods to be applied should be defined.
- In projects, the first inventory measurement data (t0 time) are the basic values for the estimated values to be made about how much carbon gain will be provided in the project implementation and management process. Therefore, the biomass and carbon

calculations to be made require the first measurements to be made sensitively and accurately in the sampling areas to be selected to represent the area.

- In the plant pattern design appropriate to the purpose of the carbon-focused project, a combination of trees, shrubs and herbaceous plants should be aimed, especially tree-based ones.
- Applicable and internationally accepted carbon accounting methods should be used in the project.
- The project management process (maintenance, repair, renewal, control and monitoring, reporting, security, workforce, budget, etc.) should be organized in a sustainable manner.
- All possible risks/threats and possible leakages should be determined during the implementation and management process.

In our country, the coefficients determined by Asan et al., (2002) are used to determine the carbon storage capacities of sample areas. The volume amounts obtained from the measurements made in the sample areas were multiplied by the coefficients specially calculated for each tree species group in the forests of Türkiye to determine the carbon storage capacities of the sample areas. For this, the following coefficients are taken into account (Asan et al., 2002).

- Above Ground Biomass Amount (broad-leaved species) (AGBA)= Planted Trunk Volume x 0.640 x1.25
- Above Ground Biomass Amount (coniferous species) (AGBA)= Planted Trunk Volume x 0.473 x1.20
- Below Ground Biomass Amount (broad-leaved species) (BGBA)= Above Ground Biomass Amount x 0.15

• Below Ground Biomass Amount (coniferous species) (BGBA)= Above Ground Biomass Amount x 0.20

• Above Ground Dead and Live Cover Biomass Amount (AGDLCB)= (AGBA Total+ BGBA Total) x 0.40

• Total Above Ground and Under Ground General Biomass Amount (TGGB)= AGBA + BGBA + AGDLCB

• Carbon Amount in Total Biomass = TGBK x 0.45

• Carbon Amount in Forest Soil = (TGBK x 0.45) x 0.58

In International Panel on Climate Change-based methodologies, annual calculations of carbon emissions and sequestrations in afforestation project areas are divided into 3 subcategories (IPCC, 2006):

a. Calculation of carbon stocks in biomass (above and below ground biomass): Calculation of all living biomass above ground, including trunk, stump, branches, bark, seeds and leaves. In the total living biomass of living roots, fine roots with a diameter of less than 2 mm (recommended) are excluded, as they are generally not empirically distinguishable from soil organic matter or litter.

b. Calculation of carbon stocks in dead organic matter (dead wood and litter): Includes all non-living woody biomass not found in the litter, standing, on the ground or in the soil. Dead wood includes wood lying on the surface, dead roots and (for example) logs with a diameter equal to or greater than 10 cm (for example). Includes all non-living biomass with a diameter of less than 10 cm (for example) in various states of decomposition on top of mineral or organic soil. This includes litter, fumic and humic layers. The specified living fine roots are included in the litter where they cannot be empirically distinguished from it.

c. Annual variation of soil carbon stocks; Includes organic carbon in mineral and organic soils (including peat) to a specified depth and is applied consistently. The specified diameter living fine roots are included in the soil organic matter where they cannot be empirically distinguished from it.

3.5.1. A Methodological Approach for Estimation of Carbon Stock from Living Biomass for Afforestation and Reforestation By CDM

This methodology developed by CDM is proposed to be used for estimating the carbon stock in living biomass for afforestation and reforestation of any land that does not fall into the wetland category.

The methodology limits the extent of soil degradation in the project to no more than 10 per cent when the Soil Organic Carbon (SOC) content is expected to be higher in the primary land use of the land than in the 'forestry' land use.

If the distribution of plant pattern biomass over the project area is not homogeneous, different strata can often be created according to the main plant species and their canopy cover and/or land use types to increase the precision of the biomass estimate.

The Stages of the Carbon Stock Estimation Methodology from Living Biomass for Afforestation and Reforestation can be summarized as follows; (Clean Development Mechanism. (CDM). 2015; Troy, 2019).

3.5.1.1. Calculation of Carbon Stocks in Biomass (Above and Below Ground Biomass):

a. Calculation of Aboveground Tree Biomass:

The simplest method (Level 1) to calculate aboveground biomass is to follow the default parameter values of the Intergovernmental Panel on Climate Change (IPCC) for Türkiye. According to this approach, the total assets and annual growth rate of broad-leaved/- tree species (leaved shrub trees, etc.) and coniferous trees are taken into account in the calculation of the planted tree trunk volume. According to the layered tree species (almond trees, lime trees, mahaleb-wild cherry trees, wild pear trees and acacia trees), the trunk volumes of trees living at the layer level are multiplied by the Carbon Fraction (CF) previously determined for Türkiye Forests by Asan (1995). First, the volume of each planted sapling is found and then the oven-dried weight is obtained and finally the result is converted to the aboveground biomass weight.

With the sampling method to be selected in the project area, the volume of each living tree in the sample area is measured. All measured values are averaged and determined (m^3). The average value obtained is multiplied by the total number of existing trees in the area and the total above-ground volume in the area is estimated in hectares.:

Volume calculation equation for each tree

$$V_t = \pi . DBHr^2 x\ BH \qquad (1)$$

In this formula;
V_t : Volume of the standing live tree trunk (m^3)

$DBHr^2$: Square diameter of the breast height of the living tree trunk (cm)
BH: Breast height of the standing live tree trunk / stem (m)
$\pi = 3,14$
BH=130 cm

$$\text{Vt (1 tree volume)} = \frac{cm^3}{1\,000\,000} = \ldots\ldots m^3$$

V_{abst} (average biomass of sample trees): $V_{n1}+V_{n2}+V_{n3}\ldots\ldots\ldots/ n = m^3$
TVm^3=Total of Number of trees/ha x $\mathbf{V}_{abst}$ = m^3 / total volume per hectare

Calculation Equation for Aboveground Biomass:

To calculate the above-ground biomass in the area (tonnes/ha), it is obtained by multiplying the average volume value according to the tree species (*broadleaf or coniferous trees*) per hectare, dried weight coefficient and carbon ratio. These coefficients are IPCC values converted according to the conditions in Türkiye.

$$\textbf{AGB ton/ha} = \textbf{TV}m^3\,\textbf{x DWx CF} \qquad (2)$$

In this formula;
ABG ton/ha: Aboveground biomass of a living tree (ton/ha)
Vm^3: Each living tree planted /total trunk / trunk volume (m^3)
DW: Oven Dried Weight (for broadleaf trees: 0.640) (for coniferous trees: 0.473)
Transforming Factors for Türkiye – IPCC values
CF Carbon Ratio: (For broadleaf trees: 1.25 and for coniferous trees: 1.20)

b. Calculation of Underground Biomass:

The amount of biomass (root) under the ground is also determined using general ratios for tree species groups. Underground biomass amounts are obtained by multiplying the aboveground biomass of species groups by 0.15 for leafy trees and 0.20 for conifers by the root ratios.

The calculation equation for underground biomass is;

UGBton /ha = AGBton/ha x CF (3)

In this formula;
UGBton/ha: Underground Biomass (Ton/Ha)
ABG: Aboveground Biomass (Ton/Ha)
FC Conversion Factor for root ratio factors: (0.15 for broadleaf trees and 0.20 for conifers) are IPCC Default parameters for Türkiye.

3.5.1.2. Calculation of Carbon Stocks in Above round Living and Dead Organic Matter (Dead Wood and Dead Cover)

The live biomass calculated above shows the total biomass of saplings with a breast height diameter of 7 cm and shrubs with a diameter of 4 cm and above in the project area. In this measurement step, the total biomass of the dead cover of trees, shrubs, branches, cones and leaf residues is calculated by multiplying the ratios determined according to the results of researchers in different countries of the world. This ratio is 40% for semi-arid latitudes where Türkiye is located.

Calculation equation for aboveground living and dead cover:

AGB live and dead cover = (AGBton/ha + UGBton/ha) x CF (4)

Here;

AGB live and dead cover: Live and dead cover aboveground biomass (tons / Ha)
AGB Aboveground Biomass (tons / Ha)
UGB Belowground Biomass (tons / Ha)
CF Conversion Factor ratio: 0.4 – The ratio given for Türkiye in the semi-arid climate zone latitude – is the IPCC Default Value for Türkiye.

3.5.1.3. Calculating the Amount of CARBON in Total Biomass

The total amount of biomass is calculated by adding the results of aboveground biomass, belowground biomass and aboveground biomass (tons / ha) and then the total amount is multiplied by the Carbon Conversion Factor Ratio at the project sites. The carbon conversion factor ratio for Türkiye is given as the default value by the IPCC. Because Türkiye is located in the semi-arid mid-latitude agricultural region where agroforestry afforestation is carried out, the CF Default Value is 45% (Brown 1997; Asan 1999).

Calculation equation for carbon content in total biomass:

$$TBCA_{ton/ha} = TB\ (AGB+UGB+AGB_{\text{live and dead cover}}) \times CF \ldots \quad (5)$$

Where
TBCA ton/ha Total Biomass Carbon Content (ton / Ha)
TB Total Biomass (AGB + UGB + AGB live and dead cover) (ton / Ha)
CF Conversion Factor Ratio IPCC Default Value for Türkiye (0.45)

3.5.1.4. Calculation of the Amount of Carbon Held in the Soil

The amount of carbon held in the soil is multiplied by the average rates of carbon in the total biomass given by geographical regions. Since Türkiye is located in the semiarid agricultural climate zone with mid-latitude climate conditions, the rate for Türkiye is 58% (Brown, 1997, Asan, 1999).

The calculation equation for the amount of carbon held in the soil is:

$$SC_{ton/ha} = TBCA_{ton/ha} \times CF \qquad (6)$$

In this formula:
SC ton / ha the amount of carbon held in the soil (ton / ha)
TBCA The amount of carbon in the total biomass (ton / ha)
CF The carbon conversion factor rate given to Türkiye (0.58)

3.5.1.5. Calculation of annual volumetric carbon increase depending on the growth characteristics and speed of trees in the project area:

The volume of growth of trees planted in agroforestry – afforestation project sites is very similar to the growth rate of trees in natural forests. The cross growth of a tree is called "growth". In some conditions, this assumption is greater and faster than forest trees due to the factors of sunlight intake, irrigation systems, and natural fertilization.

For example, the lime trees planned in the project grow at a moderate rate of 13 to 24 inches per year from the seedling stage. Acacia trees are fast-growing. Depending on the species, they can grow anywhere from 1 to 3 feet per year. Keeping these facts in mind, the conversion factor for the annual period is considered to be approximately 5%. The volume of growth of the annual carbon increase is repeated one by one for 30 years. Calculation equation:

TBC increment volume = TBCA X CF **(7)**

In this formula:

TBC increment volume Total biomass carbon increment volume (m^3)
TBCA Total Biomass Amount (AGB + UGB + AGB live and dead cover + SC) (tons/ha)
CF Conversion factor of annual increment volume (0.5)

3.5.1.6. Calculation of Total Carbon Dioxide Emission Stocks

Calculation of Carbon Dioxide Emission (tCO_2 e) equivalent (tons / ha) is done by multiplying the Grand Total of Total Aboveground Carbon, Total Belowground Carbon, Total Aboveground Living and Dead Cover and Total Biomass Growth Carbon by the Carbon Dioxide Molecular Weight (44/22) Conversion Factor. And then, soil carbon dioxide equivalent is added to the result. Finally, the Grand Total Carbon Dioxide Emission Stocks are obtained by multiplying the results by the number of project areas and multiplying the years of the crediting periods.

Calculation equation:

$$GTCO_2\ e\ y\text{-}1 = \Sigma\ (TAGBC + TUGBC + TAGBC\ l, d, c)\ x\ CF + TSC\ x\ TPA\ x\ T\ (t1 - t2)x\ Inc\ Ratio \quad (8)$$

In this formula;
$GTCO_2$ e: Total Carbon Dioxide Emissions (tCO_2 e y-1)
TAGBC: Total Aboveground Biomass Carbon (tons / ha)
TUGBC: Total Belowground Biomass Carbon (tons / ha)
TAGBC l,d,c :Total Aboveground Biomass Live and Dead Cover (tons / ha)
CF: Carbon Dioxide Molecular Weight Conversion Factor (44/12)
TSC Total Soil Carbon (tons / ha)
TPA Total Project Area
T (t1 - t2): Total Crediting Period Years

3.5.1.7. Carbon Leakage Approach and Management in the Project

In the afforestation project and carbon crediting process, possible risks and threats should be defined as 3 factors.

- In-area risks,

• Out-of-area risks

• Natural risks.

Necessary measures should be foreseen for these possible risks and threats. All activities/actions to be carried out in the proposed carbon storage afforestation project aim at sustainable management of multi-purpose land, obtaining multiple products per unit area, increasing and diversifying farming incomes, diversifying energy sources and technologies, reducing soil and water loss, combating erosion, improving soil quality, protecting biodiversity, evaluating plant residues as compost, etc. In short, the project should be carried out with special care to limit potential greenhouse gas emissions at every stage. For this purpose, land preparation, material supply, planting and sowing activities, maintenance, transportation, compost fertilizer supply, etc. expenditure items should be planned to be carried out at the lowest cost.

To this end, annual calculations should be made and documented in tabular form, with a transparent preliminary estimate of emissions (or, where appropriate, direct calculations of emission reductions) over the project period and expected leakage emissions and net GHG emission reductions over the crediting period of the project.

Net GHG Emission Reductions are calculated as follows:

$$\boldsymbol{EMy = BEy - PEy - LEy + \ldots} \qquad \textbf{(9)}$$

In this formula;

EMy = Net GHG Emission Reductions in year y (tCO2-e)
BEy = Base Emissions in year y (tCO_2-e)
PEy = Project Emissions in year y (tCO_2-e)
PLy = Project Leakage in year y (tCO_2-e).

3.5.1.8. Monitoring Plan

In afforestation projects for the purpose of creating carbon sink areas and in the carbon crediting process, the monitoring process should be carried out in two stages.

1) During the Project Preparation Process: All activities to be carried out during the project preparation process should be defined in detail within the work schedule in line with the methodological framework. In particular, after the project implementation, the holistic Monitoring Plan framework, methodology, parameters, criteria, measurement tools and equipment, recording and reporting, etc. are defined in accordance with the project purpose, all activities and methodology.

2) During the Plan Implementation and Management Process;

• Implementation and monitoring can be carried out by the relevant project managers within the scope of the Monitoring Plan envisaged in the project according to the work schedule.

• The monitoring plan implementation tools, including data management and quality assurance and quality control procedures, should ensure that the emission reductions achieved/resulting from the project activity can be reported and verified and documented in tables.

4. Conclusion and Suggestions

One of the most important approaches to developing climate change adaptation and mitigation strategies, carbon sequestration and combating soil erosion is afforestation and reforestation activities. In voluntary carbon-based afforestation projects, just like renewable energy and energy saving projects, a carbon certificate is obtained and the ‘carbon certificate' obtained with each ton of carbon dioxide equivalent sequestered in afforestation areas can be sold at the current market value in international Voluntary Carbon Markets. In this context, the project design and land management process will play a major role in both creating carbon sink areas and ensuring that carbon crediting and certification are sustainable, measurable, traceable, and that carbon emission trading can be processed in the form of a real market and in guaranteeing this process.

In voluntary carbon-based afforestation projects, carbon certification and crediting processes require the holistic handling and organization of all relevant processes such as the pre-feasibility of the project, design and approval of a suitable implementation project, its implementation, sustainable governance, measurement, calculation, evaluation, monitoring, reporting, auditing, approval of carbon sequestration and stock changes in the project area, development of institutional structure and capacity, and compliance with legislation.

The recommendations that need to be made in our country's conditions within the scope of calculating and monitoring carbon capture and storage in voluntary carbon capture afforestation and reforestation projects can be summarized as follows;

- National legislation regarding voluntary carbon sequestration afforestation project processes should be revised to be in line with international legislation.
- The official institution should assume authority and responsibility for processes such as project approval, supervision, and organization, and institutional structuring and organization should be provided. This

organization should be done by state institutions. Otherwise, if this task is given to private agencies, it may lead to monopolization and a rent-seeking system (Gül & Akten, 2022).

- The principles of transparency, reliability, consistency, comparability and integrity, which are emphasized by the IPCC guidelines (IPCC, 2003; IPCC, 2006), should be taken into account in carbon sequestration calculations prepared on the basis of voluntary carbon sequestration afforestation projects.
- Afforestation carbon calculation methods should use scientifically accepted and scientific methods, formulas and parameters. In particular, they should be compatible with international carbon calculation techniques.
- In the plant pattern design appropriate to the purpose of the carbon-focused project, it should be aimed to create a combination of tree-based trees + shrubs + herbaceous plants. In this context, agroforestry systems and carbon farming practices should be given priority.
- The rate of carbon capture and storage in trees may vary depending on factors such as tree species, growth form and characteristics, biomass, growing conditions (climate, soil, aspect, altitude, etc.) and age. Therefore, it is of great importance to calculate and estimate the biomass of the tree for each tree species using ground measurements.
- When determining the carbon storage capacities in the project area, biomass conversion coefficients should be determined for each tree or shrub species used and the amount of carbon in the biomass should be calculated accordingly.

- The lowest cost, minimum tillage, use of waste and residues in the field, water and soil protection, organic farming and practices that increase the amount of carbon in the soil, etc. should be targeted in the design and implementation of the project.
- The lands to be selected as project areas must be suitable in terms of ownership status, usage rights and zoning status, usage restrictions, protection status, legislation, actual status and the status of occupants. In particular, land ownership and rights status must be clearly defined in the project.
- Voluntary carbon sequestration afforestation projects should be implemented on privately owned lands, treasury lands, lands belonging to public legal entities (University lands, lands belonging to public legal entities such as Bar Associations, etc.), and lands belonging to local administrations (land belonging to village legal entities, lands belonging to municipalities).
- For voluntary carbon sequestration projects, treasury lands should be allocated primarily to local people and local cooperative enterprises.
- Project areas that will be subject to carbon certification must be at least 3 hectares in size.
- In afforestation projects for carbon sink purposes, a projection of at least 30 and at most 50 years should be targeted for the certification of carbon stock. It is an important feature for certification institutions that the harvested trees will not release the atmospheric carbon they hold for 30 or 60 years back into the atmosphere.
- The concept and plant pattern design of voluntary carbon sequestration projects should be compatible with the general

characteristics of the land and Sustainable Land Management (SLM) and Sustainable Forest Management (SFM) strategies (Erpul et al., 2023).

- Voluntary carbon sequestration projects should target not only carbon sequestration but also other additional benefits (soil and water protection, water production, product and income generation, compost fertilizer production, erosion prevention, biodiversity enhancement, environmental quality, social benefit and responsibility, etc.).
- Full and effective participation of relevant stakeholders, especially local people, should be ensured.
- Necessary precautions should be foreseen for existing and potential risks and threats during the project. In addition, protective measures should be taken.
- Insurance and damage compensation mechanisms should be established because voluntary carbon sequestration projects have a long administrative process.
- Measurement, evaluation and reporting (MRV) and auditing opportunities should be provided throughout the project.
- The IPCC (2006) guideline provides valid values that can be used in carbon calculations. In order to use local, regional and national values in calculations, it is of great importance that these data are calculated with model approaches and methods developed on a national basis through field observations and measurements. Therefore, updates should be made with scientific research on national and regional conditions and plant species.

- The project management process (maintenance, repair, renewal, control and monitoring, reporting, security, workforce, budget, etc.) should be organized in a sustainable manner,
- • The amount of carbon stored during the project process should be calculated and modeled using estimated artificial intelligence software.

Today, instead of the sustainable development approach that does not question the current neoliberal policies and profit-oriented production and consumption economic activities and prioritizes preserving the traditional economic development approach, there is a need for new green economy approaches that prioritize protecting nature and ecological solutions, while emphasizing fair, equal, ethical and social rights. Capital-oriented economic production and consumption activities that have lost their naturalness create damage and pressure on the natural environment. Interventions to nature without understanding the basic principles and laws of ecology both cause destruction and make people pay heavy prices in a later period. The upheaval of ecological and economic balances in the world necessitates that environmental, political, cultural and economic problems be addressed in an integrated and continuous manner that affects each other (Gül et al., 2023).

The new “low-carbon economy” or “green and circular economy” order that the current economic order has evolved into should be accepted as an ethical tool for the protection and sustainability of human health, natural ecosystems and the cultural environment, first and foremost. Carbon pricing should be organized in line with this basic goal (Gül, 2024).

In our country, the success of carbon capture and storage strategies will be possible with comprehensive laws and administrative decision processes that include and prioritize equality, justice, ethics, nature protection and ecological approaches in the processes of appropriate project design, implementation, multi-level governance, institutional organization, capacity, approval, reporting, control, monitoring, evaluation, participation, resource allocation, certification, etc.

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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 Declaration Information

All authors contributed equally to the article.

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The Contribution of Street Trees to Climate Resilient Cities in the Context of Ecosystem Services: The Case of Bahçelievler, Ankara

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1. Introduction

Climate change threatens the sustainability of ecosystems. It increases the frequency of excessive rainfall and scorching heat waves, lead the intensity of nature's destructiveness. As the intensity rises, the ecological balance enabling the sustainability of life on the planet becomes increasingly fragile (Eren, 2019). Sustainable urban planning plays a crucial role in mitigating the impacts of climate change, with street trees emerging as a key element in creating resilient cities.

As climate change accelerates, urban areas face increased threats from extreme weather events, heatwaves, and deteriorating air quality, necessitating innovative planning approaches that prioritize sustainability. Climate-resilient cities play an important role in reducing the impacts of climate change and enabling communities to adapt to these changes. Urban greenery, particularly street trees, offers multiple ecosystem services that contribute to climate resilience by improving air quality, reducing urban heat island effects, and managing stormwater runoff. Research highlights that street trees act as natural carbon sinks sequestering carbon dioxide and regulating temperatures through shading and evapotranspiration processes (Livesley et al., 2016). Furthermore, they provide social and psychological benefits by enhancing the aesthetic appeal of urban spaces and promoting well-being, which are critical components of sustainable, liveable cities. Sustainable urban planning that integrates street trees not only addresses immediate climate challenges but also fosters long-term resilience by enhancing biodiversity, improving local microclimates, and supporting urban infrastructure against environmental stressors (Gill et al., 2007). Such integration is increasingly seen as vital for cities aiming to balance urban growth with environmental sustainability, ensuring they can adapt to and withstand the multifaceted impacts of climate change.

The ecosystem approach to ensure sustainability is defined as a strategy for managing natural resources in a holistic manner that considers the balance of protection and use (Keleş, 2013). The assessment of ecosystem services and the ecosystem approach are closely related to the aim of ensuring the sustainable use and management of natural resources. By assessing ecosystem services, managers can gain a deeper understanding of the benefits an ecosystem may provide. This deeper understanding, in turn, supports developing and implementing holistic, adaptive, and sustainable management strategies inherent in the ecosystem approach. The ecosystem approach promotes the integrated management of land, water, and living resources to achieve sustainability (Yao et al., 2022; Gedikli, 2022).

In the same vein, Costanza et al. (1997) define ecosystem services as one that emphasizes the interdependence of human well-being and the health of ecosystems. Recognizing these services highlights the importance of conserving and managing ecosystems sustainably and contributing to livability. In other words, ecosystem services are the benefits that humans receive from ecosystems. These services are broadly categorized into four main types (Costanza et al., 1997):

Provisioning Services: These products are obtained from ecosystems, such as food, fresh water, timber, fiber, and genetic resources.

Regulating Services: These are the benefits of regulating ecosystem processes, such as climate regulation, disease control, water purification, and pollination.

Cultural Services: These include non-material benefits that people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences.

Supporting Services: These are the services that are necessary for the production of all other ecosystem services, such as soil formation, nutrient cycling, and primary production.

There are also benefits from ecosystems within urban areas. In their study, Bolund and Hunhammar (1999) defined seven different urban ecosystems: Street trees, lawns/parks, urban forests, cultivated areas, wetlands, lakes/seas, and streams.

Street trees play a vital role in enhancing the resilience of urban environments, particularly in the face of climate change. As cities grow and face increasing environmental challenges, the integration of natural elements such as trees becomes crucial for sustainable development. Street trees contribute to climate-resilient cities by providing a wide range of ecosystem services, including the regulation of urban temperatures, improvement of air quality, stormwater management, and the enhancement of biodiversity. These green infrastructures act as natural buffers, mitigating the effects of urban heat islands and reducing the energy demands of surrounding buildings. In addition, street trees enhance the aesthetic value of urban spaces, promoting mental well-being and fostering social cohesion. However, their role goes beyond environmental benefits; they are integral to urban planning strategies aimed at adapting to and mitigating climate-related risks.

This paper explores the multifaceted contributions of street trees to climate resilience in urban areas, with a focus on the ecosystem services they provide. By exploring their ecological, social, and economic impacts, we aim to demonstrate how urban Street trees can be a cornerstone of future city planning, enabling cities to become more adaptable and resilient in the face of climate change.

Street trees provide a wide range of benefits to people and the environment, from regulatory services to supporting services, from provisioning services to cultural services. Recognizing these services, the protection and management of street trees is critical to maintaining ecological balance and improving the quality of urban life. As the global urban population continues to rise, cities face increasing challenges related to climate change, including higher temperatures, extreme weather events, and deteriorating air quality. In this context, the concept of climate resilience—referring to the ability of urban areas to adapt and recover from climate-related disturbances—has gained significant attention in urban planning. A key component in building climate-resilient cities is the integration of nature-based solutions, particularly street trees, which provide a wide range of ecosystem services. These services, including carbon sequestration, air purification, temperature regulation, and stormwater management, are crucial in mitigating the adverse effects of climate change and improving the overall livability of cities.

Street trees offer critical ecosystem services that significantly enhance urban environmental quality and human well-being. These services include improving air quality by filtering pollutants such as particulate matter and nitrogen dioxide, thus improving urban residents' respiratory health. Additionally, street trees play a vital role in climate regulation through carbon sequestration, helping mitigate climate change's effects by absorbing carbon dioxide and releasing oxygen. Their presence reduces the urban heat island effect, lowering temperatures in city areas by providing shade and releasing moisture into the air through transpiration, enhancing thermal comfort for pedestrians. Furthermore, street trees help manage stormwater by reducing runoff, thus preventing flooding and reducing the burden on urban drainage systems. They also support biodiversity by providing habitats and food for urban wildlife, promoting a more balanced urban ecosystem (i-Tree, 2021).

Street trees offer environmental, social, and economic benefits in terms of ecosystem services for people. Many studies in the literature emphasize the benefits of street trees. However, these studies have generally evaluated street trees from an anthropocentric perspective. Street trees enable natural processes to interact and ensure the continuity of nature's functioning by creating a continuous canopy that forms a green network.

By supporting a diverse range of organisms, street trees help sustain urban ecosystems and enhance their resilience to environmental changes. Thus, when assessing the value of street trees, it is essential to consider their broader ecological significance beyond human-centered benefits, recognizing their role in fostering biodiversity and maintaining the integrity of urban ecosystems.

1.1. The Crucial Role of Street Trees in Combating and Adapting to Climate Change as Urban Guardians

Street trees are crucial in sustaining ecosystem services in urban areas and developing approaches to climate change adaptation. They provide many direct and indirect benefits for neighborhood residents and the city. Street trees reduce the adverse effects of climate change by strengthening the connection with nature. The canopy continuity provided by street trees creates connections between independent green areas and creates a green corridor. Thus, it allows the continuation of ecosystem services. The shade cover of street trees provides climatic comfort in hot weather and alleviates heat-related health problems (İnci & Görer Tamer, 2022).

Also, street trees play a significant role in climate change mitigation through various ecological processes that reduce greenhouse gases and adapt urban environments to changing climates. One of the primary ways street trees mitigate climate change is through carbon sequestration. Trees absorb carbon dioxide (CO2) from the atmosphere during photosynthesis, storing carbon in their biomass (stems, branches, leaves, and roots), reducing atmospheric CO2 levels. This long-term carbon storage is designed for extended periods, as trees act as natural carbon sinks. Street trees significantly contribute to carbon storage and sequestration, which is crucial for mitigating climate change. For instance, in Kyoto, Japan, street trees provide an annual value of $41.34 per tree for carbon storage and sequestration (Tan et al., 2021). Similarly, in Szeged, Hungary, urban trees have been evaluated for their capacity to sequester carbon, significantly impacting urban planning processes (Kiss et al., 2015).

Additionally, street trees help moderate urban temperatures provide cooling benefits, and reduce the effects of urban heat islands. Trees can significantly lower ambient temperatures by providing shade and releasing moisture through transpiration, decreasing the demand for air conditioning in nearby buildings. This reduced energy consumption translates to lower fossil fuel use and fewer carbon emissions from power plants. In Kyoto, Japan, the energy savings provided by street trees were valued at $1.67 per tree annually (Tan et al., 2021). In Germany, urban trees were found to reduce direct and thermal radiation by up to 58%, demonstrating their critical role in temperature regulation (Scholz et al., 2018). Similarly, in Shenyang, China, the total ecological benefit value of street trees was estimated at $163,965.62, with an additional combined thermal comfort benefit of $233,533.48, totaling $397,499.10 in one year (Sui et al., 2023).

Regarding air quality, street trees play a vital role by removing particulate matter and nitrogen dioxide pollutants. In Dalian, China, for example, street trees provide air quality improvement services valued at $381,088 annually (Wang et al., 2018). Likewise, street trees are instrumental in removing air pollutants in Berlin, Germany, highlighting their importance in urban ecosystem services (Döhren & Haase, 2019).

Street trees also enhance local climate resilience by improving stormwater management. Street trees mitigate stormwater runoff, reducing the risk of flooding in urban areas. Their root systems increase soil permeability, which helps absorb rainwater and reduces surface runoff by mitigating the risk of urban flooding during extreme weather events. This can prevent infrastructure damage and reduce the energy required for pumping and treating stormwater (Marando et al., 2019; Nowak, 2000). In Taipei, Taiwan, street trees contribute to runoff avoidance with an estimated economic value of $5.6 million (Cheng & Wei, 2020).

Street trees provide critical ecosystem services in urban environments, contributing to environmental sustainability, human health, and urban aesthetics. These trees are significant in carbon sequestration, air quality improvement, stormwater management, and temperature regulation, among other benefits.

Understanding and quantifying these services is essential for urban planning and policy-making to enhance cities' livability. So, the density of tree placement and street trees can be an essential tool for urban planners and designers in developing resilient and resourceful cities in an era of climatic change (Salmond et al., 2016).

The study emphasizes that urban trees serve as a critical defense system for climate-resilient settlements, highlighting the need for proactive steps to protect and develop existing trees. In Ankara's Bahçelievler District, street trees play a particularly important role in fostering climate-resilient urban environments. To successfully implement street afforestation plans, it is essential to establish a comprehensive mapped database of existing trees within cities. This database will provide the necessary foundation for effective management and expansion of urban greenery.

1.2. The Role of i-Tree Ecosystem Application in Estimating Ecosystem Service Values of Street Trees

Inventories are considered a critical tool in protecting and improving urban ecosystems. Understanding street trees' structural characteristics and ecosystem services allows city planners and managers to make more informed decisions. Street tree inventories are vital for the sustainability and improvement of urban environments. These studies provide the necessary data to optimize cities' ecosystem services and contribute to preserving long-term environmental benefits.

Tree inventory is a process that identifies and records the number, species, size, and health of trees within a given area. A tree inventory is vital for monitoring the health of ecosystems, sustainable management of natural resources, and combating climate change. In particular, the status of trees within cities is essential for planning and protecting green areas in urban planning and green space management. Such studies ensure that the services provided by street trees are comprehensively assessed and that these services are managed sustainably (Gedikli, 2022).

The prominent application in tree inventory is i-Tree. i-Tree is a set of tools and software packages for tree inventory creation and urban forest management. The i-Tree program allows for a holistic assessment of environmental, economic, and social benefits in tree inventory creation and management. For this reason, it is considered a critical tool in urban planning and environmental management. The ecosystem services of trees can be evaluated scientifically, and their benefits can be expressed in monetary terms. The created inventory is an essential source of information for municipalities, urban planners, and environmental managers, guiding them in decision-making processes and directing afforestation strategies. It provides input for scientific research and public awareness studies to examine the long-term effects of trees, combat climate change, and promote sustainable urban planning (Eren, 2021).

In Türkiye, open source access to tree information in urban areas is limited.

Some mobile or web-based applications have introduced trees. Some of these applications with different functions are “Doğa Kâşifi,” “Konuşan Ağaç, and “Anıt Ağaç” application. Local platforms focusing on a limited region and the inventory of monumental trees and trees worth protecting share them with a web page and smartphone application in a limited geographical area. The i-tree smart application can collect global inventory and calculate ecosystem service value (2021,06 16). The i-Tree Eco software was first used in Türkiye by Tuğluer & Gül (2018) in their study in Isparta.

Unlike other studies, this study is essential because it makes visible the contribution of a limited number of mature street trees to climate resilience at the neighborhood scale. In this study, street trees will be discussed, focusing on their roles within the urban ecosystem, and the regulatory ecosystem service values they provide in the context of adaptation to climate change.

Street trees growing on public sidewalks or roads provide continuity by creating a green and cool corridor within the city, connecting green areas. Street trees have countless environmental, social and economic benefits and are gradually lost because precautions are not taken. In particular, it is significant for mature and old street trees, which provide more benefits than newly planted young trees, to be protected by both local governments and neighborhood residents to prevent them from facing the danger of extinction. It emphasizes ensuring the sustainability of street trees for a nature-based climate adaptation strategy.

The i-Tree Ecosystem Analysis is a comprehensive suite of tools and software developed by the USDA Forest Service and its partners to assess and quantify the benefits provided by urban trees and forests. These tools help urban planners, foresters, researchers, and community groups understand and maximize the ecological, economic, and social services that trees offer in urban environments. Here is an overview of the i-Tree Ecosystem Analysis and its key components (Nowak et al., 2008).

Quantifying Ecosystem Services: i-Tree tools evaluate a range of ecosystem services trees provide, including carbon sequestration, air pollution removal, stormwater runoff reduction, energy savings, and biodiversity support. By quantifying these services, i-Tree helps demonstrate the tangible benefits urban trees provide to communities.

Economic Valuation: The analysis translates ecological benefits into economic terms, providing estimates of the monetary value of ecosystem services. This information is crucial for justifying investments in urban forestry and making informed management decisions.

Comprehensive Urban Forest Inventory: i-Tree tools facilitate the collection and analysis of data on tree species, size, health, and distribution. This inventory helps cities manage their urban forests effectively, identifying areas for improvement and strategic planting.

Scenario Modeling and Forecasting: i-Tree allows users to model different scenarios and predict the future impact of various management strategies. This capability aids in planning for climate change adaptation, pest outbreaks, and urban development pressures (Nowak, 2021).

Community Engagement and Education: i-Tree provides accessible tools to non-experts, helping communities understand the value of their urban forests and encouraging public participation in tree planting and care initiatives.

Policy Support and Decision-Making: The insights gained from i-Tree analyses can inform policy development, helping governments prioritize urban forestry initiatives and allocate resources efficiently. By demonstrating the return on investment of urban trees, i-Tree supports sustainable urban planning.

Flexible and Adaptable Tools: The i-Tree suite includes various applications tailored to different scales and needs, such as i-Tree Eco for detailed urban forest analysis, i-Tree Canopy for quick assessments of tree cover, and i-Tree Hydro for analyzing stormwater impacts. This flexibility allows users to choose the appropriate tool based on their objectives and resources.

Global Application: While initially developed in the United States, i-Tree tools have been adapted for use in many countries worldwide, incorporating regional data and metrics. This global applicability makes i-Tree a valuable resource for international urban forestry efforts. By providing detailed, data-driven insights into the benefits of urban trees, i-Tree Ecosystem Analysis supports the effective management and enhancement of urban forests, contributing to more sustainable and resilient cities (2021,06 16).

The i-Tree Eco application, developed by the U.S. Department of Agriculture, is used in more than 100 countries to quantify urban trees' multidimensional ecosystem service value (Rogers et al., 2015).

In Turkey, limited studies reveal the ecosystem service values of trees using the i-Tree Eco software. The first study, the i-Tree Eco software application, was carried out with a detailed inventory study of the existing road trees on the most crucial boulevard of Isparta City, “Süleyman Demirel Boulevard” (SDB) (Tuğluer & Gül, 2018). Another application, within the scope of the project titled “Tree Inventory and Ecosystem Services Technical Guide”, was carried out by the Landscape Research Association (PAD) as a mobile application with Turkish support. Within the scope of the “My Tree” application software, an inventory study of the monumental trees located on Kumrular Street in Ankara was carried out (Ağacım, 2023, 02.10). Taking into account the applications stated above, this chapter is based on the thesis entitled “An Approach to Protection of Street Trees As Green Infrastructure Unit At The Neighborhood Level: The Case Of Ankara Bahçelievler District”. The inventory recording of street trees was carried out with the “Nature at My Door” phone application, the content of which was also created within the thesis. Using the i-Tree Eco program revealed the ecosystem service value of the trees on the determined route in the Bahçelievler District (İnci, 2023).

2. Material and Method

The study area is Bahçelievler District, a settlement planned by Hermann Jansen with the garden city model in the Çankaya District of Ankara. Urban transformation gradually leads to decreased street trees in the neighborhood, with 5.5 street trees per 100 people in 2019 (İnci, 2023). Therefore, the study emphasizes the value of trees in terms of the ecosystem services they provide, starting from the importance of street tree presence in terms of climate-resilient settlements.

This study utilized the i-Tree Eco model, a software developed by the US Department of Agriculture and Forest Service (USDA), to assess and visualize the ecosystem services provided by street trees.

The study is based on estimating ecosystem value in the i-Tree Eco program of street tree data generated via the phone application. The phone application is created in collaboration with Başarsoft.

In the street tree inventory created through the “Nature at My Door” application, ten different parameters based on the physical properties of street trees, including species name, stem diameter, height at which the stem diameter is measured, total tree height, living tree height, crown base height, crown width (north-south), crown width (east-west), crown health, and degree of light intake, were selected according to the titles required for the i-Tree Eco software. The i-Tree Eco model provides detailed insights into various ecosystem services by quantifying metrics such as carbon storage, pollution removal, and runoff avoidance. This data is crucial for urban planners in making informed decisions to optimize urban greenery for both environmental and economic benefits.

Within the scope of the study, six different parameters, including the soil area of the tree above the pavement, the distance from the street corner to the tree, the distance from the measured tree to the unmeasured tree, the pavement width where the tree is located, the number of forks of the tree, and the stem circumference, were evaluated together with experts and added to the physical properties section of the application. The tree information to be recorded with the smartphone application provides comprehensive information with simultaneous tree cadastre and tree relief information compared to other inventories.

The application was utilized on the specified route to gather data about street trees using volunteers, thereby compiling an inventory based on this data. This application, considered within the citizen science framework, facilitates data collection and monitoring by automatically consolidating the user-entered information into a single database. It also contributes to forming an active database by allowing the data to be updated continuously.

The following table summarizes the key steps in the field work.

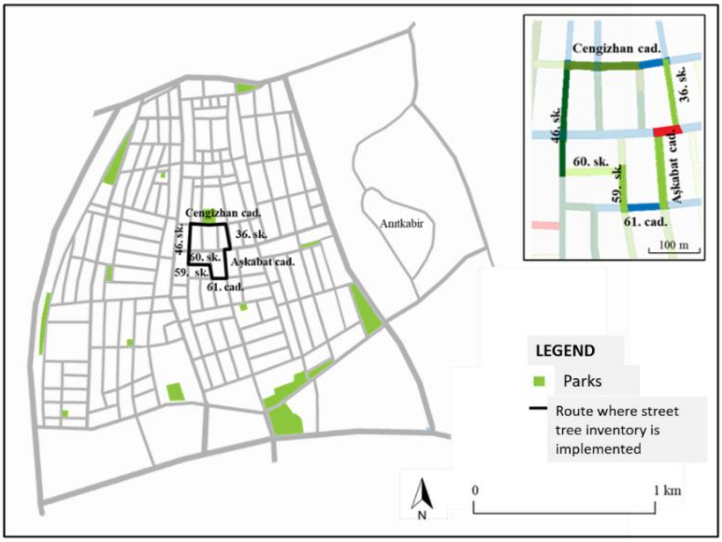
Step	Description
Feature of the study area	Decrease in street trees due to urban transformation (5.5 trees per 100 residents)
Objective	To raise awareness for the protection and dissemination of street trees by revealing their ecosystem service value and their role in planning climate resilience cities and neighborhoods.
Model Used	i-Tree Eco Model developed by the USDA Forest Service
Data Collection Method	Field study using a mobile application (Nature at My Door) developed in collaboration with Başarsoft.
Tree Inventory Parameters	- Species Name - Stem Diameter - Tree Height - Crown Width (north-south, east-west)

Step	Description
	-Crown Health - Permeable Surface Area
Assessment	Data was transferred to the i-Tree Eco program for analysis of ecosystem services provided by 115 street trees.
	Report generated in May 2023 showing ecosystem service values of the Street trees in the Bahçelievler case.

The study reveals the ecosystem service value for 115 street trees along the Route was recorded in the street tree inventory using the phone application called “Nature at My Door” (Map 1).

The route is determined to include six groups of streets (Figure 1) based on the frequency of tree presence in the street vista and canopy criteria.

Figure 1. Trees' Effect on the Street View



Map 1. Study Area and Street Trees Route in the Bahçelievler Neighborhood (Ankara) (İnci, 2023)

Table 1. Distribution of Street Trees and Species along the Route in Bahçelievler (İnci, 2023)

Street Name	Street Tree Species	Number of Trees	(%)
60. St.	*Platanus orientalis*- Oriental Plane Tree	1	0.87
59. St.	*Acer negundo* – Boxelder	3	2.61
	Acer pseudoplatanus -Mountain maple	2	1.74
	Alianthus altissima – Tree of Heaven	1	0.87
	Cupressocyparis leylandii – Hybrid Cypress	1	0.87
	Cupressus arizonica – Arizona Cypress	1	0.87
	Sophora japonica – Sophora	1	0.87
	Pinus brutia – Red Pine	1	0.87
61. St.	*Acer negundo* – Boxelder	2	1.74
	Fraxinus excelsior-European ash	2	1.74
	Alianthus altissima- Tree of Heaven	1	0.87
	Prunus mahaleb	1	0.87
Aşkabat St.	*Fraxinus excelsior* - European ash	11	9.57
	Fraxinus americana – White Ash	4	3.48
	Tilia tomentosa – Silver Linden	1	0.87
36. St.	*Aesculus hippocastanum* - Horse Chestnut	4	3.48
	Koelreuteria paniculata – Golden raintree	2	1.74

	Acer negundo - Boxelder	1	0.87
	Fraxinus excelsior - European ash	1	0.87
	Robinia pseudoacacia - Water locust	1	0.87
Cengizhan St.	*Aesculus hippocastanum* - Horse Chestnut	12	10.43
	Platanus orientalis - Oriental Plane Tree	8	6.95
	Acer negundo - Boxelder	4	3.47
	Tilia tomentosa – Silver Linden	3	2.61
	Quercus robur – English Oak	1	0.87
	Sophora japonica – Sofora	1	0.87
46. St.	*Platanus orientalis* - Oriental Plane Tree	42	36.52
	Acer negundo - Boxelder	1	0.87
	Aesculus hippocastanum - Horse Chestnut	1	0.87
Total number of street trees on the route		115	100.00

There are 16 different tree species within the study area. The distribution of these trees in terms of species and numbers on the streets of the route is given in Table 1. As can be seen in the study area, the three most common species are 32.9% Oriental Plane Tree (Platanus orientalis), 10.97% Horse Chestnut (Aesculus hippocastanum), and 9.03% European Ash (Fraxinus excelsior). In addition, the dominant tree species on each street differs (Table 1).

3. Findings and Discussion

Street trees along the Route were examined in two main sections regarding the ecosystem service value they provide. The first is structural and compositional, and the second is functional analysis.

3.1. Structural and Composition Analyses

The street trees on the route consist of native and exotic tree species. 64% of the trees are of European and Asian origin, while approximately 3% are species native to Asia. In terms of leaf area, the most dominant species were determined to be the Oriental Plane Tree (*Platanus orientalis*), Horse Chestnut (*Aesculus hippocastanu*m) and European Ash

(*Fraxinus excelsior*). When the first three street trees providing a total leaf area of 93.01 hectares are examined, the Oriental Plane Tree (*Platanus orientalis*) with 59.2 hectares, the Horse Chestnut (*Aesculus hippocastanum*) with 19.8 hectares and the European Ash (*Fraxinus excelsior*) with 9.2 hectares respectively had the highest value. Species with high values in leaf area do not always mean species that need to be encouraged in the future. Instead, these species determine the dominant species among the trees.

The three most common species are Oriental Plane Tree (44.3%), Horse chestnut (14.8 %), and European ash (12.2 %) (Figure 2). In Bahçelievler, about 3 percent of the trees are species native to Asia. Most trees originate from Europe and Asia (64.0%).

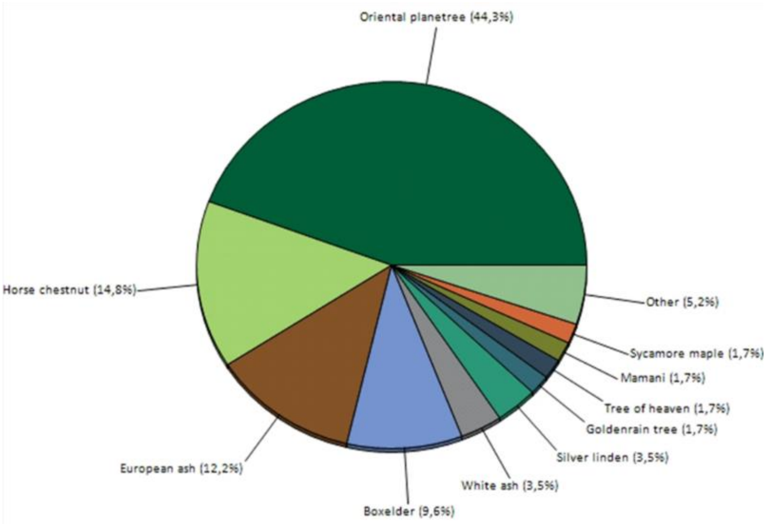


Figure 2. Tree Species Composition along The Route in Bahçelievler (i-Tree Eco, 2023)

Wang et al. (2020) evaluated trees in three classes in terms of stem diameter; less than 20 cm (young trees), trees between 20 cm and 40 cm, and trees greater than 40 cm (mature trees) diameter.

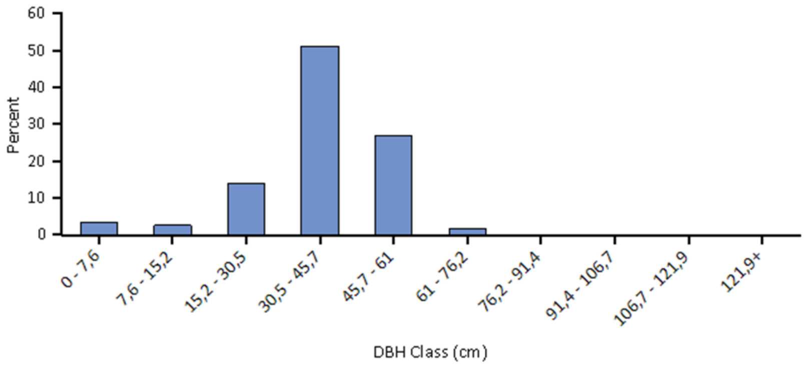


Figure 3. Percent of tree population by stem diameter class (DBH-stem diameter at 1.37 meters) along the Route in Bahçelievler Neighborhood (i-Tree Eco, 2023)

According to the measurements on the physical appearance of street trees, 8.70% of the street trees are smaller than 20 cm in terms of stem diameter; 41.7% are between 20-40 cm; 49.6% are larger than 40 cm. These results revealed that mature trees are predominant in the study area (Figure 3). In particular, mature street trees are seen on Cengizhan Street and 46th Street on the route (Table 2).

Table 2. Stem Diameter Class of Street Trees along the Route in Bahçelievler Neighborhood (İnci, 2023)

Street Name	Stem Diameter Class -DBH (cm)	Number of Trees	(%)
60. St.	20-40	1	0.87
59. St.	< 20	4	3.48
	20-40	5	4.35
	>40	1	0.87
61. St.	< 20	1	0.87
	20-40	5	4.35

Aşkabat St.	< 20	5	4.35
	20-40	7	6.09
	>40	4	3.48
36. St.	20-40	1	0.87
	>40	8	6.96
Cengizhan St.	20-40	16	13.91
	>40	13	11.30
46. St.	20-40	13	11.30
	>40	31	26.96

Analyses on the height of street trees displayed that 2.61% are under 5 meters; 7.83% are between 5-7.9 meters; 46.96% are between 8-15 meters and 42.61% are over 15 meters. In general, it was determined that there are medium-sized street trees in the study area. Newly planted and small trees are pretty rare (Table 3).

Table 3. Height Class of Street Trees along the Route in Bahçelievler Neighborhood (İnci, 2023)

Street Name	**Tree Height (m)**	**Number of Trees**	**(%)**
60. St.	>15 (tall tree)	1	0.87
59. St.	<5(newly planted tree) (sapling)	3	2.61
	5-7,9 (small tree)	1	0.87
	8-15 (medium sized tree)	3	2.61
	>15 (tall tree)	3	2.61
61. St.	5-7,9 (small tree)	1	0.87
	8-15 (medium sized tree)	5	4.35
Aşkabat St.	5-7,9 (small tree)	5	4.35
	8-15 (medium sized tree)	11	9.57
36. St.	8-15 (medium sized tree)	8	6.96
	>15 (tall tree)	1	0.87
Cengizhan St.	5-7,9 (small tree)	1	0.87
	8-15 (medium sized tree)	26	22.61
	>15 (tall tree)	2	1.74
46. St.	5-7,9 (small tree)	1	0.87
	8-15 (medium sized tree)	1	0.87
	>15 (tall tree)	42	36.52

3.1.1. Street tree cover and leaf area

Many tree benefits equate directly to the plant's healthy leaf surface area. Trees provide 93.01 hectares of leaf area on the route in Bahçelievler.

In Bahçelievler, the most dominant species in terms of leaf area are Oriental Plane Tree, Horse Chestnut, and European Ash. The ten species with the most significant importance values are listed in Table 4. Importance values (IV) are calculated as the sum of the percent population and percent leaf area. High importance values do not mean that these trees should necessarily be encouraged in the future; rather, these species currently dominate the urban forest structure.

Table 4. The Top 10 Species along the Route in Bahçelievler Neighborhood (i-Tree Eco, 2023)

Species Name	Population (a) %	Leaf Area (b) %	Importance values (a+b) %
Oriental planetree	44.3	59.2	103.5
Horse chestnut	14.8	19.8	34.5
European ash	12.2	9.2	21.3
Boxelder	9.6	5.2	14.8
Silver linden	3.5	3.9	7.4
White ash	3.5	0.1	3.5
English oak	0.9	1.6	2.5
Tree of heaven	1.7	0.2	2.0
Goldenrain tree	1.7	0.2	2.0
Sycamore maple	1.7	0.2	1.9

3.2. Functional Analyses

The i-Tree Eco application was reported under five headings as ecosystem service value in the package program transferred as an Excel file. These were evaluated as ecosystem services through air pollution removal, carbon sequestration, and storage, air quality improvement, and avoided runoff rainwater. The i-Tree-Eco report is summarized below.

3.2.1. Air pollution removal by urban trees

Poor air quality is a common problem in many urban areas. It can lead to decreased human health, damage to landscape materials and ecosystem processes, and reduced visibility. The urban forest can help improve air quality by reducing air temperature, directly removing pollutants from the air, and reducing energy consumption in buildings, consequently reducing air pollutant emissions from the power sources. Trees also emit volatile organic compounds that can contribute to ozone formation. However, integrative studies have revealed that increased tree cover reduces ozone formation (Nowak et al., 2000).

Pollution removal by trees in Bahçelievler was estimated using field data and recent pollution and weather data available. Pollution removal was most significant for nitrogen dioxide (Figure 5).

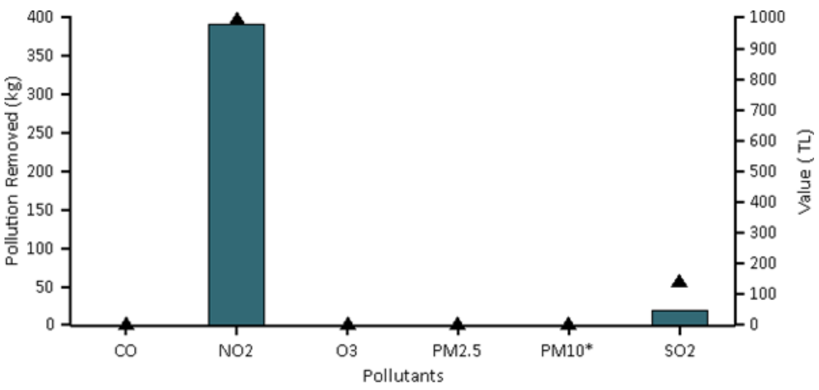


Figure 5. Annual Pollution Removal (points) and Value (bars) by Urban Trees, along the Route Bahçelievler (i-Tree Eco, 2023)

It is estimated that trees remove 452 kilograms of air pollution (ozone (O_3), carbon monoxide (CO), nitrogen dioxide (NO_2), particulate matter less than 2.5 microns (PM2.5), particulate matter less than 10 microns and more significant than 2.5 microns (PM10*)2, and sulfur dioxide (SO_2)) per year with an associated value of TL. 1030 (€ 48) (The average euro exchange rate for May 2023 was taken as reference, May 2023 1Avro=21,5 TL.)

3.2.2. Carbon sequestration and storage

Climate change is an issue of global concern. Urban trees can help mitigate climate change by sequestering atmospheric carbon (from carbon dioxide) in tissue, altering energy use in buildings, and consequently altering carbon dioxide emissions from fossil-fuel-based power sources (Abdollahi et al., 2000).

Trees reduce the amount of carbon in the atmosphere by sequestering carbon in new growth every year. The amount of carbon annually sequestered is increased with the size and health of the trees. The gross sequestration of Bahçelievler trees is about 2 086 metric tons of carbon per year with an associated value of TL. 1860 (77,5 €). The most effective tree is the Oriental Plane Tree, 46.1% of all sequestered carbon (Figure 6).

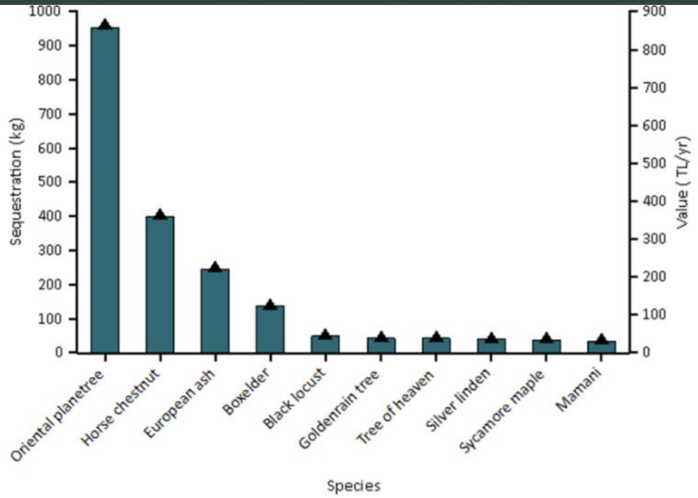


Figure 6. Estimated Annual Gross Carbon Sequestration (point) and Values (bars) for Urban Tree Species with the Greatest Sequestration along The Route in Bahçelievler (i-Tree Eco, 2023)

Carbon storage is another key way trees influence global climate change. As trees grow, they store more carbon in their accumulated biomass. As a tree dies and decays, it releases much of the stored carbon back into the atmosphere. Thus, carbon storage indicates the amount of carbon that can be released if trees are allowed to die and decompose.

Street Trees in Bahçelievler on the route stored 47.25 metric tons (1000 kilos) of carbon, with a total value of TL 42100 (1750 €). Among the sampled species, the tree species with the highest carbon storage amount (approximately 45.8% of the total carbon) was the Oriental Plane Tree (Platanus orientalis), with a total of 21.64 metric tons (Figure 7).

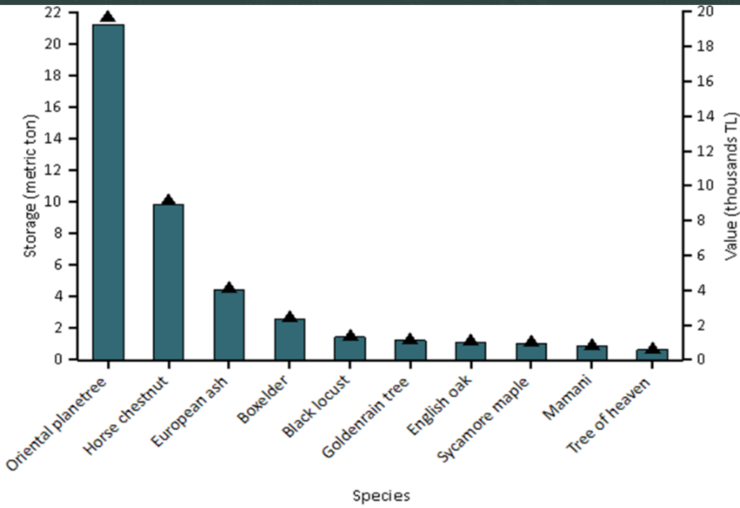


Figure 7. Estimated Carbon Storage (point) and Values (bars) for Urban Tree Species with the Greatest Storage along The Route in Bahçelievler (i-Tree Eco, 2023)

3.2.3. Air quality improvement

Oxygen production is one of the most commonly cited benefits of urban trees. The annual oxygen production of a tree is directly related to the amount of carbon sequestered by the tree, which is tied to the accumulation of tree biomass.

Trees in Bahçelievler are estimated to produce 5.563 metric tons of oxygen annually. Oriental Plane and Horse Chestnut trees contribute the most to oxygen production species. They are mature trees in stem diameter and leaf area and are the dominant tree species (Table 5).

Table 5. The Top 16 Oxygen Production Species along The Route in Bahçelievler (i-Tree Eco, 2023)

Species	Oxygen (kilogram)	Gross Carbon Sequestration (kilogram/yr)	Number of Trees	Leaf Area (hectare)
Oriental plane Tree	2.563,48	961.31	51	5504
Horse chestnut	1.078,01	404.25	17	18.38
European ash	661.29	247.98	14	8.52
Boxelder	369.83	138.69	11	4.87
Black locust	133.33	50.00	1	0.23
Golden rain tree	114.77	43.04	2	0.21
Tree of heaven	113.16	42.44	2	0.22
Silver linden	110.94	41.60	4	3.66
Sycamore maple	103.09	38.66	2	0.18
Mamani	94.50	35.44	2	0.03
English oak	83.96	31.48	1	1.53
White ash	83.03	31.14	4	0.05
Mahaleb Cherry	40.05	15.02	1	0.04
Cypress spp	6.26	2.35	1	0.00
Arizona cypress	6.26	2.35	1	0.03
Turkish pine	1.45	0.54	1	0.01
Total	*5.563,41*	*2.086,29*	*115*	*93.00*

3.2.4. Avoided runoff rainwater

Surface runoff can cause concern in many urban areas as it can pollute streams, wetlands, rivers, lakes, and oceans. During precipitation events, some portion of the precipitation is intercepted by vegetation (trees and shrubs) while the other portion reaches the ground. The portion of the precipitation that reaches the ground and does not infiltrate into the soil becomes surface runoff (Hirabayashi, 2012). In urban areas, the large extent of impervious surfaces increases the amount of surface runoff.

Urban trees and shrubs, however, are beneficial in reducing surface runoff. Trees and shrubs intercept precipitation, while their root systems promote infiltration and storage in the soil.

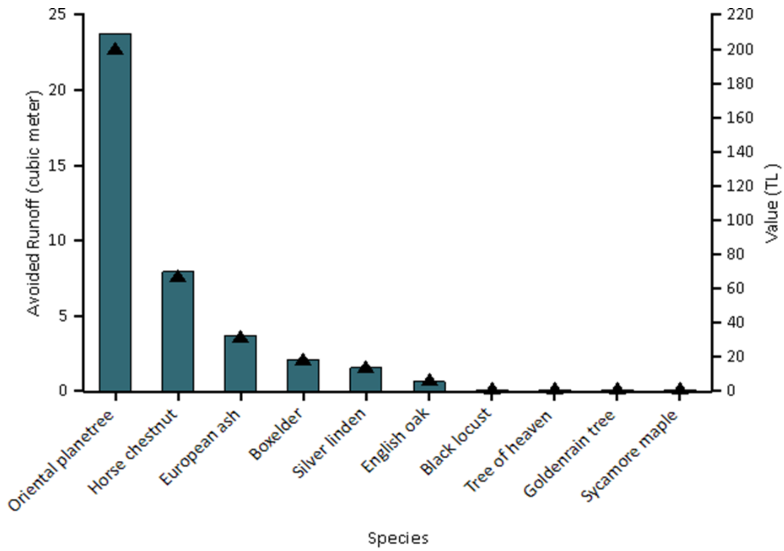


Figure 8. Avoided Runoff (point) and Value (bars) for Species with Greatest Overall Impact on Runoff, along The Route in Bahçelievler (i-Tree Eco, 2023).

The street trees of Bahçelievler help to reduce runoff by an estimated 38.2 cubic meters annually, with an associated value of TL 354 (15 €). Avoided runoff is estimated based on local weather from the user-designated weather station. In Bahçelievler, the total annual precipitation in 2017 was 10.3 centimeters.

Finally, the total street tree replacement value was determined as TL 1.42 million (59.166 €). The replacement value of a tree defines the cost of replacing a tree with a similar tree. This value tends to increase with the number and size of healthy trees. The ecosystem service values of street trees can be increased by protecting and managing them (i-Tree Eco, 2023) To summarize the ecosystem value of 115 street trees on the route in the Bahçelievler case study, they have stored 47.25 metric tons of carbon during their lifetime and sequestered 2.09 tons of carbon per year. It was determined that the street trees on the route produced 5.56 metric tons of oxygen annually and eliminated a total of 452 kg of air pollution. In addition, the street trees on the route delay 38.24m³ of rainwater runoff annually. The tree with the highest ecosystem service value among the street trees along the route was the Eastern Plane Tree (Platanus Orientalis). In this context, the protection of street trees, such as old Plane Trees (Platanus orientalis), which form canopy continuity on 46th Street, is essential to maximizing the value of street trees in terms of ecosystem services.

With this study, the number of research projects focusing on street trees using the i-Tree-Eco software in Turkey is steadily increasing. These studies play a crucial role in highlighting the ecosystem services provided by street trees, paving the way for further exploration and analysis. The following examples illustrate the growing body of work in this field.

One of these works was implemented within the project titled "Tree Inventory and Ecosystem Services Technical Guide" conducted by the Landscape Research Association (PAD). Kumrular Street in Ankara city center, 71 trees were recorded with the "My Tree" application. The total replacement value of the trees on Kumrular Street was 137,585.00 €, and their carbon storage value was 1,114.00 €. The average functional values of each tree were calculated as follows: carbon storage 0.10 €, surface runoff prevention 28.50 €, and pollution prevention value 3.65 € (Ağacım, 2023, 02 10).

A similar study conducted in Isparta City observed that similar types of trees have superior carbon retention properties. Biomass and carbon storage values were obtained from the inventory data of 1498 trees on Süleyman Demirel Boulevard. According to these results, it was determined that the trees on this Boulevard held a total of 197.566 kg of carbon throughout their lifespan. It was observed that the tree species with the highest carbon storage amount was Platanus Orientalis, with an average of 564 kg per tree. The annual carbon storage amounts of the trees were also calculated, and it was determined that all trees stored 21.839 kg of carbon per year. When examined on a species basis, it was determined that Platanus orientalis had the highest annual carbon storage average of 45.8 kilograms (Tuğluer & Gül, 2018, p. 301).

In a similar study handed out using i-tree eco reporting to research by Selim & Atabey (2023), 388 trees in Antalya Atatürk Boulevard have annual carbon storage of 48.5 metric tons.

Another i-Tree Ecosystem reporting was conducted on 588 trees in Burdur city center. In this study, it was seen that street trees produced an ecosystem service value of 66.79 kg of pollution removal, 12.92 metric tons per year of carbon sequestration, 34.44 metric tons per year of oxygen production, and 52 cubic meters per year of stormwater runoff avoided (Kaçmaz Akkurt et al., 2023).

Based on the findings of the above studies, street trees' environmental service values in terms of carbon storage and sequestration come to the fore. This study highlights how important street trees, especially mature ones, are in terms of the diversity and value of the services they provide within a limited area. The findings highlight the significant role of street trees in improving urban environments. For instance, the economic valuation of pollution removal and carbon storage by trees like the Oriental Plane Tree provides strong evidence for including street trees in future urban planning efforts.

The studies mentioned above provided numerical data that revealed the ecological and economic importance of street trees. Street trees play a crucial role in the protection and sustainable management of urban areas by delaying rainwater runoff and providing various ecosystem services. This is particularly important in mitigating the harmful effects of climate change. It is essential to plant new trees to maintain canopy continuity, increase tree shade coverage in cities, and protect existing trees to maximize their ecosystem service values.

4. Conclusion and Suggestions

Street trees provide essential ecosystem services that greatly contribute to urban sustainability and quality of life. Some of the primary benefits of street trees include carbon capture and storage, air quality improvement, stormwater management, and temperature regulation. Additionally, they offer cultural, aesthetic, and biodiversity-related benefits.

For instance, in London, the i-Tree Eco program is used to assess the physical properties of trees and the ecological benefits they provide throughout the year. Similarly, in Washington, the i-Tree application is employed to evaluate the amount of carbon storage, stormwater runoff prevented by trees, and their impact on air quality. Similar analyses conducted in major cities around the world assess the ecosystem services provided by street trees as a tool for climate-resilient urban planning.

Urban tree inventory studies also offer opportunities for citizen participation in environmental management. Urban planners, policymakers, and managers should prioritize the preservation and expansion of street tree populations to maximize the benefits they offer. Ongoing studies are essential to comprehensively understand and optimize the advantages that street trees can provide within the frameworks of urban planning and development. To maximize the ecosystem services provided by street trees, local governments, and urban planners must develop comprehensive afforestation strategies, ensure the preservation of mature trees, and integrate street trees more effectively into urban planning frameworks.

Recognizing the ecosystem service values provided by street trees is vital for informing urban climate action plans and guiding planning initiatives. The effective application of tools like i-Tree requires integrating them into broader urban planning and management strategies. This can be complex due to the need for coordination between various departments and alignment with other urban initiatives. Therefore, it is imperative to acknowledge and safeguard the value of street trees as critical assets that benefit both humans and all living organisms.

In the context of designing resilient cities to combat climate change, attention must be given to the ecosystem services offered by street trees. Cities must prioritize their adaptation to climate change while also focusing on the preservation of urban ecosystems. City planners and policymakers must understand and evaluate these aspects to foster sustainable urban environments. Ultimately, the continued investment in and protection of street trees will be a cornerstone in creating climate-resilient cities, ensuring a sustainable future for urban populations.

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

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The Role of Urban Green Spaces in Achieving the Net-Zero Carbon Target

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1. Introduction

Since the Industrial Revolution, our world has been heavily dependent on the overuse of natural resources. The widespread use of fossil fuels, deforestation, land use changes, and anthropogenic activities have caused global climate change by continuously increasing greenhouse gases [(carbon dioxide (CO_2), methane (CH_4), ozone (O_3), nitrous oxide (N_2O), chlorofluorocarbons (CFCs), and water vapor (H_2O)] in the atmosphere (Çakır, 2021; Wang et al., 2021). From pre-industrialization to the present, the global average atmospheric carbon dioxide concentration has increased significantly by approximately two-fold (Chen et al., 2022). As long as fossil fuels continue to be the main energy source for humanity, anthropogenic carbon dioxide emissions worldwide are expected to increase further (Kenarsari et al., 2013; Öztekin Kara, 2022). Continued greenhouse gas emissions will cause further warming and long-term changes in all climate system componentsclimate system components, increasing the likelihood of severe, widespread, and irreversible impacts on humans and ecosystems. Limiting climate change will require significant and sustained reductions in greenhouse gas emissions, which, together with adaptation, can limit climate change risks. Anthropogenic greenhouse gas emissions are mainly caused by population size, economic activity, lifestyle, energy use, land use patterns, technology, and climate policy. Surface temperatures will remain stable at high levels for centuries after net anthropogenic CO_2 emissions are eliminated (Pachauri & Meyer, 2015). In this case, the greenhouse effect and global warming are expected to continue (Tuğluer & Çakır, 2019; 2021).

The "greenhouse effect" is a natural phenomenon that regulates the temperature of the Earth. The greenhouse effect is the reflection of short-wavelength rays coming from the sun back to the Earth by greenhouse gases in the atmosphere in the form of long-wavelength heat rays after reaching the Earth (Aksay et al., 2005). A significant portion of solar radiation passes through the atmosphere, reaches the Earth, and is absorbed there. However, the long-wavelength rays reflected from the Earth's surface are reflected to the Earth's surface by greenhouse gases in the upper levels of the atmosphere (Figure 1.). The disruption of this natural cycle, that is, the increase in greenhouse gases in the atmosphere due to anthropogenic effects, causes global warming by warming the Earth's surface more than it should. The ability of the atmosphere to retain heat due to greenhouse gases is called the greenhouse effect, and the resulting increase in temperature on Earth is called global warming (Tuğluer, 2019).

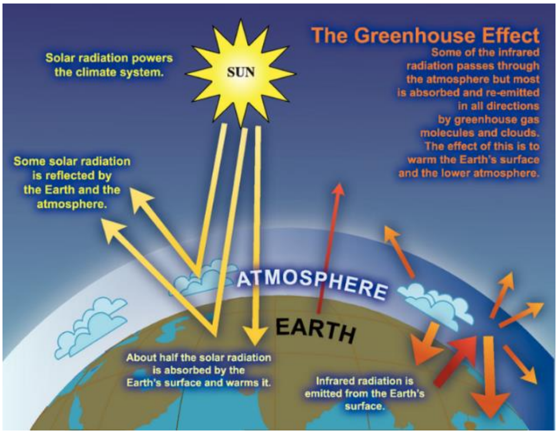

Figure 1. An idealized model of the natural greenhouse effect (IPCC, 2007).

The Earth's climate system includes the atmosphere, ocean, soil, cryosphere (ice and snow), and biosphere. Climate is defined by characteristics such as temperature, precipitation, humidity, and the condition of soil, snow, and ice cover. The climate is constantly changing due to many different natural factors. In the last 200 years, human activity has become the most influential factor in changing the Earth's climate (Mikhaylov et al., 2020). Global climate change is a change caused by human activities in addition to the natural variability of climate experienced throughout the long geological history of the Earth. In parallel, climate change is defined in the United Nations Framework Convention on Climate Change (UNFCCC) as "a change in climate that occurs as a result of human activities that directly or indirectly disrupt the composition of the global atmosphere, in addition to the natural climate change observed over a comparable period" (Republic of Türkiye, Ministry of Environment, Urbanization and Climate Change, 2024a).

The burning of fossil and biomass fuels is the largest source of human-induced greenhouse gas emissions. Cement production releases carbon dioxide, and agriculture and landfills release methane gas. Fertilizer use and nylon production increase nitrous oxide, and refrigerators and air conditioners increase fluorine greenhouse gas emissions. Land use changes also significantly affect the climate system. Clearing land for agricultural purposes increases the amount of dark-colored surface, and as a result, incoming solar radiation is absorbed rather than reflected. Land clearance also means that trees and plants that capture and store carbon dioxide are reduced due to the destruction of forests. Desertification can have an effect that slows down global warming by reducing the energy coming from the sun to the Earth's surface and causing an increase in the amount of dust passing into the atmosphere. Urbanization leads to the formation of urban heat islands, i.e., areas in cities that are hotter than their surroundings (Republic of Türkiye, Ministry of Environment, Urbanization and Climate Change, 2024a).

Some of the potential consequences of climate change due to global warming;

- Melting of glaciers on Earth and rising sea levels,
- Thinning of the ozone layer due to greenhouse gases causing global warming and ultraviolet rays passing through the ozone layer, endangering life on Earth,
- An increase in natural disasters such as floods, landslides, erosion, hurricanes, tornadoes, and lightning,
- Increase in sea and ocean temperatures, adversely affecting living things,
- Decrease in freshwater resources with increasing temperature,
- Increase in forest fires and drought,
- Increase in day-night temperature differences and desertification,
- Thawing of frozen soils in the poles and releasing greenhouse gases that have been in them for thousands of years into the atmosphere,
- Increase in diseases and epidemics caused by sudden climate changes,

- All these negative situations experienced on Earth also negatively affect human psychology and increase mental disorders (Akın, 2006; Tuğluer, 2019; Malhi et al., 2021).

Countries have signed some agreements to reduce CO_2 emissions, combat global warming, and prevent climate change. Especially after the establishment of the IPCC and UNFCCC, significant efforts have been made to reduce CO_2 at the global and national levels (Wimbadi & Djalante, 2020). The problem of climate change has been addressed in six main policy documents created under the leadership of the UN: the 1985 Vienna Convention, the 1987 Montreal Protocol, the 1992 United Nations Framework Convention on Climate Change (UNFCCC), the 1997 Kyoto Protocol, the 2015 UN Sustainable Development Goals (2030 SDGs), and the 2015 Paris Convention.

The issue of ozone depletion was first discussed in 1976 at the Governing Council of the United Nations Environment Programme (UNEP). After the Coordination Committee for the Ozone Layer (CCOL) was established by UNEP and the World Meteorological Organization (WMO) to periodically assess ozone depletion, experts on the ozone layer came together at a meeting in 1977. The first intergovernmental contacts on reducing substances that deplete the ozone layer (OTDs) began in 1981, and this initiative culminated in the adoption of the Vienna Convention for the Protection of the Ozone Layer in March 1985. The Vienna Convention encouraged intergovernmental cooperation in research, systematic observation of the ozone layer, monitoring of CFC production, and sharing of information. The convention mandates parties to take general measures against anthropogenic activities that alter the structure of the ozone layer and to protect the environment and human health. It is a framework agreement that does not include legally binding controls or targets (Republic of Türkiye, Ministry of Environment, Urbanization and Climate Change, 2024c).

The Montreal Protocol is the Protocol on Substances Related to the Ozone Layer, adopted in Montreal on September 16, 1987, and subsequently amended and modified. The Vienna Convention encouraged intergovernmental cooperation in research, systematic monitoring of the ozone layer, monitoring of CFC production, and the sharing of information. Following the adoption of the Vienna Convention for the Protection of the Ozone Layer, a framework agreement that did not contain legally binding controls or targets, work began on a protocol to control the use and production of substances that deplete the ozone layer. The Montreal Protocol on Substances That Deplete the Ozone Layer was adopted in September 1987. With the detection of the ozone hole over Antarctica in 1985, governments concluded that stringent measures were needed to reduce the production and consumption of many CFCs and some halons. The Montreal Protocol was designed so that the phase-out schedule could be revised based on periodic scientific and technological assessments. Following these technical and scientific evaluations, the Protocol was revised in 1990 (London), 1992 (Copenhagen), 1995 (Vienna), 1997 (Montreal), 1999 (Beijing), and 2007 (Montreal) to accelerate the reduction in the calendar. In addition, these regulations resulted in the inclusion of new control articles and new measures in the agreement. The Montreal Protocol, to which 196 countries are parties, is defined as the most successful multilateral agreement on the environment. In June 1990, a "Multilateral Fund (MLF)" was established in London, which is seen as a great success of the protocol and was established with the contributions of developed countries. This fund is used for technical expertise, new technologies, and equipment in projects aimed at eliminating OTCs by the industry of developing countries. The Multilateral Fund has provided support to more than 8600 projects for developing countries since 1991 (Republic of Türkiye, Ministry of Environment, Urbanization and Climate Change, 2024d).

Climate change, desertification, and biodiversity loss are all interconnected and pose existential challenges for humanity. Governments came together to discuss and address such existential challenges at the 1992 Earth Summit in Rio de Janeiro. It is a "Rio Convention," one of two treaties opened for signature at the 1992 "Rio Earth Summit." The UNFCCC was also created at this summit. The UNFCCC entered into force on March 21, 1994. Today, it has a nearly universal membership. The 198 countries that have ratified the Convention are called Parties to the Convention. The ultimate goal of the UNFCCC is to prevent "dangerous" human interference in the climate system. The Rio Conventions work together, with the overlap in their work becoming stronger as the challenges of climate change, desertification, and biodiversity loss increase and intersecting solutions are developed (Republic of Türkiye, Ministry of Environment, Urbanization and Climate Change, 2024e).

The Kyoto Protocol was adopted on December 11, 1997, as a first step towards clarifying the steps to be taken to combat climate change. At the

COP 3 held in Kyoto, Japan, in 1997, the UNFCCC parties concluded the Kyoto Protocol, their first agreement with specific targets and timelines for reducing greenhouse gas emissions. The Kyoto Protocol entered into force in 2005. Currently, there are 192 parties to the Kyoto Protocol. The Kyoto Protocol commits industrialized countries and economies in transition to the United Nations Framework Convention on Climate Change to limit and reduce greenhouse gas (GHG) emissions with individual targets agreed upon. The Convention itself only asks these countries to adopt policies and measures on reductions and to report periodically (Wimbadi & Djalante, 2020).

The Paris Agreement is a legally binding international agreement on climate change. It was adopted by 196 parties at the UN Climate Change Conference (COP 21), held in Paris, France, on December 12, 2015. It entered into force on November 4, 2016. The Paris Agreement is based primarily on the United Nations Framework Convention on Climate Change and aims to regulate the climate change regime after the expiration of the Kyoto Protocol in 2020. The agreement aims to “hold the increase in global average temperature to well below 2 °C above pre-industrial levels” and to continue efforts to “limit the temperature increase to 1.5 °C above pre-industrial levels." While climate action will need to be significantly increased to achieve the goals of the Paris Agreement, the years since its entry into force have already ignited low-carbon solutions and new markets. More and more countries, regions, cities, and companies are setting carbon neutrality targets. Zero-carbon solutions are becoming competitive in economic sectors that represent 25% of emissions. This trend is most evident in the energy and transportation sectors and has created many new job opportunities for early movers. By 2030, zero-carbon solutions could be competitive in sectors that represent more than 70% of global emissions (Fankhauser et al. 2022; T.C. Republic of Türkiye, Ministry of Environment, Urbanization and Climate Change, 2024b)

In the process that has continued with the signing of the Kyoto Protocol by governments in 1997 and the Paris Climate Agreement in 2015, countries and important global actors have been searching for ways to combat climate change and collaborating to take various measures in this regard. The issue of combating climate change, which has left its mark on the 21st century, has drawn attention to economic activities responsible for CO_2 emissions. The concept of net-zero carbon, which was put forward in this context, has emerged as a result of the search for ways to combat climate change. The term “Net-Zero Carbon” basically refers to the situation where carbon emissions originating from all kinds of activities of an individual, an organization, a city, or a country are at a net-zero level. Accordingly, net-zero carbon status is a goal that climate change efforts are expected to reach in the long term (Gümüş et al., 2018). Depending on whether zero CO_2 emissions can be achieved or not, technological ways to achieve carbon neutrality can be divided into two types: zero emissions and net-zero emissions. Due to the high uncertainty of reaching the zero emission route, many countries and regions have chosen the more probable net-zero emission path (Fan & Wei, 2022). Countries are trying to reach the net-zero carbon target through the agreements they have joined. This target aims to reduce carbon emissions to net-zero levels by changing production and consumption needs. However, there is not yet sufficient infrastructure and data to reach the targeted values. Natural carbon sinks are often overlooked in reaching the net-zero carbon target. The only natural carbon sinks in the world that can be increased by human intervention are green areas. Therefore, the importance of green areas that serve as carbon sinks should be well understood (Tuğluer, 2023).

2. Carbon Sinks in Cities: Urban Green Spaces

A carbon sink is any process, activity, or mechanism that removes a greenhouse gas, an aerosol, or a precursor to a greenhouse gas from the atmosphere. In other words, carbon sinks are natural or man-made systems that absorb and store carbon dioxide from the atmosphere (UNFCCC, 1992; Tuğluer & Oğuz, 2022).

The global ecosystem is a large carbon sink and generally has major impacts on carbon reduction and mitigation of global warming. The world's carbon sinks are oceans, soil, and forests. It has been reported that approximately 2030–2538 Pg of carbon is stored in the global terrestrial ecosystem, including 508–609 Pg in vegetation and 1523–1929 Pg in the top 1 m of soil (Li et al., 2021).

One of the most important sources of carbon sinks is natural carbon sinks, largely provided by vegetation, water, and soil. The areas with the highest greenhouse gas emissions are urban areas. Therefore, it is important for greenhouse gases, especially carbon dioxide, to be captured and stored by carbon sinks in cities. Plants, which are the main component of urban open green spaces, have many benefits such as providing habitat for wild animals, regulating micro-climate, reducing air pollution, erosion control, noise reduction, energy saving, space creation, positive contributions to urban aesthetics, as well as carbon sequestration (Gülçin & Van Den Bosch, 2021; Çorbacı & Ekren, 2021).Trees take in carbon dioxide through the biochemical process of photosynthesis and store it as carbon in the trunk, branches, leaves, roots, and soil. There are two important carbon sinks on Earth in terms of carbon sequestration. The first of these is terrestrial ecosystems, and the other is the oceans. On a global level, 19% of the carbon in terrestrial ecosystems in the world is stored in plants and 81% in soil. In forests, approximately 31% of the carbon is stored in biomass and 69% in soil. In tropical forests, approximately 50% of the carbon is stored in biomass and 50% in soil. In cities, where carbon dioxide emissions are highest, green areas undertake this function (Nakicenovic et al., 2000; Karakuş, 2010; Tuğluer & Oğuz 2022). Carbon sequestration is the process of capturing (via photosynthesis) and storing atmospheric carbon dioxide (CO_2) for the long term. Plants take carbon into their cells and release oxygen (O_2) back into the atmosphere. Forests and soils sequester atmospheric CO_2 in their biomass or organic matter stored in the soil. Approximately 50% of dry tree biomass is carbon. Biomass can be any part of tree tissue, living or non-living, such as the trunk, branches, leaves, or roots (Malhi et al., 2002).

The imbalance between anthropogenic carbon emissions and vegetation carbon sequestration exacerbates climate change. A great deal of research is being conducted to identify ways to reduce anthropogenic carbon emissions and increase the carbon sequestration capacity of terrestrial ecosystems. These studies have mostly focused on ways to reduce anthropogenic carbon emissions or increase vegetation carbon storage

(IPCC, 2024). Green areas, which are an important component of terrestrial ecosystems, play a vital role in regulating the carbon balance. Vegetation absorbs and fixes carbon through photosynthesis, and this process constitutes the most important natural carbon sink. Increasing the carbon sink function of vegetation is an effective way to reduce the increase in atmospheric CO_2. Green areas and plants in these areas reduce the amount of greenhouse gases by storing carbon and make positive contributions to achieving the net-zero carbon target (Wei et al., 2022, Tuğluer & Oğuz, 2022).

3. Urban Green Spaces in the Net-Zero Carbon Target

Urban green spaces provide ecosystem services such as biodiversity and climate regulation. A comparison of the effects of green space on air quality and heat shows that a greater prevalence of trees reduces urban heat islands, provides thermal comfort, and improves air quality. Green spaces improve air quality in urban environments by reducing urban heat islands and air pollution (Vargas-Hernández et al., 2023; Dönmez & Çakır, 2016).

In addition, urban green spaces play an important role at environmental and ecological levels in improving air, soil, and water quality, reducing noise levels, reducing thermal amplitude changes, protecting against winds, reducing erosion processes, managing waste, improving rainwater infiltration and drainage, reducing flood risks, and promoting biodiversity (Quintas & Curado, 2009; Çorbacı & Ekren, 2022).

In addition to being the main source of greenhouse gas emissions, green spaces within the city also play a role in reducing emissions. The most important carbon sinks in cities are urban green spaces and trees in these areas. In this context, the use of urban trees and forests as a resistance factor against global warming is based on a strong infrastructure. Urban trees serve as an important carbon sink in the city (Tuğluer, 2023). Studies show that calculating carbon emissions and sequestering carbon in urban areas is an important tool in achieving the net-zero carbon target. In this context, studies are accelerating day by day to numerically determine the carbon sequestration capabilities of urban green areas. For this purpose, the importance of green areas in urban areas has begun to be understood to a large extent.

4. Conclusion and Suggestions

The net-zero carbon target is an indispensable step in the fight against global climate change. Carbon emissions, which have been increasing rapidly since the Industrial Revolution, have led to climate change worldwide, which has significantly affected both ecosystems and human life. The rapid increase in urbanization has further increased carbon emissions and large cities have become one of the largest sources of these emissions. In this context, cities need to develop effective policies and sustainable practices that will reduce carbon emissions (Çakır & Dönmez, 2018). Urban green areas play a critical role in this context. Green areas and urban trees are of great importance not only for improving the quality of urban life, reducing air pollution, strengthening water retention capacity, and supporting biodiversity but also for their carbon retention capacity. Urban green areas function as natural carbon sinks in terms of ensuring carbon balance in cities. Expanding and protecting these areas is a critical element in achieving the global net-zero carbon target. However, expanding these areas should be a priority not only for their environmental benefits but also for their positive effects on the physical and mental health of urban residents. Increasing green areas enables people living in cities to become more resilient to the negative effects of climate change.

However, achieving the carbon neutrality goal should not be limited to increasing urban green areas alone. Other strategic steps, such as increasing energy efficiency, expanding the use of renewable energy sources, and reducing the use of fossil fuels, should also be implemented simultaneously. In this process, strong cooperation between governments, the private sector, and civil society organizations is essential. Governments should make the necessary legal arrangements for sustainable urban planning and the protection of green areas, while the private sector should contribute to this process by developing low-carbon technologies. In addition, raising awareness in all segments of society will enable individuals and communities to effectively participate in the fight against climate change.

As a result, increasing and protecting urban green areas is of central importance to achieving the net-zero carbon target. In addition to increasing the carbon retention capacity of cities, green areas also greatly contribute to the sustainability of urban life. However, to achieve this goal, in addition to increasing green areas, multifaceted strategies such as energy efficiency, the use of renewable energy sources, and the development of sustainable transportation systems should be implemented together. Public and private sector collaboration, dissemination of awareness activities, and strengthening of legal regulations are also integral parts of this process. Achieving the net-zero-carbon target will only be possible with the integrated implementation of all these strategies. In this process, the fulfillment of the responsibilities of all stakeholders will play a key role in achieving the global target of net-zero carbon.

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Author Contribution and Conflict of Interest Declaration Information

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Using Biodiversity and Some Ecological Parameters for Sustainability of Protected Areas

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1. Introduction

Protected areas are areas of land or sea designated to conserve and manage natural resources, biodiversity and cultural heritage. These areas are set aside to protect the environment, provide wildlife refuge, and maintain ecosystem services that benefit human communities. There are many studies on the sustainability of protected areas (Aydın, 2005; Aydın, 2006; Aydın & Kazak, 2010; Aydın, 2011a; Aydın, 2018; Aydın & Demir, 2020; Silay et al., 2021). In addition, many scientific studies prove that human activities and some ecological factors such as global climate change cause habitat destruction, increase the risk of extinction of endemic species and reduce the species richness in the ecosystem (Şekeroğlu & Aydın, 2002; Lillig & Aydın, 2006; Aydın & Avcı, 2010; Aydın, 2011b; Dinç Ortaç et al., 2015; Aydın & Karaca, 2018). Biodiversity parameters are among the most used ecological parameters for the sustainability of protected areas and their transfer to future generations without degradation (Aydın & Karaca, 2009; Aydın, 2021; Oğuz, et al., 2021). In addition to biodiversity, it is also important to use ecological parameters to determine biological indicator species (Aydın et al., 2005; Arndt, et al., 2005; Aydın & Kazak, 2007). Species richness estimators are ecological parameters used to test whether the species sampled in the habitat and even the number of species individuals were taken correctly or not (Aydın & Şen, 2020). These ecological parameters highlight three major parameter networks essential for ensuring the sustainability of the protected areas.

But can biodiversity parameter values sometimes mislead us? Can biodiversity values sometimes make habitats seem higher and more protected than they actually are? What should be done to eliminate this mistake? The primary goal of this section is to offer insight into the about the mentioned ecological parameters as well as how to use them.

1.1. Brief Information About Protected Areas

In short, protected areas are protected by certain regulations and classified according to their intended use. The main mission is to ensure these ecosystems are transferred to future generations without damage.

Protected areas are categorized based on their level of protection and intended use. This classification is generally as follows:

National Parks: Large natural areas reserved to protect the ecological integrity of ecosystems and ensure their sustainability, and to provide educational and recreational opportunities (e.g.: Yellowstone, Rocky Mountain, Yosemite, Acadia, Grand Teton, Joshua Tree, Grand Canyon, Yumurtalık Lagun, Kazdağları, Kızıldağ, Kovada, Küre Mountains, etc).

Nature Park: Natural parts suitable for public recreation and entertainment within the integrity of the landscape, with vegetation and wildlife characteristics (e.g.: Uluru-Kata Tjuta, Yosemite, Cinque Terre, Fuji-Hokone-Izu, Galapagos, Kruger, Karataş, Frig Valley, Sultandağı, Kurşunlu Waterfall, etc).

Nature Monument: Natural parts with characteristics and scientific value created by nature and natural events and protected within the principles of national parks (e.g.: Zeytintaşı Cave, Kocain Cave, Yüzen Adalar, Nemrut, Samandere Waterfall, etc).

Nature Conservation Area: Natural parts containing rare, endangered or on the verge of extinction ecosystems, species and outstanding examples of natural events that are important in terms of science and education, and that require absolute protection and are reserved for use only for scientific and educational purposes (e.g.: Marae Moana, French Southern Territories).

Wildlife Development Area: Areas where game and wild animals and wildlife are protected, developed, game animals are settled, habitat improvement measures are taken and hunting can be done within the framework of a special hunting plan when necessary (e.g.: Gavurdağ, Giden Gelmez Mountain, Kızılkuyu, etc).

Nature Reserves or Wildlife Protection Areas: Areas managed for the protection of certain species or the habitats of these species. They usually have stricter protection measures than national parks and restrict human activities more severely (e.g.: forest of Aulanko, Alam-Pedja, Yob Wildlife, etc).

Marine Protected Areas (MPAs): These are areas designated for the protection of marine species and ecosystems. MPAs can be opened to sustainable resource use or closed to certain activities (purse seine, trawling, diving, etc.) or all activities. These areas, which are representatives of healthy seas, ensure their sustainability by protecting natural and cultural values and supporting local economies with effective management (e.g.: Ross Sea Region Marine Protected Area, Papahānaumokuākea Marine National Monument, etc).

Biosphere Reserves: These are areas that combine the protection and sustainable use of natural resources. These areas include core protected areas, buffer zones and transition areas where sustainable practices are encouraged (e.g.: Çukurova delta, Atlantic Forest Biosphere Reserve, etc.).

Conservation Rights: These are legal agreements that permanently limit the use of land to protect conservation values.

World Heritage Sites: These are places recognized by UNESCO as having cultural, historical, scientific or other forms of importance and legally protected by international agreements (e.g.: Nemrut Mountain, Hierapolis, City of Safranbolu, Neolithic Site of Çatalhöyük, Pergamon, Ephesus, Göbekli Tepe, etc).

Ramsar Sites: These are wetlands of international importance designated under the Ramsar Convention, which aim to protect and use wetlands and their resources wisely (e.g.: Rio Negro, Ngiri-Tumba-Maindombe, Aulnaie de Aïn Khiar, Riviere Sangha, Loubetsi-Nyanga, Tana River Delta, Göksu Delta, Lake Burdur, Akyatan Lagoon, etc) (European Commission, 1992; European Environment Agency, 2009; European Commission, 2021a; 2021b; 2021c).

Sample of two important protected regions of threatened: terrestrial and marine.

The Amazon rainforest is one of the world's largest biodiversity centers. However, due to threats such as deforestation and wildfires, its protection is critical. International cooperation and sustainable management strategies support efforts to protect the Amazon. **The Great Barrier Reef** is an important area for marine biodiversity conservation and faces threats such as climate change and pollution. Conservation projects are supported by strategies such as the establishment of marine protected areas and sustainable fishing practices.

Protected areas are crucial for; biodiversity conservation, ecosystem services (e.g. water purification, climate regulation, and soil fertility), cultural and recreational values, and research and education (Gardoni et al., 2020).

2. Biological Diversity and Its Measurement

The definition of biological diversity refers to the variety and variability of life on Earth. It includes mostly three main components. (i) *Genetic Diversity* (diversity within species): It refers to the variety of genetic information within species. This diversity includes the DNA differences among individuals within a single species and the differences among populations of the same species. (ii) *Species Diversity* (diversity between species): It refers to the variety of species within a habitat or region. This diversity, which is often used by ecologists, includes the number of different species within an ecosystem and the abundance of each species. (iii) *Ecosystem Diversity* (diversity between ecosystems): It refers to the diversity of ecosystems within a given area. This diversity includes different habitats, biotic communities and ecological processes, and the diversity in many different ecosystems.

If the number of species found in a single habitat is determined locally, this situation is expressed as "alpha diversity". In short, it is the diversity that expresses the number of species found in a single habitat. While beta diversity is the ratio of species found among local habitats (the degree of diversity present among different habitats of an ecosystem), gamma diversity refers to the diversity in a large region formed by the combination of many habitats and therefore more sample areas (the species diversity of a community consisting of more than one habitat).

Biodiversity is crucial for ecosystem health and stability. Biodiversity indices provide valuable information about the health, diversity and sustainable of protected areas, which can guide conservation and management efforts. By regularly calculating biodiversity indices such as species richness, Shannon-Wiener Diversity Index, and Simpson's Diversity Index, managers can monitor changes in biodiversity over time. Moreover, detecting declines in biodiversity early can prompt timely interventions to address issues by managers such as habitat degradation, pollution, or invasive species. Based on the results from biodiversity indices, management practices can be adjusted to better meet conservation goals. Biodiversity indices can be used to assess the effectiveness of different management practices, such as habitat restoration, controlled burns, or species reintroductions. Regular biodiversity assessments in protected areas can help adapt management practices to changing conditions, such as climate change or increased tourism. Monitoring biodiversity in MPAs can guide sustainable fishing practices and protect critical habitats like coral reefs. Biodiversity indices can help identify species that are critical for ecosystem functioning, guiding efforts to protect these keystone or umbrella species.

By using biodiversity indices as tools for monitoring, planning, and evaluating conservation efforts, natural protected areas can be managed more sustainably, ensuring the long-term preservation of biodiversity and ecosystem services.

Reliable data collection is essential for accurate biodiversity indices. This requires adequate funding, trained personnel, and consistent methodologies. Biodiversity is influenced by a complex interplay of factors. Indices provide a snapshot, but understanding the underlying causes of changes in biodiversity requires comprehensive ecological studies.

Threats to biodiversity include habitat destruction, pollution, climate change, invasive species, and overexploitation of resources. Protecting biodiversity is essential for maintaining ecosystem services, which are vital for human survival and well-being.

Several metrics and indices are used to quantify biodiversity, each capturing different aspects of diversity. Here are some common methods and indices (diversity, dominance, evenness, and similarity):

Species diversity calculations

Shannon-Wiener and Simpson diversity indices are given as examples in determining species diversity.

Shannon-Wiener diversity index;

$$H' = -\sum p_i \ln(p_i)$$

pi: The ratio of the number of individuals of the ith species to the total number of individuals

ln: It gives the base of the natural logarithm (Magurran, 1988; Magurran, 2004).

Simpson diversity index;

$$S = 1 - \sum n_i(n_i - 1) / N(N - 1)$$

i: Number of species

ni: Number of individuals belonging to a species

N: It shows the total number of individuals of species in a region (Magurran, 1988, Magurran, 2004).

Dominance calculations

Simpson dominance index is given as an example in determining dominance.

Simpson dominance (D)

$$D = \sum n_i(n_i - 1) / N(N - 1)$$

i: Number of species

ni: Number of individuals belonging to a species

N: Shows the total number of individuals of species in a region (Magurran, 1988, Magurran, 2004).

Population density relationship calculations

Shannon Evenness and Simpson Evenness indices are given as examples in determining the population density relationships of species.

Shannon Evenness (EH)

$$EH = H' / \ln(N)$$

H': Shannon-Wiener diversity index

ln: Natural logarithmic

N: Shows the total number of individuals of species in a region (Magurran, 1988, Magurran, 2004).

Simpson Evenness (ES)

$$Es = (1/D) / S$$

1/D: Simpson diversity index

S: Shows the total number of species (Magurran, 1988, Magurran, 2004).

Similarity indices

Sörensen and percentage similarity indices are given as examples in determining similarity relationships.

Sörensen similarity (Bs)

$$Bs = 2C / A + B$$

A: Number of species in habitat A

B: Number of species in habitat B

C: Indicates the number of common species obtained from habitats A and B (Southwood, 1971; Magurran, 1988; Krebs, 1999; Magurran, 2004).

Percentage similarity (%S)

$$\%S = \sum \min(a, b, ...x)$$

min: It represents the sum of the smallest values calculated for percentage ratios within the habitat and the smallest values in the other habitat whose similarity is calculated (Krebs, 1999).

3. Bio-Indicator Species

The negative effects of human activities on insects and nature have been clearly demonstrated by studies (Aydın & Kazak, 2007; Aydın, 2011c; Aydın & Karaca, 2011). For a sustainable world, ecological balance and biodiversity must be protected. Different biotope types reflect different ecological and environmental conditions, thus different components of biodiversity. When human activities are included in all of these, the presence or absence, scarcity or abundance of these components can be used as indicators of these activities.

The Indicator Species Analysis (ISA) is done to explore the associated groups of species (Dufrêne & Legendre, 1997). The calculation of ISA is as follows:

(1). The proportional abundance of a particular species in a group was calculated relative to the abundance of that species in all groups. It was expressed as a percentage and the intermediate result was displayed.

Let:

A = sample unit x species matrix

aijk = abundance of species j in sample unit (SU) i of group k

nk = number of sample units in group k

g = total number of the groups.

Firstly, the mean abundance xkj of species j in group k is calculated:

$$xkj = \sum_{i=0}^{nk} aijk / nk$$

Then the relative abundance RAkj of species j in group k is calculated:

$$RAkj = xkj / \sum_{k=1}^{g} xkj$$

(2). The proportional frequency of species in each group was calculated (i.e., the percentage of sample units in each group that contain that species). It was also expressed as a percentage and the intermediate result was displayed.

Firstly, A is transformed into a matrix of presence absence B:

1,5

$$bij = a_{ij}^{0}$$

Then relative frequency RFkj of species j in group k is calculated:

(3). The two proportions calculated in steps 1 and 2 are combined by multiplying them. The result is expressed as a percentage, yielding an indicator value IVkj for each species j in each group k.

(4). The highest indicator value (IVmax) for a given species across groups is saved as a summary of the overall indicator value for that species.

(5). The statistical significance of IVmax by using the Monte Carlo method is evaluated. The SU's were randomly reassigned to the groups a large number of times (default=1000). Each time, IVmax was calculated. The probability of type I error is based on the proportion of times that the IVmax from the randomized data set equals to or exceeds the IVmax from the actual data set. The null hypothesis is that IVmax is no larger than it would have been expected by chance (i.e., that the species has no indicator value) (Aydın & Kazak, 2010).

Biological indicator species are defined as species that can provide information about ecological changes and provide early warning signals about ecosystem processes due to their sensitive responses to ecosystem processes in conditions specific to a particular region (McGeoch & Chown, 1998). Threats to biodiversity include habitat destruction, pollution, climate change, invasive species, and overexploitation of resources. Biological indicator species can be positively or negatively affected by these ecological factors. Some species are better indicators than others (Dufrêne & Legendre, 1997; New, 1998).

4. Species Richness Estimators

Species estimators have been used for many years to estimate species richness in habitats and to determine the duration of the sampling method applied in the habitat. Species richness estimators are measured with many different parameters. Some of these are:

Chao 1 type estimators (for abundance data) (Chao, 1984; Colwell & Coddington, 1994):

$$S_{Chao\,1} = S_{obs} + F_1^2/2F_2$$

where S_{obs} is the observed number of species, F_1 is singletons (species with only one individual), and F_2 is doubletons (species with only two individuals) (Chao, 1984; Chazdon et al., 1998).

Chao 2 type estimators (for replicated incidence data) (Chao, 1987; Colwell & Coddington, 1994).

$$S_{Chao\,2} = S_{obs} + Q_1^2\,/2Q_2$$

where Q_1 is the frequency of uniques and Q_2 is the frequency of duplicates.

Jackknife 1 type estimators (for abundance data) (Burnham & Overton, 1978, 1979; Heltshe & Forrester, 1983)

$$S_{Jack\,1} = S_{obs} + Q_1\,(m - 1/m)$$

where m is the total number of samples.

Jackknife 2 type estimators (for incidence data) (Smith & van Belle, 1984).

$$S_{Jack\,2} = S_{obs} + \left(\frac{Q_1(2m-3)}{m} - \frac{Q_2\,(m-2)^2}{m(m-1)}\right)$$

Bootstrap type estimators (based on repetition) (Smith & van Belle, 1984).

$$S_{boot} = S_{obs} + \sum_{k=1}^{S_{obs}} (1 - p_k)^2$$

where p_k is the proportion of samples that contain species k.

ACE (abundance coverage estimator) type estimators (for abundance data) (Chao & Lee, 1992; Chao et al., 1993).

$$S_{ace} = S_{abund} + \frac{S_{rare}}{C_{ace}} + \frac{F_1}{C_{ace}} Y_{ace}^2$$

where S_{abound} is the number of abundant species (each with more than 10 individuals) when all samples are pooled, S_{rare} is the number of rare species (each with 10 or fewer individuals) when all samples are pooled, C_{ace} is the sample abundance coverage estimator and Y^2_{ice} is the estimated coefficient of variation of the F_i for rare species

ICE (incidence coverage-based estimator) type estimators (for incidence data) (Lee & Chao, 1994).

$$S_{ice} = S_{freq} + \frac{S_{\inf r}}{C_{ice}} + \frac{Q_1}{C_{ice}} Y_{ice}^2$$

where S_{freq} is the number of frequent species (each found in more than 10 samples), $S_{\inf r}$ is the number of infrequent species (each found in 10 or fewer samples), C_{ice} is the sample incidence coverage estimator and Y^2_{ice} is the estimated coefficient of variation of the Q_i for infrequent species.

5. Could Biodiversity and/or Other Ecological Parameters Giving Us Misleading Results?

Biodiversity parameters measured in the short term may give us misleading results. Especially in protected areas, no results may be obtained from biodiversity parameters measured without periodicity. For example, biodiversity parameters measured for the sustainability of protected areas may show the ecological factor effect occurring in protected areas as having increased positively. This result may also mislead us in the short term. In order to prevent this illusion, biodiversity parameters should be measured in the long term, especially in protected areas. Biodiversity values measured in the long term will react numerically to the slightest change or effect in protected areas and will show decreasing or increasing curves. These curves are tested using biological indicator species and indispensable species richness estimators, and the increase or decrease in the fluctuation curve can be evaluated according to years.

In a study about to be published, beta diversity results were measured every year in habitats selected as two natural juniper and two pine afforested areas and reflected on the graph. However, in the 3rd year of the study, the habitat selected as the natural juniper ecosystem was afforested with pine. In the afforested juniper ecosystem, the biodiversity parameters showed an extraordinary increase on the graph for 3 years, but after the 4th year, this rising curve suddenly decreased and became the weakest ecosystem in terms of biodiversity.

The reason for this can be explained by Aydın & Kazak Principles. When the habitat changes, some species are negatively affected by this change and leave the habitat (migration). Some species are positively affected by this change and these species that were not seen in this habitat before migrate from outside to inside (immigration). The second effect is the effect of population fluctuations in the species in the habitat. Some species are positively affected by this change and their populations increase. However, some species are negatively affected by this change and their populations decrease. The third phenomenon is lack of interaction. Some species are not affected by this change in the habitat.

In the example study, the reason for the sudden increase in species richness and diversity of the juniper ecosystem, which was later afforested with pine species, after afforestation can be explained as follows;

(i) Some species are positively affected by the change and increase in species richness due to their migration from outside to inside,

(ii) Some species whose individual numbers were previously measured to be very low compared to others are positively affected by the change and increase their populations in the habitat and approach the individual numbers of other species, creating a balance in the habitat,

(iii) The populations of dominant species that are negatively affected by the change decrease due to this effect and the populations of species living in the habitat are balanced.

The measured biodiversity parameters may be increasing due to these and similar reasons. However, the measurement of biodiversity parameters continued in the study and it was observed that the diversity in the mentioned habitat suddenly decreased. The reasons for the sudden decrease in species richness and diversity over the years can be explained as follows;

(iv) some species are negatively affected by the change and their migration from outside to inside results in a decrease in species richness

(v) Some species whose individual numbers were previously measured balanced compared to others are negatively affected by the change and their populations decrease in the habitat and their individual numbers are measured much lower than the individual numbers of other species, creating an imbalance in the habitat in terms of population density,

(vi) The populations of species positively affected by the change increase due to this effect and become dominant by being measured more than the populations of species living in the habitat (Figure 1).

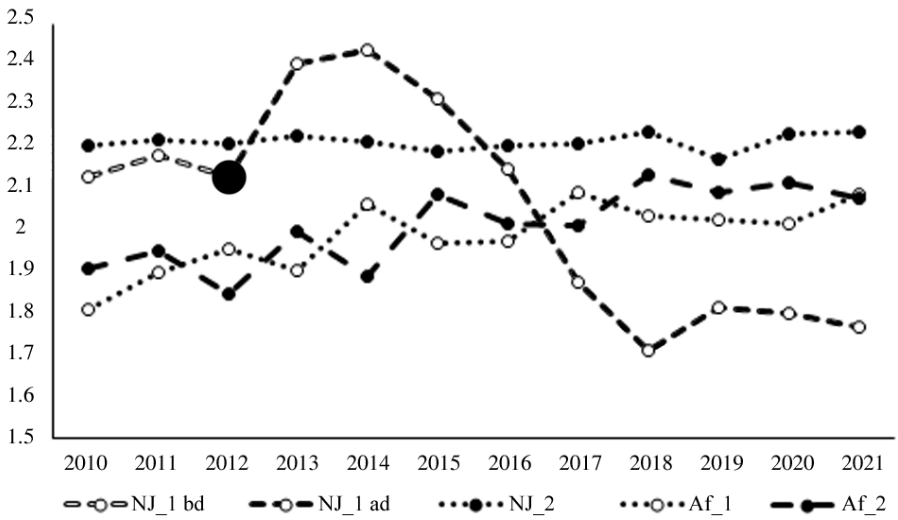

Figure 1. Shannon-Wiener diversity results calculated with the data obtained from the pitfall trap sampling method in NJ_1, NJ_2, Af_1 and Af_2 between 2010 and 2021. (bd: before degradation; ad: after degradation in which the NJ_1 afforested with *Pinus* spp.). (The largest solid black circle mark indicates the year in which the NJ_1 afforested with *Pinus* sp) (Aydın & Kazak, 2024-in press).

6. Conclusion and Suggestions

(i) In the use of ecological parameters such as biodiversity and determination of biological indicator species in nature conservation studies, absolute species estimators should also be used, and protection strategies should be developed by determining most of the species living in the habitat.

(ii) Biodiversity parameters measured in short periods may not reflect the correct values for that habitat. For this reason, the mentioned ecological parameters provide benefits as a result of long-term studies and can be useful in habitat protection. Biodiversity measurements may not mean anything until they reach a standard curve for many years.

(iii) Biodiversity parameters measured in the long term and showing a standard curve can be proven by the up and down fluctuation of the curve whether the slightest change in the habitat will be beneficial for the habitat.

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Testing Chemical and Organic Fertilizers in the Maize-Growing Lands in Türkiye

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1. Introduction

Today, strategic actions are envisaged to reduce the negative effects of climate change, which is accepted as a global problem, and to reduce carbon emissions in the adaptation process. In this context, one of the strategic actions in order to ensure food security and sustainability, food supply, production, cultivation, feeding, marketing and supply, cost, etc. It has made it necessary to reconsider food policies in rural and urban areas. In this context, practices such as organic agriculture, ecological agriculture, nature compatible agriculture, urban agriculture, agroforestry systems, carbon farming have come to the fore (Gül, 2022; Yücedağ et al., 2023).

The ever-increasing world population and the associated food and nutritional requirements have brought new dimensions to agricultural inputs and methods. The correct treatment and use of soil, which plays an important role in agricultural activities, is of great importance in terms of increasing its functionality and passing it on from generation to generation. The way to achieve this is to be able to use this material as much as possible according to its purpose and without damaging it. In plant production in Türkiye, one of the main elements that can be considered the most important occupation and increase the cost of production is plant nutrition activities. Plants need certain conditions such as suitable light, temperature, air, water and soil to maintain their vital activities. They obtain C, H, and O from air and water, and other nutrients from soil (Dinç, 2008).

The fertilization process in plants is a cultural practice that has an important effect on the healthy life of plants and they need to be fertilized periodically. In the fertilization process, the type of fertilizer, the amount of fertilizer, the time of fertilization, and the method of application are of great importance, especially considering many factors (such as the type of seedling material to be used, the purpose of use, the maturation and biological characteristics, the ecological requirements and the growing environment conditions of the planting site, etc.) (Gezer & Gül, 2009). The positive effects of organic compounds in soils are listed as follows (Karaçal, 2004). Forming organic structure with plant nutrients (Kileyt), increasing soil microbiological activity, increasing nutrient uptake of plants, especially nitrogen, phosphorus and sulfur uptake, increasing the solubility of minerals and providing the release of plant nutrients, increasing plant nutrient uptake by stimulating root cells, improving soil structure, increasing soil water holding capacity. Among these factors, soil organic matter has an important place.

Soil fertility is the ability of the soil to provide basic plant nutrients in sufficient quantities and appropriate proportions to sustain plant growth. When examined the general soil factors affecting soil fertility, it can be seen that they are soil water, soil texture, soil air, soil temperature, soil reaction, soil organic matter, biological properties of soil, plant nutrient amounts and ratios, soil plant water relations, colloidal properties of soil, cation and anion exchange in soil, soil salinity etc. When there are not enough nutrients in the soil for plant nutrition, supplementary nutrients are added to the soil. In the researches carried out up to today, it has been observed and known that methods away from scientific methods and based on traditional understanding are applied for the majority of the productions in Türkiye.

1.1. Plant nutrition and its stages

Plant nutrition is the process of supplying the plant with the plant nutrients needed by the grown crop material in various ways and methods during the process from seed to harvest in production activities. Plant nutrients can be found in soil as (1) salts, (2) adsorbed or exchangeable on organic and inorganic surfaces, (3) in the interlayers of clay minerals, (4) in organic matter, (5) in soil biomass, (6) immobile as building blocks of silicates, and (7) bound (occluded) in iron and manganese oxides. On the other hand, the loss of nutrients in soil occurs in the form of (1) uptake by plants, (2) washing away, (3) erosion, (4) immobilization, (5) gaseous (N_2, NH_3, nitrous oxide) atmospheric pollution as in the case of nitrogen (Özbek et al., 2001). According to the needs of plants, nutrients are divided into macro and micro elements. Macro nutrients are elements that are more needed by plants than micro elements. For this reason, micronutrients are also called minor or trace elements. Macro elements are named as C, H, O, N, P, K, Ca, Mg, S according to the needs of plants. Of these, C, H and O are taken from water or air and under growing conditions these elements do not have an effective limiting role on plant growth like other macronutrients. The other elements are mainly absorbed from the soil and their usefulness to the crop material varies according to the form in which they are present in the soil and the texture and structure characteristics of the soil (Table 1).

Table 1. Classes of essential nutrients for plants (Kacar & Katkat, 2010 with reference to Bergmann, 1992)

Nutrient Elements		
Basic Elements in Organic Matter	**Macronutrients**	**Micronutrient Elements**
C	**N S**	**B Cu (Al)°**
H	**P Ca**	**Cl Fe (Co)**
O	**K Mg**	**Mo Mn (Na)**
		Zn (Ni)
		(Si)
		(V)

As it can be seen from Table 1.2, it is noticeable that macro and microelements, which are accepted as useful to the plant, have different atomic weights, dry matter contents and the way they are useful to the that they undertake different tasks in different processes during the vegetative phase of plants. All of the elements given in the table are essential elements. On the other hand, there are also elements such as sodium (Na), cobalt (Co) and silicon (Si), which are commonly found in certain ratios in the structure of most plants but are not necessarily required for plant growth and development (Arnon & Stout, 1939; Gardiner & Miller, 2008; Fageria, 2009).

According to Epstein & Bloom (2005), there are two criteria for a plant nutrient requirement. First, the nutrient must form part of a molecule that is an essential part of plant metabolism or structure. Secondly, the abnormal growth and development of the plant are due to the lack of nutrients in the environment in which the plant grows, while the normal growth and development of the plant occurs in the presence of nutrients. The plant nutrients in Table 2. are essential for some plants and not essential for others.

Table 2. Plant nutrients and some of their properties (Epstein & Bloom, 2005)

Element			Content in dry matter		
	Symbol	Atomic weight	%	ppm	Usefulness to plants
Hydrogen	H	1.0	6		H2O
Carbon	C	12.0	5		CO2
Oxygen	O	16.0	45		O2, H2O
Nitrogen	N	14.0	1.5 (1-5)		NO3 , NH4
Potassium	K	39.1	1.0		K+
Calcium	Ca	40.1	0.5 (0.2-1)		Ca2+
Magnesium	Mg	24..3	0.2 (0.1-0.4)		Ca2+
Phosphorus	P	30..1	0.2 (0.1-0.5)		H2PO4 , HPO4
Sulfur	S	32.1	0.1 (0.1-0.4)		SO4
Chlorine	Cl	35.5		100 (100-1000)	Cl^-
Boron	B	10..8		20 (6-60)	BO3 , B4O7
Iron	Fe	55.8		100 (50-250)	Fe^{2+}, Fe^{3+}
Manganese	Mn	54.9		50 (20-200)	Mn2+
Zinc	Zn	65.4		20	Zn2+
Copper	Cu	63.5		6	Cu^+, Cu^{2+}
Nickel	Ni	58.7		0.05	Ni2+
Molybdenum	Mo	95.9		0.01	MoO4

1.2. Fertilization in organic farming and its effect on carbon emissions

Studies have shown that excessive chemical use has a direct positive effect on activated carbon, particulate organic carbon, microbial components and biomass carbon, which constitute the organic carbon components of the soil. However, it has been determined that plants grown under organic fertilizer applications bind more carbon from the atmosphere to the soil through the photosynthesis mechanism than plants grown under inorganic applications and are transported to the soil through the roots (Ortaş & Sarıyev, 2019). Organic fertilization can be described as the conversion of plant and animal residues or wastes into a form that can be used in plant production after being subjected to certain processes and making them applicable. In addition to this structure, green fertilizers are also made by mixing the plants grown for fertilization into the soil. Microbial fertilization, in which plant nutrients are added to the soil as a result of the activities of microbial organisms present in the soil, is included in the classification of organic fertilizers.

Organic agriculture briefly means all kinds of agricultural activities carried out by protecting soil parent material, water resources and climatic inputs in order to grow healthy products. Fertilization methods in organic agriculture are of particular importance. Because in sustainable agriculture, protecting the soil parent material and transferring its functionality from generation to generation can be realized with organic fertilization and methods. All kinds of organic and inorganic practices in agricultural activities have a serious impact on the carbon cycle in the soil and atmosphere. Regarding the negative effects of climate change and global warming, the states of the world have come together at the United Nations and accelerated their work and it has been decided to make their own carbon budgeting on a state-by-state basis. Each country is making intensive efforts to prevent carbon losses, especially in their lands, and to preserve the existing carbon. Due to this issue, which has been on the agenda frequently in Türkiye in recent years, ways are being sought to minimize the carbon loss in our soils and to eliminate the negativities that may arise from plant nutrition activities carried out with a traditional understanding. In particular, it should be ensured that the amount of carbondioxide released into the atmosphere is reduced, the existing carbondioxide is captured by agricultural production and natural means, and that it is returned to the soil and carbon losses are prevented.

In agricultural activities (soil, fertilizer, pesticide and climatic requirements) should be correctly determined and feeding should be done, synthetic origin fertilizers and inorganic products, that will damage the soil parent material, affect the texture and structure, and accumulate residues, should be avoided as much as possible during the feeding phase. Soils in Türkiye are generally poor in organic matter. This has a direct negative effect on productivity. In order to increase the productivity of soils poor in organic matter, soils must be enriched in terms of organic matter (OGM, 1986). Compost, green manure and other organic fertilizers should be preferred instead of artificial fertilizers unless it is compulsory, and especially the use of compost formed from various organic residues increases productivity (Akgül, 1985; Çiçek et al., 2021; Çiçek &Yücedağ, 2021; Çiçek et al., 2022; Çiçek et al., 2023; Çiçek &Yücedağ, 2023).

Animal manure is the fertilizer that provides the best nutrients on soil structure and soil texture. If it is properly applied to the soil, it is preferred because it has better nutrient content than commercial fertilizers and is economical. When animal manure is applied to the soil; it enriches the soil in terms of nitrogen, phosphorus, potassium and sulphur and increases the water holding capacity of the soil (Kaçar & Katkat, 2009).

In accordance with the regulations published in the Official Gazette No. 22145 of 1994, the principles of fertilization methods for organic agriculture should be followed. Studies have shown that plants grown with organic fertilizer applications bind more carbon from the atmosphere to the soil through the photosynthesis cycle than plants grown as a result of inorganic applications and are transported to the soil through the roots (Ortaş & Sarıyev, 2019). In the same study, it was concluded that as the water use efficiency increases, more carbon dioxide is bound from the atmosphere through photosynthesis due to more development of plants. As a result of global climate changes, the low level of carbon amounts in the soils of Türkiye has become a more serious problem with the traditional understanding and excessive chemical fertilization and feeding methods.

In agricultural activities and practices, one of the main objectives is to maintain the level of organic carbon in the soil and prevent it from falling below critical levels. Therefore, maximum attention should be paid to the plant nutrient element contents applied in the feeding activities. Various studies have shown that chemical inputs used in excessive amounts reduce the content of soil microbial carbon in soils where production is carried out. When only NPK fertilizer is used (Kapoor, 2006) and when it is mixed with farmyard manure, it increases the microbial carbon content in the soil (Manna et al., 2006, Sekhon et al., 2009 and Bhattacharya et al., 2011).

In another study conducted by Başak et al. (2012), it was determined that barnyard manure increased soil microbial carbon content more compared to the soils determined as control. Yuan et al. (2013) and Liang et al. (2012) showed in their studies that NPK fertilizer alone is not sufficient to increase the amount of organic carbon in soil. The application of compound fertilizers with green manure was found by Sekhon et al. (2009) to significantly increase the organic carbon concentration in soil. It was reported by Manna et al. (2006) that nitrogen decreased the organic carbon content in soil from mineral fertilizer applications, and Antil & Singh (2007) reported a decrease in the amount of phosphorus. Ortaş & Lal (2014) determined that organic carbon content was higher in soils where organic fertilizers were applied compared to soils where inorganic fertilizers were applied.

1.3. Soil carbon cycle

Various biotic and abiotic events cause carbon to move through the atmosphere, earth, water and living organisms. These are realized through events such as photosynthesis, decomposition, erosion, burning, respiration and nutrition, which is called the carbon cycle. If this cycle is disrupted and disrupted, it can lead to climate change, loss of biodiversity and other environmental problems. Climate change is one of the most important consequences of disrupting the carbon cycle. Increasing greenhouse gas emissions leads to an increase in the amount of carbon dioxide in the atmosphere. Many soil-oriented activities, especially in agricultural practices, can disrupt this cycle. Various measures are considered for the high amount of CO_2 in greenhouse gases released into the atmosphere, which is touted as one of the major problems today. The gases and especially the amount of carbon dioxide released into the atmosphere as a result of agricultural activities have reached threshold values that pose a serious danger. The level of carbon dioxide emitted from the soil to the atmosphere is directly related to fertilization, relative temperature, moisture content, drainage, bacterial activities and crop material grown. The release of carbon dioxide present in the soil is largely carried out by soil microorganisms that are associated with plant roots. These are mycorrhizal fungi, bacteria, heterotrophic respiring organisms. Thus, it is expected that CO_2 gas will be released from the root zone, called the rhizosphere, into the atmosphere in very large quantities**.** Thus, it is expected that CO_2 gas will be released into the atmosphere in large quantities from the root zone, called the rhizosphere. (Ryan & Law 2005).

It is among the issues determined in the studies that producers and people will be adversely affected in terms of nutrition as a result of the exposure of the soils of underdeveloped countries to negative external factors and especially erosion due to the decrease in the amount of organic carbon in the soil and deficiencies (Lal, 2010).

2. Material and Method

In the maize plant grown in the soils of the region with different characteristics, chemical and organic fertilizers were used and the obtained results were compared in terms of productivity, product quality, soil residue and elements and gases accumulated in the soil. The study were carried out in 6 different geographical regions including Aegean, Mediterranean, Marmara, Central Anatolia, Black Sea and Southeastern Anatolia. In this context, NPK (Compound fertilizers), Organic fertilizers (Humic-Fulvic acid, Barn manure and Green manure) were applied at different Humic-Fulvic doses in the 6 zones determined in Denizli-Kütahya, Eskişehir-Konya, Şanlıurfa-Diyarbakır, Samsun-Tokat, Bursa-Balıkesir, Antalya-Isparta provinces. In the trial stations carried out under producer conditions, especially compound fertilizers and HA, FA and HA+FA product groups rich in C, H and O were preferred and the results were recorded. Humic+fulvic acid (HA+FA) used in the trials was obtained by separating insoluble (humin) and soluble (humic acid+fulvic acid) parts of leonardite by extraction with alkaline solution. HA+FA used is 20%. As basic fertilization, N, P, K prepared from NH_4NO_3, TSP and K_2SO_4 were applied and mixed with soils. Soils were irrigated at 80% of field capacity throughout the experiment. The experiment was established according to the random plots experimental design and carried out with 4 replications covering the whole trial area.

3. Findings and Discussion

When the effect of HA+FA applications on the remaining nutrient contents in the soil was examined, it was determined that the differences between the averages of the doses applied in Kütahya, Eskişehir, Konya provinces in terms of phosphorus were not statistically significant.

As a result of the analysis of variance on Ca content in soil, the 'region x dose' interaction was not statistically significant. The difference between the level averages of the dosage factor is also not statistically significant. However, the difference between the level averages of the region factor is statistically significant ($p<0.01$).

When analyzed in terms of Mg remaining in the soil, according to the results of the research, it was seen that the differences between the level averages of the region x dose interactions and the dosage factor were not statistically significant. However, the difference between the level averages of the region factor was statistically significant ($p<0.01$).

According to the results of the analysis of variance on the effect of humic+fulvic acid applications on the Fe content remaining in the soil after the experiment, it was determined that the 'region x dose' interaction was statistically significant ($p<0.05$). It was determined that the differences between the averages of the applied doses did not remain constant from region to region but varied, or similarly, the differences between the regions did not remain constant from dose to dose but varied.

When examined in terms of Cu remaining in the soil, it was seen that the differences between the level averages of the region x dosage interactions and dosage factor were not statistically significant. However, the difference between the level averages of the region factor was statistically significant ($p<0.01$).

As in the other microelements, as a result of the variance analysis for Manganese and Zn content, the 'region x dose' interaction was not statistically significant. The difference between the level averages of the dose factor is also not statistically significant. However, the difference between the level averages of the region factor is statistically significant ($p<0.01$).

As it can be seen from the results, different results were determined in the HA+FA applications of C, H and O in different regional soils, especially these elements were found to encourage their uptake by the roots by dissolving the bound compounds in the soil due to the chemical structure of the soil. Humic and fulvic acids are used less than organic fertilizers (Gezgin, 2012). Humic and fulvic acids significantly support the aggregate structure of the soil by bringing together the sand, dust and clay structures of the soil in the structure due to their structure. They increase the water retention capacity of the soils to which they are applied, and reduce or prevent the formation of the cream layer, which occurs due to alkalinity. By regulating the intra-soil voids, it provides homogeneous distribution of water and air in the main material.

As a result of the research, it was observed that the results were much better in terms of vegetative organs and product quality criteria in corn fields where green manure + chemical fertilizer was applied compared to the witness fields where only chemical fertilizer was applied. According to Buck (1996), green fertilizers increase microorganism activities and the amount of organic matter in the soil, while increasing the water holding capacity of the soil, protecting it from natural phenomena such as erosion and weed infestation. Green manure plants retain the chemical fertilizers given to the soil and keep these nutrients as soluble organic compounds in their own bodies. The released plant nutrients are absorbed as they are in a usable form for the seedlings and plants produced.

4. Conclusion and Suggestions

Continuing to produce by adhering to the traditional understanding due to the general structure of the soils in our country has reached a level that causes concern on behalf of our country's economy, whose national economy is largely based on agriculture, as well as endangering human and animal health and food safety.

In sustainable agricultural activities, it is necessary to focus on products that will not harm the environment and natural resources as much as possible, especially organic origin products. It is understood from all the studies that both the amounts and conditions of carbon emissions and other gases released into the atmosphere are in a one-to-one relationship with agricultural activities and related soil parent material.

In particular, more organic-based fertilizers should be preferred rather than inorganic fertilizers. The negative effects of chemical fertilizers containing excessive salt on both physical and chemical structure are seen from the analysis results of the research. The preferred fertilizer types are generally generic products. The use of products such as new generation fertilizers, slow-release, organomineral, multi-component water-soluble composites should be encouraged and product trial areas should be established in pilot regions (Leventoğlu, 2024).

Soil organic carbon has a significant contribution to soil physical, chemical and biological properties. It has been clearly demonstrated in a study that rapid oxidation of soil organic carbon due to tillage and management causes changes in atmospheric chemical properties (Lal, 2010). The increase in the concentration and amount of CO_2 gas of the gases formed as a result of oxidation affects climatic events, physiological development of plants, microbial activity in the soil, organic matter formation, and decomposition of organic matter at considerable levels. In particular, the preference of inorganic substances at higher levels compared to products richer in C, H and O_2, such as humic-fulvic, will reduce the side effects such as environmental pollution, decrease in yields, deterioration in product quality, residues in plants and soil, as well as natural disasters caused by climate changes caused by greenhouse gas emissions. In order to clearly see the effect of humic acid and similar organic products, which have been preferred in agricultural activities in recent years, on the development of plants and nutrient contents and to examine how this effect varies according to soil properties, soils with very different properties were selected for the study. In different plantations where studies were carried out for the use of these soils with low nutrient contents, it was determined that the amount of soil carbon increased and the levels of CO_2 and some other harmful gases released into the atmosphere decreased (Leventoğlu, 2011).

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World Heritage List Candidate Assos Ancient City-Cultural Sustainability

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1. Introduction

Assos Ancient City

The ancient name of the region known as the Biga Peninsula, located between the Marmara Sea, the Dardanelles and the Gulf of Edremit, is considered to be Troad or Troas. One of the important ancient cities in the Traod (Troas) region, where dozens of ancient settlements from various periods were established, is the Ancient City of Assos within the borders of Çanakkale province. Assos Archaeological Site is in the southwestern part of the Biga Peninsula, 17 kilometers south of Ayvacık district of Çanakkale province, within the borders of Behramkale Village. The ancient city is located on a steep hill, 235 m above sea level, and borders the fertile valley of the Tuzla River (ancient Satnioeis) to the north, along the southern coastline of the Troad and the Aegean Sea to the west, and to the Aegean Sea to the east. It commands panoramic views (Figure 1 and 2).

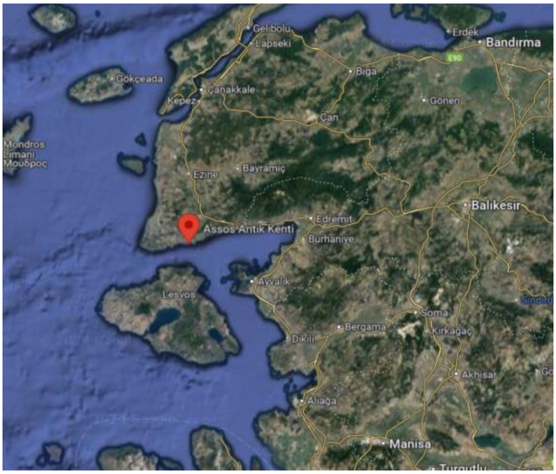

Figure 1. Location of Assos Ancient City (google.com., 2024)

Although it is not certain, archaeological remains have been found in Assos indicating that there were people living here in the Bronze Age (3000-1200 BC). Homer stated that Lelegs lived in the south of Tiria and that they were seafarers and pirates in the region during the Trio War. Southern Troyes, where Thracian and Mysian people settled, B.C. In the 7th century, it was occupied by the Aeolians who came from Lesbos Island (Lesbos). Describing this period, Strabon says; He also mentioned that immigrants from Methymna settled in Assos and that Gargara was the city of the Gargara people, a semi-barbarian tribe, 20 km east of Assos. B.C. In 560, this entire region was taken over by the Lydians, and Assos, like the cities of Western Anatolia, became their satrap. However, it gained its independence with the defeat of the Persians in Slamis and the arrival of Alexander to Anatolia. In 216 BC, Assos united with the Kingdom of Pergamon, and this situation lasted until 133 BC, when the Kingdom of Attalos was transferred to the Roman Empire by will. Assos showed great development during the Roman period. During this period, it also became famous for the productivity of its agricultural lands. Assos was among the cities that accepted Christianity earliest in Anatolia. In 381-390 AD, in line with the influence of Christianity and the orders of the empire, many temples were demolished, and their stones were used in the construction of churches and houses. Assos Athena Temple and the altar of the temple were destroyed during this period (UNESCO, 2024).

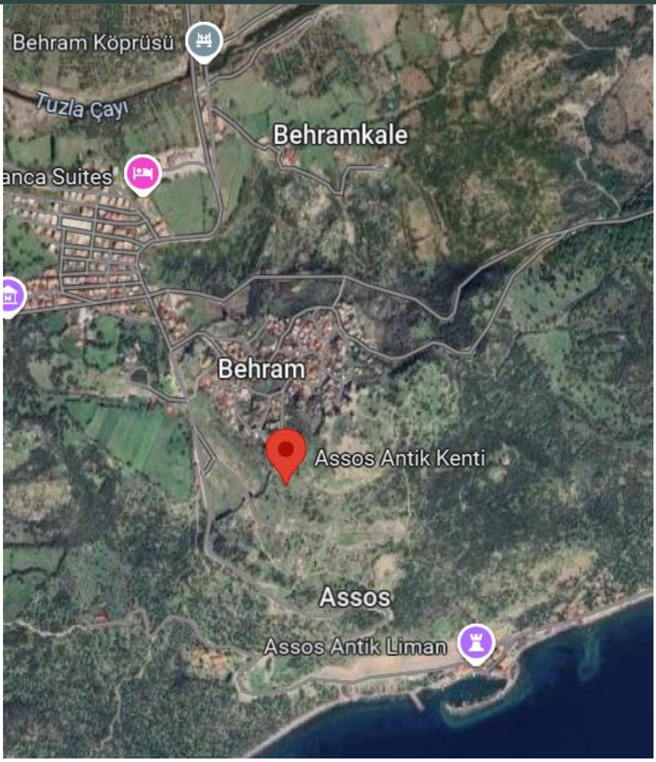

Figure 2. Location of Assos Ancient City 2 (google.com. 2024).

The location of the Assos settlement is unique with its interaction with the use of the natural environment and the integration of architecture. The most striking structure of Assos is the acropolis with steep rock walls located at the highest point of the city. On the east side of the acropolis is the Temple of Athena, which can be easily seen when approaching the city from the sea. The temple of Athena is the only known example of the Doric order in Archaic Anatolia, and it is also unique with its combination of the Doric order with the Ionic frieze and other unusual architectural decorations (Figure 3).

Figure 3. Temple of Athena in Assos Ancient City (assosrehberi.com., 2024)

There are a total of 34 columns, 5 meters long, in the temple, and all but two have capitals. The columns serve to surround the internal structure and exterior of the temple. The temple, built with andesite stone extracted from quarries in the region, was built in the Doric order by placing columns on a rectangular platform.

Today, the decorative architectural remains of the temple are kept in the collections of museums in Paris (France), Boston (USA), Istanbul and Çanakkale (Türkiye). Assos was chosen as the first excavation site of the American Archaeological Institute in 1881 because it reflects all the basic characteristics of a Greek poleis (UNESCO, 2024)

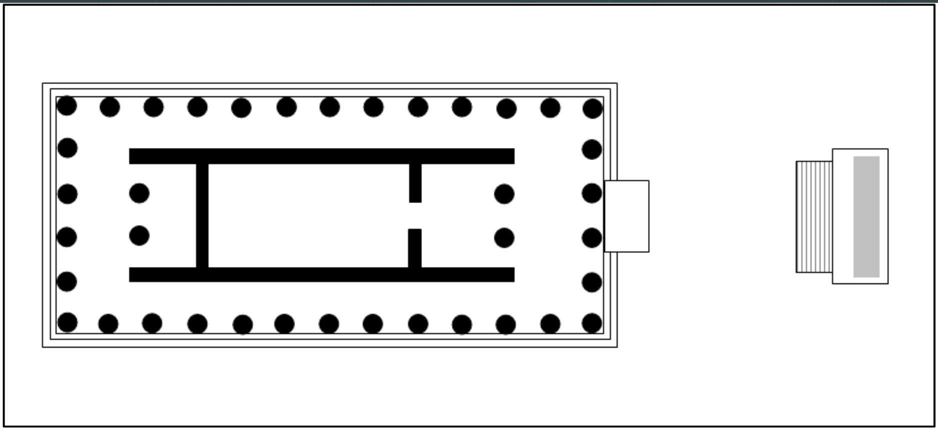

Figure 4. Athena Temple Plan (en.wikipedia.org. 2024)

These buildings, where young people receive physical and social education and do sports, are very important in a city. It is located between the Agora and the western gate. There is a Byzantine church in the northeast and a cistern in the southwest. The Gymnasium is also surrounded by Doric style columns (Altıpat, 2009).

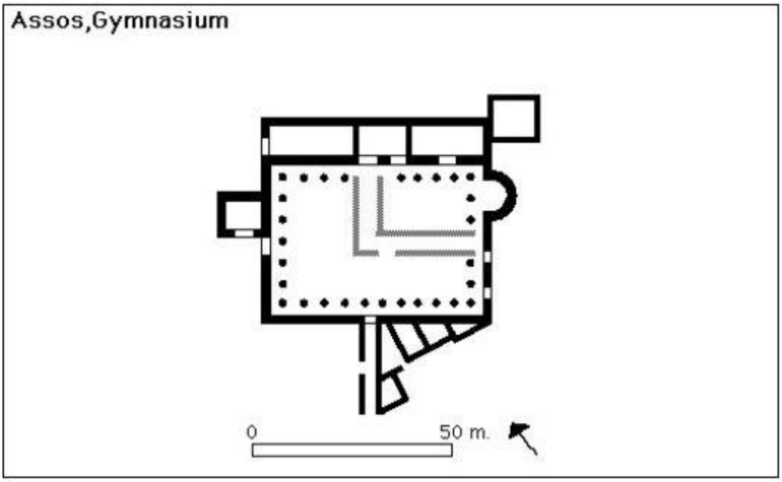

Figure 5. Assos Gymnasium Plan (perseus.tufts.edu., 2024).

Figure 6. Assos Settlement Diagram (tutkutours.com**.,** 2024).

The surroundings of Assos Ancient City; It is surrounded by walls that are 3200m long and 20m high. 4th B.C. It was built in the century. There are two main gates providing entry and exit to the city. The area in front of the east and west gates was used as a necropolis (cemetery). In addition to simple tombs, magnificent monumental tombs are also found. In the early days, the ashes of cremated corpses were placed in jars and buried with their mouths closed. Later, larger jars were used. The dead were placed in jars in the fetal position and buried with gifts. With the use of sarcophagi, the dead began to be buried with precious ornaments. Since the sarcophagi were close to the surface, they were easily uncovered and robbed by treasure hunters. The most interesting among the seized gifts; It is a "Women's Orchestra" figurine made of terracotta (UNESCO, 2024).

It is known that the theater built in the south of the ancient city of Assos was destroyed after an earthquake. The theater built opposite Lesbos Island; Located in a natural rock cavity, it has a capacity of 2500 people and is a Roman theater in terms of its construction technique and plan features. It was used as a quarry in the following years. As a result of the restorations, the collapsed walls of the theater were rebuilt, and the seating rows were rearranged in accordance with the original. The theater, which has the capacity to host a total of 1500 people, can host various festivals and concerts.

Figure 7. Assos Ancient Theater (kucukkuyu.com**.,** 2024).

There are two stoas in Asos. One is to the south of the Agora, the other to the north. BC in the north It is estimated that it was built at the end of the 3rd century or the beginning of the 2nd century. It has two floors in Doric style. On the ground floor, the spaces between the columns are decorated with rectangular panels, and on the upper floor, holes in the tree logs covering the ceiling can be seen. The South Stoa was built in the same period, has 3 floors, and there are 13 shops on the middle floor. There are 13 baths and cisterns on the lower floor.

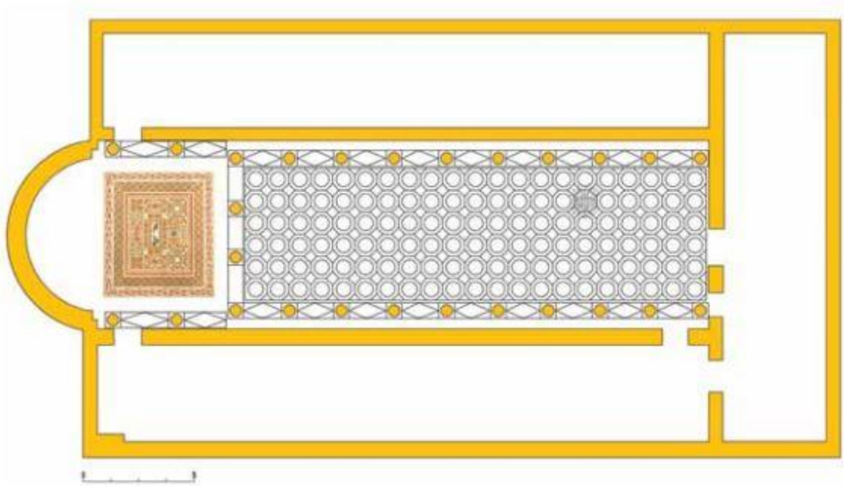

Figure 8. Assos The West Church Plan (Clarke et al., 1902)

The West Church is on the same terrace as the theater and to the south of the Agora. It was revealed by Clarke and Bacon. The church, which was cleaned again in 1990, has three naves and a semicircular form. During the latest excavations, the narthex section with two rooms was unearthed. The narthex and the rooms in front of it are divided by buttresses and marble covered plates are preserved. The threshold of the entrance door to the narthex remained intact. The entrance to the naus opposite the door is blocked by a wall. The main space is divided into three separate naves with two rows of columns. The floor of the northern nave is covered with stone slabs, and the wall behind it is divided by arched niches. It is thought that this section belongs to the Roman period. The floor of the side nave in the north is higher than the floor of the naos. The side nave in the south is narrower and lower than the naos floor. Since the land is sloping, filling was done to compensate for the elevation difference. The large stone blocks on the walls of the spaces used at different levels and the column drums lying on the ground are exactly Roman period structures. The columns lying on the floor of the side naves are made of marble and andesite. There is a cross shape on one of the marble columns. Some of the arch stones were found inside the church. Andesite and basalt pieces were used inside the church. Inside the semicircular apse wall from the outside, a row of smooth rectangular block stones stands out. The inner part of the apse, unlike the outer part, is built with rubble stone.

The ancient pier can be seen when looking towards the sea from the Temple of Athena. The pier, which was built in place of the sunken ancient port today, fascinates people with its beauty, although it is not as active as it was in history (Koçyiğit, Uysal, 2013).

When we consider the religious and political ties between Lesbos (Lesbos) Island and Assos, we see that this is a very busy port. Until the eighties, the pier was used for bonito shipment and the buildings here were used as bonito warehouses. Today, both are used for tourism purposes. Camel caravans loaded with acorns are being replaced by tourist groups from all over the world. Today, the pier; It is a tourist attraction with restaurants and hotels.

Figure 9. Assos Ancient Port (kepezhotel.com., 2024)

Due to the lack of fertile lands around Assos to feed the city; Livestock farming, fruit, wine and olive cultivation have been sources of income. They also processed iron and silver. Iron ore was found on the eastern slopes of the acropolis. Port services and customs are another source of income.

The ancient city of Assos is on the temporary list of Türkiye's World Heritage List. In order to be included in the main list, an area management plan must be prepared, setting out the conservation approaches for the area in detail.

2. Assos Ancient City on the World Heritage List

Asoss archaeological site was included in the tentative list of the UNESCO World Heritage List on 15.04.2017. For a field to be included in the main list, it must first be included in the temporary list. Therefore, it is very important that the area is included in the temporary list. The history of the area dates to the Bronze Age. He spent many years under the protection of the Persian empire. In 133 BC, it came under Roman protection. Assos was one of the first Western Anatolian cities to convert to Christianity and was listed as a bishopric in lists dating from the 5th century AD to the 14th century. The Turks conquered the city in the early 14th century. The port of Asoss never lost its function until the 18th century, when it became an important trade port.

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The location of the Assos settlement is unique with the interaction of the use of the natural environment and the intertwining of architecture. The most notable "landmark" of Assos is the steep rock-walled acropolis at the highest point of the city. On the east side of the acropolis is the temple of Athena, which can be easily seen when approaching the city from the sea. Raised and isolated on top of the acropolis, visible far away from the sea and commanding panoramic views, the location of the

Temple of Athena is as impressive today as it was in ancient times. The temple of Athena is the only known example of the Doric order in Archaic Anatolia, but it is also unique in its combination of the Doric order with an Ionic frieze and other unusual architectural decorations. Because the ancient city was never overbuilt in Ottoman and modern times, and no large-scale excavations had been carried out before, the city center is one of the best examples of the early Hellenistic building program, with changes and additions in the Late Hellenistic and Roman Imperial periods.

In order for an area to be included in the World Heritage List, it must have outstanding universal value and be able to support this value with originality and superiority. For this reason, the UNESCO World Heritage Center has published a list consisting of 10 items. It was requested that the outstanding universal value be defined through these 10 items. The first 6 items are defined for cultural heritage areas and the last 4 items are defined for natural heritage areas.

Assos, which was an important polis in the Archaic Period, maintained its important role in the region until the Byzantine period. Most of the buildings in Assos, built from andesite, have preserved the historical features of the period in which they were built. In this respect, it is an ideal place to investigate the development of Greek art from Orientalism to Hellenic splendor. When the outstanding universal value of the Assos archaeological site is examined, we see that it is nominated for the list with items (iii)(iv)(vi).

Criterion (III) (Being an exceptional, rare representative of a living or extinct cultural tradition or civilization): Assos, one of the best preserved Greek cities of Asia Minor with all its important religious and public buildings, is the history of a Greek poleis in Asia Minor. It bears an exceptional testimony to its development. The combination of city and place attracted the attention of early antiquarians, for example WM Lake (1800) described Assos as» the idea of the most perfect Greek city that exists anywhere«. In fact, Assos has an impressive physiognomy that has dominated the city throughout all ages. From the lowest residential terrace above the ancient harbor to the Acropolis plateau, the relief of the landscape increases by 170 meters, reaching a total height of 235 meters above sea level. There is actually no other city on the west coast of Asia Minor with such good topographic conditions for a representative vertical cityscape. Buildings such as the temple of Athena on the Acropolis, gymnasium, bouleuterion, stoa buildings, agora, palestra and theater are well preserved. Assos is therefore one of the few ancient cities from which one can have a clear idea of the spatial layout of a Greek Poleis.

Criterion (IV) (Demonstrating an important phase or stages of human history being an exceptional example of a building type, architectural or technological whole, or landscape): The Temple of Athena in Assos, the oldest Doric temple in Asia Minor, is unusually located on top of the acropolis in a region dominated by the Ionian order. The temple, which is an archaic example of the Doric order, is an important building in terms of architectural history. It is also noteworthy that it carries statues not only on the metopes but also along the epistyle. The epistyle and metopes of the Temple of Athena were carved with reliefs of sphinxes, lions, wild boars and centaurs, representing the earliest stages of the Doric order. Some parts of these animals display "fine mastery", while others are corrupted by "Eastern harshness". Therefore, the sculptures can be considered "the most important link in the chain connecting the carvings of the early civilizations of the East and the unique sculptures of Greece" and show "the path taken by the early Greek artists in the advancement towards the highest level of perfection".

Criterion (VI) (Relating directly or indirectly to artistic or literary works, beliefs, ideas, living traditions and events of exceptional universal significance - the Committee considers that this criterion should preferably be used in combination with other criteria): Hermias, Aristotle, Callisthenes and A school of philosophy founded by important philosophers such as Theophrastus took place in this field. Due to the presence of these great philosophers, the city became for a short time the most important center of Platonic teaching in Asia Minor (UNESCO, 2024).

Asoss archaeological site is a 1st degree archaeological site. Behramkale village, located in its location, is also protected as a historical urban protected area. In this way, the originality and integrity of the area was largely preserved. In this section, where it is defined that the area preserves its originality and integrity and meets its outstanding universal value with articles (iii)(iv)(vi), it is useful to emphasize that the area management plan required for the area to be included in the list must also be produced.

When the criteria met by the properties on the world heritage list are compared, it can be seen that the criterion most met by all candidates in the world and all candidates in Türkiye is criterion 4 (Figure 10-11). This is followed by Criterion 3.6. The criterion remains a supporting criterion (Özbey, Saban, 2019). This shows us that the field is in an advantageous position in terms of the criteria it provides for being included in the main list.

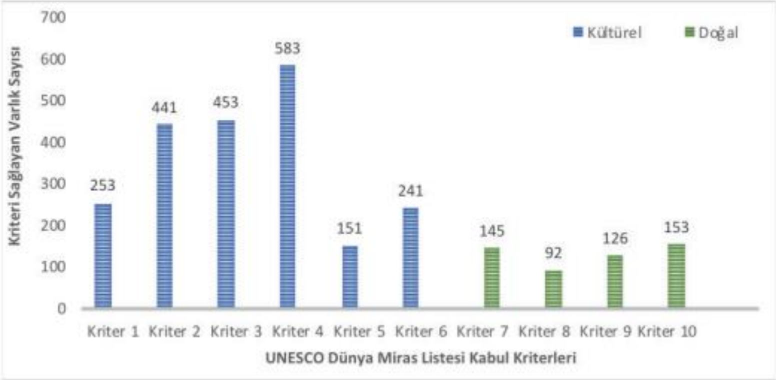

Figure 10. UNESCO Criteria Met by All Properties on the World Heritage List (Özbey & Saban, 2019)

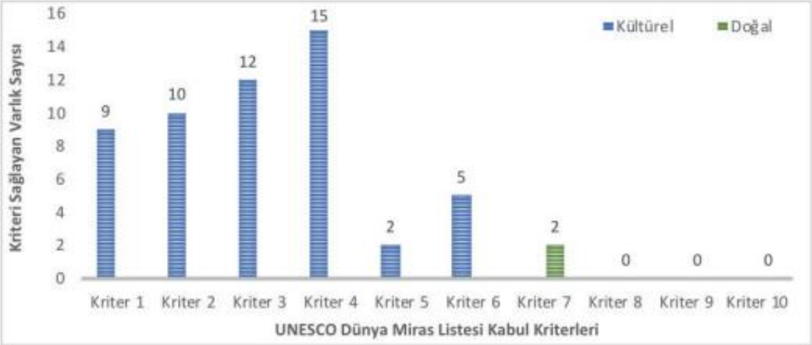

Figure 11. Türkiye UNESCO Criteria met by Properties on the World Heritage List (Özbey & Saban, 2019)

3. Assos Ancient City Conservation Approaches

Assos Archaeological Area was registered as a first-degree archaeological site by the decision of the Supreme Council of Real Estate, Antiquities and Monuments in 1982 and was protected within the scope of the Law on the Protection of Cultural and Natural Assets. The protection, promotion and restoration of the ancient city and historical city are carried out by the Ministry of Culture and Tourism, Çanakkale Governorship and Behramkale village local government. The excavated monuments are part of the conservation program and are constantly monitored and maintained. Restoration works inside the ancient city walls are carried out in accordance with the Venice Charter.

Figure 12. Appearance of the Stunes After Restoration (Arslan, 2008)

When we look at the conservation practices in figure 12 covering the ancient city of Asoss, we see reconstruction and restoration practices specific to the buildings. The columns at ground level in the temple of Athena were elevated and reconstructed.

The theater, which had an audience area of 5000 people in ancient times, was seriously damaged after the earthquake. After the earthquake, it was used as a quarry and most of the stones were removed and taken away. It was restored with andesite stone and the missing parts were completed as much as possible. Some of the previous restorations made of concrete in the Temple of Athena were replaced with andesite pieces between 2009 and 2011. The west gate chapel complex, the west gate, the early Byzantine walls outside the city, the lower agora structure, the lower agora Tetrapylon structure and the spaces to the south of the Agora Temple, unearthed during the excavation, were built with rubble stones in 1 or 2 rows, as required, and frozen with lime mortar (Arslan, 2010) (Figure13).

Figure 13. Excavations in the West of the North Stoa (Arslan, 2010)

As the touristic value of the region increases, hotel construction has accelerated both in Behramkale Village (figure 14) and in the surrounding villages. The fact that some hotel buildings were built outside the planning permission made a stir with the petitions of the local people and the excavation team, and the hotel construction was stopped with the intervention of KUDEB (Başaran & Somuncu, 2021).

Figure 14. Assos Hotel Construction (arkeolojikhaber.com., 2024)

In the study carried out for the region by the Ministry of Industry and Technology in 2019, together with Onsekiz Mart University, which made significant contributions to the excavations in the archaeological field, the Assos region was approached as a brand. A regional solution is being tried to be offered by considering the region as a whole and increasing interest in protected areas and tourism. It defines the main objectives of the study to improve the tourism supply in the Assos region qualitatively and quantitatively, to increase the touristic demand for the Assos region, to increase the income from tourism in the Assos region, and to create the tourism image of the Assos region (Atay et al., 2019).

3. An Evaluation and Conclusion on the Current Problems of Assos Ancient City

Asssos is currently an ancient settlement with the advantages of its natural structure. Having different viewpoints located at different elevations, having a clean seaport, having a long axis, being located close to the Kaz Mountains region, and growing endemic plant species are the naturally advantageous points of this region. Apart from this, the historical background of the area, the fact that there are parts of the structure with cultural value that have been preserved until today, the fact that the area can be perceived as a whole, and the local people's knowledgeable and sensitive approach to the cultural heritage value of the region constitute important potentials. Assos being a brand creates an important resource for tourism. Its high accessibility from metropolitan cities, the relationship between neighboring Greece and especially the island of Lesbos, and the existence of the Küçükkuyu customs gate are the geological potentials of the area.

When the current problems of the field are examined, problems of different scales and scopes are encountered. The protection of an area is primarily successful at the point where it is understood and adopted by the current users of the area. It is a problem that the public does not have sufficient awareness about existing cultural and natural values and their sustainability.

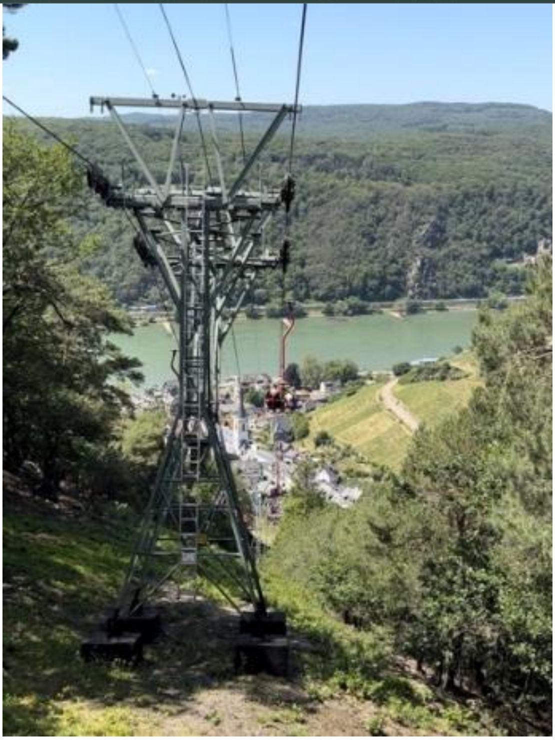

Figure 15. A Cable Car Example from Germany

In addition, the fact that summer tourism in the area is more developed than cultural tourism poses a challenge in directing tourism. Although cultural tourism should be independent of the season, it is associated with summer tourism in this region, and the short duration of summer tourism creates a disadvantage. Although the local people are willing, they cannot contribute sufficiently because they are unaware of cultural tourism. There are problems such as physical access problems, lack of guidance and information, and inadequate infrastructure systems. Unplanned construction poses the biggest threat to the coastline, which is very important for tourism. Historical artifact smuggling and immigrant trafficking are also some of the problems of the region.

In order to use the tourism potential more accurately, it is necessary to implement practices that develop tourism facilities in the area and increase tourism income. If the concentration of tourism facilities in the port area is prioritized, the threat of the archaeological area being under the pressure of construction will be eliminated. In the archaeological area, it is necessary to move the current irregular touristic product sales to a closed area that will adapt to variable weather conditions at the entrance of the ruins. In this context, new projects are planned to educate the public on the production of local products and souvenirs. Additionally, since tourism is an important source of income for people living in Behramkale, they pay special attention to the preservation of ancient and historical building ruins.

In order for tourism not to be seasonal, it is necessary to prevent exceeding the seasonal carrying capacity by ensuring that tourist visits are distributed over the months as much as possible throughout the year. In this context, ensuring that Far Eastern tourist tours organized to the ancient city of Troy are gradually directed to the ancient city of Assos will be a step to prevent seasonal density.

If accommodation is planned on the beach in association with the port, the issue of transportation comes to the fore. Creating a cable car line(figure 15), with the advantage of the topography of the area, would be suitable for connecting the port and the ruins. Improvement of the existing transportation axis and organizing tours with small vehicles that will not damage the area will also increase the number of visits

The topography of the area has shown itself throughout history, making the area a natural observation deck. Establishing a planned observation terrace and associating it with a monumental element such as a statue or a photo point will contribute to the photographing of the area and its promotion through social media. In addition, it is necessary to foresee the problems that the area will experience in the face of increasing tourism as it enters the UNESCO World Heritage List and to create an integrated conservation approach.

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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.

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Sustainable Agriculture Alternatives in Urban Areas: Hydroponic Agriculture

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1. Introduction

The fact that the demand for agricultural and animal products may increase in parallel with the increase in the world population, which today exceeds 7 billion and continues to increase rapidly, increases the pressure on governments that have difficulty in meeting the food needs of individuals. This pressure will drive governments to create new agricultural areas or to utilize land in use and dwindling water resources. However, while intensive use of already fragile natural resources will cause agricultural stress, more intensive use of land will increase greenhouse gas emissions and cause climate change (Six et al., 2004).

According to the data in the World Urbanization Prospects report published by the United Nations in 2014, 30% of the world's population lived in cities in 1950 and 54% in 2014, and this situation is gradually increasing. It is estimated that 66% of the world's population will live in cities in 2050 (United Nations, 2014).

Today, with the rapid population growth of cities and settlement areas with high attraction power and the multifaceted demands of many sectors and related actors such as housing, service, commercial, education, industry, etc., the tendency to obtain effortless economic benefits (rent), etc. factors have created and are creating unhealthy and irregular cities and urbanisation. As a result, the quality of life of the city is decreasing day by day as a result of negative factors such as mechanised, horizontal and vertical block constructions, heavy vehicle traffic, environmental pollution, visual pollution, crowding, noise, natural disasters, reduction of green areas and agricultural areas, destruction or overuse of water resources, etc (Gezer & Gül, 2009). The increasing number of people living in cities and rapid urbanization bring along environmental problems. This means that 75% of global and natural resources are consumed in cities. Fertile land, food, clean water and clean air are becoming scarcer and the world is rapidly moving towards a state of scarcity. Green-blue infrastructure and nature-based solutions are being developed to increase the capacity of cities to adapt to resource consumption and scarcity. Small-scale manufacturing, circularity and circular economy in the urban built environment, and urban agriculture are some of the applications of these solutions.

Urban agriculture, which has recently become a very popular concept, helps to solve and improve many socio-cultural, economic and ecological problems in cities, such as reducing poverty, ensuring food security, increasing employment, improving air pollution, waste management and increasing biodiversity, as well as helping to create more sustainable and greener cities. Urban agriculture, which constantly interacts with rural agriculture and is an element of food systems, is now applied at different scales, typologies, with different production techniques and for different purposes with the development of technology. The ecological, economic and social benefits of urban agriculture and its land use potential provide an important tool for planners and decision makers. Especially vacant and idle areas in cities have significant land use potential for urban agriculture. It has been proven by some studies that these areas will provide significant benefits for cities by implementing and planning these areas with a holistic and sustainable approach, taking into account socio-demographic, natural and urban factors (Gül, 2022; Türker & Akten, 2020; Türker et al., 2021; Akten & Akten, 2019). In a study conducted by Clinton et al. (2018), a total of 30-70 thousand hectares of vertical, 1.3 million hectares of roof area, and 7-11 million empty areas with the potential to be used for urban agriculture in the world were identified. These figures constitute 1.4-11% of the total urban areas worldwide. The use of these suitable areas for urban agriculture and related activities on a global scale means annual food production of 100-180 million tons, energy savings of approximately 15 billion kiloWatt hours, billions of dollars worth of income and savings in many other areas (Türker & Akten, 2022).

Another factor that emphasizes the importance of urban agriculture is factors such as global epidemics, disasters and pandemics. For example, the Covid-19 pandemic, which emerged in 2019, has caused many problems in the field of agriculture as well as in "many areas such as transportation, tourism, education, etc.", "especially health problems" (Akın et al., 2020). One of the biggest challenges created by the Covid-19 pandemic is access to economically accessible, fresh and nutritious food for the growing population (Lal, 2020). It is assumed that the pandemic may also disrupt the balance between farmers, agricultural inputs, business facilities and food supply chains (Cullen, 2020). For this reason, since the pandemic has disrupted the food system, which is dependent on "long food supply channels", it brings the process of transition to urban agriculture, which has "shorter local supply channels", and discussions on this issue to the agenda (Tandoğan & Özdamar, 2022).

One of the benefits of the pandemic process is that it has provided a benefit for all countries to "reconsider their self-sufficiency policies" due to their difficulties in food supply. In this context, the need to support agriculture and the sustainability of farmers' agricultural production activities, as well as the production of domestic products, becomes evident. Therefore, situations such as epidemics, disasters, wars, etc. indicate that "the agricultural sector has an important place in the economic policies of countries". This situation reveals the necessity for countries to have alternative plans and policies regarding agriculture (Akın et al., 2020; Tokgöz & Gül, 2023).

In addition to the damages caused by misuse of land, desertification, excessive fertilizer use (Leventoğlu & Gül, 2022), excessive water consumption in conventional agriculture, it has been reported that herbicides used to increase crop yields cause changes in the physical, chemical and biological structure of the soil and as a result, deterioration in the soil ecosystem.

It was also stated that the negative effects on soil relations and the deterioration of plant nutrients such as greenhouse gases, insecticides, nitrogen, and phosphorus that occur in conventional agriculture result in negative effects (Aune, 2012). In this context, the sustainability of the agreement, depending on the increasing food demand and the lack of additional land, requires an urgent solution (Pomoni et al., 2023). As a result of the emergence of these negative situations, it is seen that they focus on alternative soilless agriculture techniques such as hydroponic, aeroponics, and aquaponic systems, depending on the technology of the technology.

Decline in soil fertility and soil nutrient reserves, limited availability of irrigation water and climate changes are among the parameters to be taken into account in the search for new production. From this point of view, soilless cultivation systems are among the systems emphasized (Mir et al., 2022). Thanks to these systems, it is possible to produce in a controlled manner and continuously throughout the year. Hydroponic farming systems, which have different techniques and costs, are expected to increase diversity and reduce costs. Many countries have switched to hydroponic farming practices due to the scarcity and inefficiency of usable agricultural land (Despommier, 2017).

Hydroponic farming practices provide more efficient results in terms of sustainability for reasons such as more efficient use of resources in the production process, reduction of intermediary institutions that increase costs, reduction of waste due to logistics costs, and prevention of production disruptions due to natural events. In line with the current problems and new developments in today's ornamental plant production and cultivation sector, aeroponic system, especially known as soilless rooting technique, has become increasingly important (Şimşek & Gül, 2018).

While the emphasis of this study is on 'urban agriculture' and soilless agriculture, the aim of the study is to examine the ecological measures that need to be taken in terms of human health, environmental health and food safety threatened by environmental problems caused by irregular urbanization and the management policies that can be addressed in terms of social and economic sustainability in this context in terms of landscape architecture discipline.

1.1. Concept and Types of Urban Agriculture

The concept of agriculture, which is mostly associated with the rural context, has gained a new dimension with its urban character in recent years. Economic, environmental and social problems caused by rapid urbanization, rural-urban migration, high unemployment and urban poverty have led to an increase in agricultural activities in the urban context. This new trend is called "Urban Agriculture". Urban agricultural activities are rapidly developing worldwide due to their positive impacts on economic, environmental and social areas. For this reason, it is used as a sustainable development strategy in many countries (Kayasü & Durmaz, 2021; Akten & Akten, 2010). Sustainable development goals related to urban agriculture announced by the United Nations (Sachs et. al., 2021):

Goal-01 To end poverty in all its forms everywhere,

Goal-02 To end hunger, ensure food security and achieve good nutrition and promote sustainable agriculture,

Goal-3 To ensure sustainable consumption and production patterns,

Goal-4 Protect, restore and promote the sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, halt and reverse land degradation and prevent biodiversity loss.

Urban agriculture is defined as "the cultivation, processing and distribution of food and other products through intensive plant cultivation and animal husbandry in and around cities" (Bailkey & Nasr, 2000). Urban agriculture is "agricultural activities carried out primarily within urban boundaries” (Koç, 2003). In the simplest definition, it can be defined as “the cultivation of plants and animals in and around the city”, while urban agriculture can also be defined as a concept that encompasses “subsistence production and processing, from household-level processing to commercialized agriculture” (Tandoğan & Özdamar, 2022).

It is a sector that covers all activities from the production to marketing of food and related non-food products to meet the daily needs of urban residents by using and recycling urban waste and natural resources in and around urban areas (Smit et. al., 1996).

Urban agriculture is an industry concerned with the production, distribution and marketing of food and related non-food products by using and transforming resources on a large scale in and outside settlements (Mougeot, 2000).

Urban agriculture is a system that can be affected by various factors, produces for urban people using the potential resources of the city, has an impact on the socio-economic dynamics of the city, and includes related activities such as packaging and marketing in addition to agricultural production (Orsini et. al., 2013). Urban agriculture, which is the agricultural initiatives in the city, is in constant interaction with rural agriculture, urban land management, urban survival strategies, urban food security, sustainable urban development and urban food supply systems (Mougeot, 2000). Urban agriculture, which is a part of the food system, is an alternative food system that is an integral element of rural agriculture. Mougeot (2000) explained that the most important difference between urban agriculture and rural agriculture is the integration of urban agriculture with the ecological and economic systems of the city and defined the basic building blocks of urban agriculture as follows (Türker & Akten, 2022):

- Type of economic activity
- Food / related non-food product categories
- Urban location of the area
- Type of area
- Destination of the product
- Scale of production

These six components clearly demonstrate the difference between urban agriculture and rural agriculture.

Type of economic activity: Urban agriculture is not only a system focused on crop and animal production. It encompasses all types of activities related to the production, distribution and marketing of food and related non-food product categories.

Food and related non-food product categories: Since urban agriculture is an agricultural activity, all products that can be produced within this scope constitute the product category of urban agriculture.

Smit et. al. (1996) categorized urban agricultural products into 5 product categories: horticultural products, aquatic products, livestock products, agroforestry products and other related products. The food and related non-food products identified by Smit are as follows:

- Horticultural products; vegetables, fruits and compost
- Aquaculture; fish and aquaculture products, seaweed and feed

- Livestock products; milk, eggs, meat, fertilizer, leather and hides
- Agroforestry products; fuel materials, fruit, nuts, compost, building materials
- Other products; flowers, potted plants, medicinal and aromatic plants and pesticides

In addition to the above, products such as silk, tobacco (Mougeot, 2000), mushroom and yeast production, beekeeping products, field crops, other ornamental plants and the production of related inputs (seeds, etc.) are urban agricultural products.

Urban location of the area: Considering the spatial location of urban agriculture in the urban macro-form, it is analyzed in two categories: urban agriculture and peri-urban agriculture.

a) Urban agriculture: The implementation of urban agriculture activities at various scales within the city (very dense, dense and medium dense urban fabric).

Urban agriculture is small-scale and practiced in smaller areas with less natural resource potential, with users with a different profile than peri-urban agriculture. The user profile is generally women. Part-time employment potential is high. Easy market access and high land and labor costs. Production is primarily for livelihood purposes (Drescher, 2001).

b) Urban periphery agriculture: Urban agriculture at various scales is practiced on the periphery/periphery of the city, outside the dense urban fabric (low-density and very low-density urban fabric).

Peri-urban areas are located in the transition zone between urban and rural areas and can easily change for a variety of reasons (Douglas, 2012). Mougeot noted that defining the boundaries of peri-urban agriculture areas is problematic and that they tend to change on a larger scale than peri-urban agriculture (Mougeot, 2000).

Peri-urban agriculture is more economically dependent on the city and intensive, market-oriented and commercial production is carried out in large areas with more natural resources. The potential for full-time employment is high. Lower cost land and labor opportunities are available. However, these areas are threatened by urban growth and are located further from markets. With rapid urbanization, peri-urban agriculture can be transformed into peri-urban agriculture (Drescher, 2001) and they are in constant interaction with rural agriculture (Mougeot, 2000).

Type of area: Urban agriculture can be practiced in ponds, streams, lagoons, wetlands, home gardens, parks, rooftops, containers, greenhouses, open spaces, hillsides, green belts, urban forests and many other urban environments (Smit et. al., 1996).

The destination of the product: Urban agriculture is practiced for two purposes: consumption and commercial, with the main destination of the product being households and producers (Mougeot, 2000).

Scale of production: The scale of production in urban agriculture is applied at various scales, from micro scale to national and international scale (Rasouli, 2012a).

In this context, within the framework of the above information, urban agriculture is an alternative food system that contributes to the ecological, economic and social system of the city, which enables the production, processing and marketing of all kinds of food and related non-food products that are applied with different methods on various surfaces from micro scale to macro scale within and on the periphery of settlements (villages, towns, provinces, districts, metropolitan cities, megacities) and aiming sustainable resource management.

Urban agriculture is defined by the United Nations Development Organization as the provision of agricultural and animal products to meet the daily demands of the inhabitants of towns, cities or metropolitan areas, extending over land and water in urban and peri-urban areas (Smit et. al., 1996).

According to Chenarides et al. (2021), urban agriculture is a growing sector within the agricultural industry that aims to increase overall food production in urban and peri-urban areas through the conversion of existing land into agricultural farms.

The scope of urban agriculture ranges from “small-density urban farms, food production in public housing, land sharing, rooftop gardening, bee-keeping, greenhouses in schoolyards, salad gardens for restaurants, food production in public spaces, guerrilla gardening, allotment gardens, balcony and window vegetable gardening and other initiatives” (Koç, 2003). However, it ranges from “food production by low-income families for their own consumption, to community and hobby gardens, to larger-scale agricultural enterprises” (Koç, 2003).

Accordingly, “urban agriculture is divided into three categories: commercial, non-commercial and hybrid practices”. “Commercial practices” include ‘market-oriented practices, urban and peri-urban farms, beekeeping, soilless and hydroponic systems, and the equipment, materials and infrastructure required for the processing, distribution and sale of food products’. “Non-commercial applications;” “private, community, institutional, demonstration and guerrilla gardens, edible landscaping, hobby beekeeping and poultry farming”. “Hybrid practices“ include social activities consisting of the production, processing, distribution and marketing of food, and free educational activities carried out by various institutions for social, economic or environmental purposes” (Tandoğan & Özdamar, 2022).

1.2. Benefits of Urban Agriculture

Urban agriculture is an activity that has many positive benefits for the city in terms of security, economic, ecological, aesthetic and social aspects. In addition to its benefits in terms of food security and nature conservation, urban agriculture can reduce the formation and effects of heat islands in cities, floods, and “energy, quality, product loss and pollution caused by transportation since food production takes place locally”. In addition, it can change the form of the city and improve the air quality of the city (Kayasü & Durmaz, 2021).

Urban agriculture “integrates rural areas, urban peripheries, suburbs and urban areas,” enabling “local development, poverty alleviation, food security, sustaining biodiversity and reuse of urban waste and wastewater” (Kanbak, 2016).

Urban agriculture has four main benefits to the urban system (Korgavuş & İnan, 2021). The benefits of urban agriculture are shown in Figure 1 (Türker & Akten, 2022).

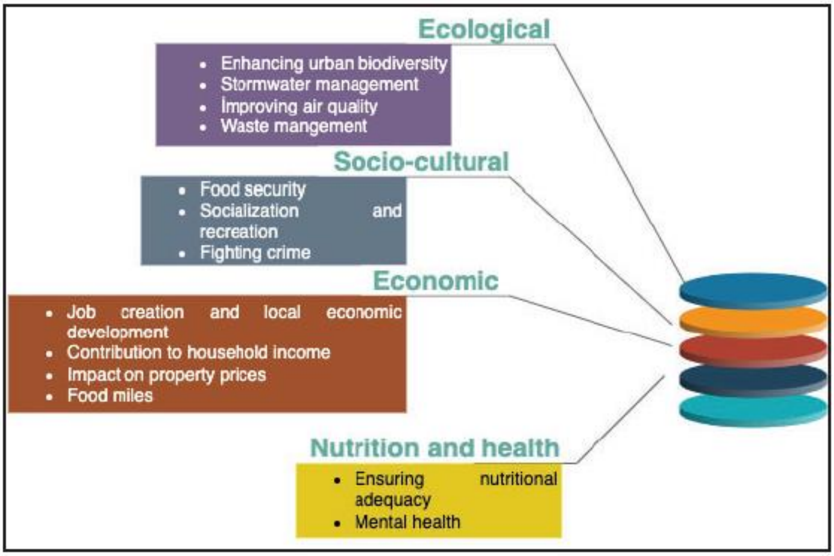

Figure 1. The Benefits of Urban Agriculture

1.2.1. Ecological Benefits

Urban agriculture contributes to environmental management and the efficient reclamation of contaminated land. It also contributes to stormwater drainage and air pollution reduction through increased vegetation cover, while increasing urban biodiversity and helping to conserve species (Kaufman & Bailkey, 2000). It also helps to reduce dependence on fossil fuels and electricity and thus carbon footprint, as it requires less transportation and less packaging due to its proximity to markets. In addition, in urban agriculture, household waste can be converted into compost and used in agricultural areas, increasing agricultural productivity and contributing to recycling.

In addition, since urban agricultural areas are urban green spaces, the ecological contributions of green spaces to the city are also valid for urban agricultural areas. In this context; reducing the urban heat island effect, absorbing noise, increasing air quality and oxygen levels, contributing to urban environmental aesthetics, reducing the greenhouse gas effect, providing soil management, urban waste and water management (Lohrberg et. al., 2016) are among the other ecological contributions of urban agriculture. With these multifaceted impacts, urban agriculture has an important role in ensuring sustainable urban development.

1.2.2. Economic Benefits

Urban agriculture makes many economic contributions to cities. However, not all forms of urban agriculture have the same impact. Since most urban agriculture production is used for subsistence consumption, the assessment of its impact on the economy may not be fully realized. The economic benefit is usually related to the market-oriented part of the products. Activities that generate a direct economic activity largely involve large-scale entrepreneurial and sometimes small-scale family-based enterprises (farms) operated by private investors or producer associations. Products include not only plant and animal food production but also non-food products such as flowers and ornamental plants (Kanbak, 2016).

Urban agriculture also encourages individual and small-scale entrepreneurship, such as establishing necessary agreements, processing, packaging, marketing, and transportation of food. In particular, change production is considered an important factor in sustaining local development (Yücedağ et. al., 2023).

The economic contributions of urban agriculture include reducing public land maintenance costs, increasing local employment opportunities and income generation, utilizing underutilized resources (e.g. rooftops, roadsides, utilities, vacant land), increasing property values, and generating multiplier effects through business facilities, restaurants, farmers' markets, transportation and distribution equipment, etc. In addition, production for consumption reduces household food costs, allowing household income to be used for other purposes (Hodgson et. al., 2011).

1.2.3. Socio-cultural Contributions

Urban agricultural activities draw attention as an activity that brings together people from many different educational levels, age groups, ethnic and social groups that make up the city on the basis of production. For this reason, it promotes mutual trust, sharing, responsibility, peace and friendship for social development. It also enables the reuse of idle land and therefore reduces risk factors in society such as crime, vandalism, littering, fire and so on. Therefore, urban agricultural areas contribute to the creation of safe spaces within the city (Golden, 2013).

Hybrid urban agriculture, community gardens, school gardens and direct marketing strategies (such as Community Supported Agriculture or CSA, farm to school programs and farmers' markets) increase social interaction between different ethnic and age groups, ensure social participation and strengthen social communication.

In addition, urban agriculture can prevent youth unemployment to some extent, while ensuring that young people do not stray, pick up bad habits and engage in criminal activities. At the same time, urban agriculture programs are also used in many countries to reintegrate criminals into society and ensure the cultural integration of refugees (Korgavuş & İnan, 2021; Türker & Akten, 2023).

Production experiences in urban agricultural areas raise social awareness on sustainability, food systems, ethical and environmental issues through education and youth programs. The development of social awareness is the most fundamental requirement for urban sustainability. In these ways, urban agriculture makes an important contribution to solving many social problems and even preventing some problems before they occur.

1.2.4. Nutrition and Health

Today, an increasing number of people lack access to land, production and sufficient food. Research has shown that the urban poor are more disadvantaged than other groups in terms of food security.

Urban agriculture is one of the successful strategies used to achieve food security as it makes food access routes easier. Urban agriculture increases food security by providing access to fresh fruits and vegetables to low-income groups with limited access to fresh and healthy foods, by providing access to food over shorter distances, less transportation, packaging and intermediary costs, and lower prices. It also creates social awareness through health programs and awareness-raising activities on nutrition issues (Bellows et. al., 2004).

2. Innovative Practices and Vertical Farming in Urban Areas

In urban agriculture, innovative practices are preferred instead of traditional cultivation techniques due to expensive and limited land, low soil fertility, various environmental problems and in order to make the business more profitable.

In recent years, innovative practices and investments in urban agriculture have focused on environmentally controlled urban farms. Environmentally controlled urban farms are mostly rooftop greenhouses or completely enclosed spaces inside buildings, artificially illuminated plant factories.

2.1. Vertical Agricultural

Vertical farming is actually a method of large-scale agriculture in an urban environment called controlled environment agriculture or building integrated agriculture.

In 1999, Dr. Dickson Despommier, a microbiologist from Columbia University, conducted detailed studies on vertical farming with a group of his students. Dr. Despommier, who also attracted the attention of the American press, said that with climate change increasing the cost of traditional farming, technological advances would make greenhouse farming cheaper and therefore vertical farming would become more attractive. Despommier's biggest dream is that within 50 years, half of the food produced in the world will come from vertical farms. In this way, he says, a significant amount of agricultural land will be abandoned, which will quickly restore the functions of the ecosystem and slow down global warming. He claims that multi-storey vertical farms will reshape urban life and that vertical farming is the only way to make sustainable agriculture while obtaining healthier, fresher products (Bingöl, 2019).

Vertical agriculture is based on the proposal to grow agricultural products vertically with different materials and systems in places where there is little or no arable land (skyscrapers, apartment buildings, balconies, terraces, shrinking land, mini gardens, etc.).

Although agriculture is still practiced in open or closed areas today, vertical farming makes greenhouse cultivation more efficient with high technology.

The aim of vertical farming is to reduce the use of environmentally polluting pesticides such as pesticides and herbicides. To prevent the loss of agricultural land and to prevent the conversion of forest land into agricultural land. The spread of vertical agriculture is also expected to reduce adverse weather conditions due to climate change and prevent food prices from rising excessively due to a decrease in supply. High production technologies in vertical farming also bring early production, yield and quality increase. It provides economy in water consumption (Bingöl, 2019).

Today, examples of vertical farming can be seen all over the world. The idea of farming in the city began when most people started to change. Although the idea of production in projects in metropolises, which is one of the goals of vertical farming, has not yet received sufficient interest at a renewable level, the systems used in vertical farming are constantly renewing themselves with continuous developments in technology and reveal that the idea may be realized in a different way in the future. In addition, soilless production techniques and vertical farming are promising in continuous improvement programs.

2.1.1. Advantages of Vertical Agriculture

The advantages of vertical agriculture applications are listed as follows (Bingöl, 2015);

1. Water economy: It saves 70-95% of water compared to normal agriculture.

2. Controllable climate control: Brings earliness, yield and quality increase.
3. Soil economy: Provides agricultural production opportunities everywhere without being dependent on soil.
4. Proximity to the market: Provides local production and offers seasonal market opportunities.
5. Disease, pest and weed control: Insecticide is not used as in traditional agriculture.
6. Optimized production: The techniques used in the system ensure a 90% harvest from the planted products and prevent crop losses.
7. Environmentally friendly: It has no negative impact on biodiversity and the environment.

2.1.2. Vertical Agriculture Classifications

Vertical farming systems are classified according to their construction methods as follows (Bingöl, 2015);

a. Open: Exposed to sunlight and the elements (Rooftop, open-air farms).
b. Enclosed: Protected from the elements, but still uses sunlight as the main source of heating and illumination.
c. Indoor: No natural sunlight. Plants are grown using LED plant lighting technology.
d. Other: Does not receive natural sunlight. Plants are grown using other plant lighting technologies (TL, HPS, etc.)

2.1.3. Vertical Agriculture Production Systems

Vertical farming is divided into three types according to the growing environment within soilless farming.

a. Aeroponics
b. Aquaponics
c. Hydroponics

a) Aeroponic systems: Aeroponic systems are basically an air-water culture based on the principle of providing nutrient solutions to the bare root system in the form of intermittent or continuous mist.

Water and nutrients, which are determined in advance according to the type of plant to be grown in the system, are sprayed to the root system with modular systems from the water basin through a pump channel connected to a timer to meet plant requirements.

The biggest advantage of the system is that it provides economy in water and fertilizer use. Since low-quality water can be easily used in this system, this system can be used successfully in regions where water quality is low and quantity is low.

The disadvantage of the aeroponic system is that the basins where the roots are suspended are constantly moist, so these basins must be treated with hydrogen peroxide solution to prevent the growth of harmful bacteria and fungi. The basin where the roots are suspended in the system must be opaque. Because roots do not like light, they have evolved to develop underground (Okur, 2015). Nowadays, LED systems are also used instead of sunlight in aeroponic systems. Different modular systems are designed with high-intensity LED lights in long rows or V-shaped to meet the needs of the plant. LED systems that meet the red and blue wavelengths required for photosynthesis not only save energy but also reduce cooling costs by staying cooler (Okur, 2015).

Aeroponic system can be used especially for rooting of stem cuttings of species that can grow in humid and high ground water areas or have high water requirement. Thus, it is possible to realise faster rooting and growth in a short time (Şimşek & Gül, 2018).

b) Aquaponic systems: Aquaponic is a sustainable food production system alternative that combines traditional Aquaculture (fish, crayfish, shrimp production from aquatic organisms) with the Hydroponic System. Aquaponic is an application based on the use of water used in aquaculture in hydroponic systems. The main purpose of this system is to reduce or completely eliminate the pollution load of water used in aquaculture. The water used in fish farming is quite rich in terms of nutrient elements. By giving this water to hydroponic systems, plants benefit from the nutrient elements. The water is filtered by the plants and the plants act as the purification unit of the cultivation unit. The pollution load of the water purified by the plants is reduced. The system is in the form of bringing the water used in aquaculture to the tanks where the plants are grown through pipes or by opening holes wide enough to accommodate the plants and placing them there (Backyard, 2007).

The biggest advantage of this system is that it is used to prevent or reduce the direct mixing of waste products resulting from the metabolic activities of fish in fish farming in semi-closed or closed circuit systems, especially in terrestrial environments, into the natural environment (Kerim & Tırıl, 2009).

Other advantages are that the number of food products that can be grown is large and that it does not require special nutrient solutions for plant roots to receive sufficient nutrients, as in other systems (Okur, 2015).

The disadvantage of the system is that the costs of establishing the system are high and it requires constant observation and control (Kerim & Tırıl, 2009).

c) Hydroponic systems: Hydroponic systems are the first technique used in soilless agriculture. (Hydroponics literally means growing plants in a nutrient solution without support. However, growing plants in a solid medium using a nutrient solution is also included in the hydroponic system (MEGEP, 2008).

Hydroponic systems are divided into two as liquid or aggregate systems. While there is no solid medium to support plant roots in liquid systems, there is solid medium support in aggregate systems.

Hydroponic systems can also be called open and closed systems apart from this classification. In an open system, the nutrient solution is given to the plant roots once and is not reused. In a closed system, excess solution is collected and circulated again (MEGEP, 2008).

These systems can also be divided into two as active systems or passive systems. Passive systems use a very high capillary effect with a filter and nutrient medium. This allows water to be absorbed by plant roots. Active systems work by actively passing the nutrient solution through the plant roots (Shrestha & Dunn, 2013).

a) Passive Systems
   - Filter System

b) Active Systems
   - Aquaculture technique
   - Tidal system
   - Drip system

- NFT system
- Aeroponic system

3. Contributions of Hydroponic Systems to Sustainability

As a requirement of being a society, one of the most important problems that public institutions must combat is poverty. A state whose citizens are afflicted with poverty cannot be expected to be successful in the fields of human and social development. Although poverty is widely covered in the human development reports prepared by the United Nations Development Program (UNDP), it does not have a clear definition. While this is a normal situation brought about by the relativity of poverty in time and space, it is also a situation resulting from the multidimensionality of the concept. In this sense, a judgment based only on the national income per capita will be unsupported. Therefore, some indicators regarding the qualitative dimension of the concept of development also emphasize the meaning of poverty. According to Tomar, who reaches a judgment based on this, poverty; It is necessary to perceive some problems as a whole, such as "low income level", "inadequate and unbalanced nutrition and ill health", "psychological and individual economic insecurity", "vulnerability to shocks, inability to respond to risk and uncertainty", "deterioration of the natural environment and vicious circle in the social environment" (Tomar, 2013). Therefore, based on the definition of poverty here, it is understood that development is not an economic issue alone. Based on this, it is concluded that development should be addressed from a perspective that encompasses all environmental, social and individual dimensions, in accordance with the "more balanced, holistic development" approach that was determined as the slogan of the Regional Development National Strategy 2014-2023 published in 2014.

On the one hand, the destruction of agricultural lands due to the pressure of increasing population and rapid urbanization and the increasing food security problem, on the other hand, the need for shelter of the increasing population and the environmental problems caused by this increase have brought issues such as sustainable city models and planning approaches, the integration of agriculture with the city, and sustainable high-rise buildings to the focus of discussion in physical planning disciplines (Çarıkçı, 2019).

Products that can be produced economically and commercially in cities are generally used for fresh and functional foods. Products with high water content (90-95%) are usually bulky and fragile, and therefore difficult to transport without refrigeration or careful packaging. Ordinary commercial trucks used to transport fresh foods from rural areas to cities produce CO_2 emissions of 0.8 kg to 1.9 kg per ton (Ohyama et. al., 2008).

In addition, additional CO_2 is emitted by cooling the food during transportation. Therefore, transporting perishable fresh food over long distances leads to the consumption of resources and pollution of the environment. In addition, additional resources are required to manage food waste.

The yield and profit obtained from the unit area increase in plant production carried out using hydroponic systems. Since the system is controllable, the amount of residue in the obtained products is reduced to a minimum. It is thought that the ease of harvesting, the ability to obtain products in every season, the high yield obtained will increase the tendency towards soilless agriculture and plant cultivation with hydroponic systems will become widespread. The most important issues in soilless cultivation are the growing medium used for plants, pots, raw material transportation and the energy requirement of the system. For example, the use of paper containers instead of plastic containers provides a significant reduction in greenhouse gas emissions, the use of abiotic resources and acidification situations. The use of by-products and environmental wastes in terms of electrical energy needs has the potential for an efficient and symbiotic change. In addition to these features, the materials, water and nutrient solutions used in the system must be sterile. Because plant pathogens can infect the system and cause various problems (T.C. Çevre, Şehircilik ve İklim Değişikliği Bakanlığı, 2024).

Among the hydroponic systems that include open and closed systems, the reasons why closed systems are preferred include the prevention of disease-causing elements. In the majority of aggregate systems, when more than one plant benefits from a single root, the disease also infects these plants. In open systems, diseases spread more easily and quickly. In closed systems, such a situation does not occur and healthy growth of plants can be ensured. As a result of different techniques applied in Turkey, it has been understood that the failure rate of the system in a problem that may be experienced in water culture is higher than in substrate culture and that substrate culture is more suitable for the greenhouse environment.

Although controlled environment agriculture (CEA) vertical farms vary in size, model or design, the common point of all of them is that they are based on a system principle that operates on hydroponics or nutrient mineral nutrient solutions in water instead of soil. In businesses in this category, most of the production stages are carried out with computer-controlled systems. In this way, excessive nutritional supplements are not applied to plant products and chemical applications are prevented (Yılmaz, 2015). It is known that CEA is applied in large cities in South Korea, Asia, Europe, Australia and North America. Vertical agriculture is more economical in terms of energy use in the production of basic grain products that cover most of the global food consumption compared to conventional production.

The most important possible disadvantage of CEA is capital. In addition to the initial investment costs of vertical farms, energy is the main item in operating costs. Energy is as valuable in vertical farms as water is in traditional agriculture. A high amount of energy is consumed for a production activity that continues all year round and 24 hours a day. Another factor that increases the cost is the difficulty of finding suitable land in cities and the fact that it is much more costly than in rural areas when found (Bostancı, 2020).

4. Conclusion and Suggestions

The realization of a more balanced and holistic development basically requires that access to resources be equally easy for citizens residing in each settlement. The accessibility of food as a basic source of life has always been one of the most important factors in determining the location of human settlements, and therefore food resources have been directly linked to urban structure in primitive settlements. However, as Rasouli conveys, with the emergence of industrial developments, agricultural trade, cheap transportation and food preservation technologies, the distance between agricultural land and markets has increased rapidly, and due to the form of the current built environment, food production systems are no longer included in urban areas. However, this existing rural-urban distinction constitutes the main source of many problems we face in the world today. Climate change, poverty and health problems are some of them. The damage to the natural environment in current industrial food production systems, the low nutritional quality of agricultural products and the high energy consumption due to the long distances covered in food transportation lead to criticisms against these systems (Rasouli, 2012b).

The sustainable urban development approach is a multifaceted strategy with environmental, social, economic, spatial and administrative dimensions. Urban agriculture, which is an important strategy in sustainable urban development policies, provides many contributions to cities in terms of economy, ecology, social and health. Urban agriculture provides access to cheap, fresh and healthy food and food security as transportation distance and the number of vehicles are reduced.

In addition, urban agricultural areas provide income for many people working in the food production, distribution and marketing sectors, contribute to the family budget for those who produce for consumption and support the reduction of urban poverty. In addition, urban agriculture contributes to urban sustainability in many ways such as reducing carbon footprint, increasing biodiversity, contributing to recycling and so on.

The issue of food production has been questioned throughout history by leading modernist planners and theorists. The first approach to draw attention to this problem was Ebenezer Howard's theory of Bahçeşehir. In all of Howard's city proposals, 5/6 of the land was allocated to agricultural activities (Howard, 1965). Howard's ideal city appears in his book "Garden Cities of To-Morrow" published in 1902 and also in the diagrams he drew. Howard generally showed a city that was a mixture of city and agriculture as the ideal city. The relationship between city and agriculture also formed the basic idea of the works of Patrick Geddes, a pioneer theorist like Howard in the early 20th century. Geddes' concept of land use section (transect) emerged in order to clarify the relationship between production areas and city centers (Geddes, 1915).

Urban agricultural areas also contribute to the increase of social and cultural ties and social awareness in society, the reintegration of criminals into society and the creation of safe spaces. For all these reasons and for us to be a self-sufficient country in terms of agricultural production, urban agricultural areas should be addressed, planned, managed and a monitoring mechanism should be established within urbanization policies. In the implementations in this regard, not only central administrations but also local administrations have important duties in the institutional structure.

The intense migration from rural areas to urban areas has caused the production in rural areas to be moved to cities where consumption is high, which has resulted in different problems such as transportation, product price, freshness. For these reasons, the idea of shifting production from rural areas to urban areas has emerged, and as a result, the idea of vertical farming has emerged.

The aim of vertical agriculture is to create large-scale, controlled, structure-integrated agricultural systems in cities. Thanks to this system, it is possible to do agriculture in open or closed areas in cities. They can be easily applied inside or on abandoned warehouses and industrial facilities in city centers. Vertical agriculture has many advantages over traditional farming. Water and soil economy is provided thanks to the techniques used in vertical farming. Controllable climate control brings earliness, yield and quality increase. Production in cities offers proximity to the market, local production and seasonal market opportunities. Optimized production prevents crop losses and increases harvest amount. No pesticides are used as in traditional farming methods. Vertical farming has no negative impact on biodiversity and the environment (Bingöl, 2015). It is seen that the key concept that emerges as a solution to the problems pointed out by the studies conducted in this context is “sustainability”.

Although there are positive criticisms for vertical agriculture, there are also negative criticisms. The disadvantages of vertical farming are the high land prices in city centers, the high installation and operating costs. In addition, the high energy requirement of the business for heating and cooling is another criticism. However, today, different construction designs and techniques are constantly looking for new ways to increase the amount of product and efficiency, and to reduce construction and operating costs. Continuously developing and renewed technology provides more efficient and cheaper opportunities for vertical agriculture.

Turkey is among the leading countries in the world in agricultural production. However, the fragmented soil structure seen in agricultural areas, erosion and drought problems experienced in some regions reduce productivity. It is thought that the necessary importance should be given to agriculture and both the producer and the consumer should be informed about soilless agriculture. Since the appearance of the products grown with the soilless agriculture method is uniform and beautiful, the hormone prejudice should be broken. Since soilless agriculture can be done both in the open and under cover, the most suitable place should be selected according to the product to be produced and the area where the facility will be established. Since there are many fertile agricultural lands in Turkey, attention should be paid to the fact that the areas where hydroponic systems will be established are unproductive, and fertile lands should be approached with the same sensitivity shown towards soilless agriculture. The number of studies conducted for product diversification should be increased and the trial dimension should be reached.

As a result, although vertical agriculture has not yet received sufficient attention at the industrial level, it may lead to the emergence of different systems that will replace traditional agriculture in the future. Vertical agriculture studies provide new perspectives not only for our world but also for space programs.

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There is no conflict of interest.

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Strategies and Actions for Village Design Guides in the Global Climate Change Process

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1. Introduction

Climate change emerges as one of the biggest environmental problems today. This problem is a global situation that affects not only the individual and the country but also our world, which is our common home (İklim Değişikliği Başkanlığı, 2024a). The possibility of climate change due to changes in carbon dioxide (CO_2) accumulation in the atmosphere was first predicted in 1896 by Nobel Prize reward S. Arrhenius (Arat et al., 2023). Until the mid-20th century, most atmospheric scientists assumed that climate changes were caused only by natural factors. However, after the 1960s, the idea that various human activities in addition to natural causes could also have effects on the climate system became dominant (Hekimoğlu & Altındeğer, 2008).

The clear observation of climate change due to the accumulation of carbon dioxide (CO_2) in the atmosphere dates back to the Industrial Revolution. Developing technology with the Industrial Revolution has caused the increased use of fossil fuels and the rapid increase in greenhouse gas emissions (İklim Değişikliği Başkanlığı, 2024a).

The current level of CO_2 accumulation in the atmosphere is well above the natural CO_2 accumulation changes in the record of approximately 700 thousand years (ranging between approximately 180-300 ppmv). This situation weakens the cooling efficiency of the earth, causing positive radiative forcing to occur. It means strengthening the natural greenhouse effect (Türkeş, 2021a).

The important consequence of the greenhouse effect, which has been strengthened as a result of the rapid increase in the accumulation of greenhouse gases in the atmosphere, has caused the world climate to become hotter, drier, and more variable in some regions. At the First World Climate Conference, *"If society's long-term dependence on fossil fuels as an energy source and deforestation continues in the future, the accumulation of CO_2 in the atmosphere is likely to increase significantly. It shows that this increase in CO_2 accumulation may lead to significant and possibly long-term changes in the global climate. The removal of CO_2 from the atmosphere by human activities is a slowly developing process, so the climatic consequences of CO_2 accumulation are effective for a long time*" (Türkeş, 2021b).

Today, the main concrete observable issues of climate change are developments such as increasing temperatures, decrease in potable and irrigation water, regional and urban air pollution, decrease in biodiversity, deterioration of soil quality, etc. (Kızmaz, 2021).

International studies and agreements have begun to be made against all these negative effects. The United Nations Framework Convention on Climate Change (UNFCCC) was signed for the first time in 1992. The greenhouse gas reduction obligations of the countries that are parties to this agreement have remained inadequate over time. By signing the Kyoto Protocol in 1997, it was aimed to reduce greenhouse gas emissions through legally binding regulations. With the Paris Agreement in 2015, for the first time, all countries were obliged to reduce greenhouse gas emissions (T.C Dışişleri Bakanlığı, 2024).

Türkiye signed the Paris Agreement in 2016 with representatives of 175 countries at the High-Level Signing Ceremony held in New York. In line with the Paris Agreement, we set out with the "Net Zero Emission

Target" until 2053 (T.C. Dışişleri Bakanlığı, 2024). In this direction, preparations for the Climate Change Mitigation Strategy and Action Plan (2024-2030) have started (İklim Değişikliği Başkanlığı, 2024a).

Today, greenhouse gas emissions are mostly seen in urban settlements, and the majority of solution-oriented actions cover these settlements. However, rural settlements are a very sensitive point in the climate change process due to reasons such as laws and policies, as well as a lack of spatial infrastructure and superstructure. In this study, spatial strategies and action suggestions were developed based on the problem of how Village Design Guides (KyTR), which are an important tool for rural settlements in the process of climate change, can be adapted to the "Net Zero Emission Target" in line with the Paris Agreement.

1.1. Global Climate Change and Causes

The global climate has shown significant changes and changes in all space and time scales, from the formation of our Earth, which is approximately 4.6 billion years old, to the present day (Türkeş, 2021a). Climate has been observed to change continuously over time according to the movements of the earth and the atmospheric layer surrounding it (Topcuoğlu & Doğan, 2011).

Climate change, regardless of the cause, is a long, continuous, and slowly developing change in climatic conditions that has global and local effects (Türkeş et al., 2000). The fact that this change began to be observed by human beings dates back to the Industrial Revolution and its aftermath. Especially with the development of the rapidly developing industrial sector in the 18th and 19th centuries, the change in nature's dynamics was accelerated by human intervention.

Air is a part of the atmosphere that tends to heat up more due to the accumulation of greenhouse gases such as carbon dioxide (CO_2), water vapor (H_2O), nitrogen monoxide (N_2O), methane (CH_4), various suspended particles and ozone (O_3), variable gases and aerosols in the atmosphere. The formation of positive radiative forcing was observed. The positive contribution to the energy balance of the atmospheric common system is called the strengthened greenhouse effect (Türkeş, 2021a). The positive force of greenhouse gases, which started to accelerate with the Industrial Revolution, is shown among the main reasons for climate change (Topcuoğlu & Doğan, 2011).

Many scientists say that in the last 150 years, the positive force of carbon dioxide (CO_2) concentration in the atmosphere has increased by 35% (to 378 ppm), from 280 parts per million before the industrial revolution, as a result of human activities, causing the average global warming to increase (Justus & Fletcher, 2006).

In the report of the International Panel on Climate Change (IPCC), it is stated that the main actor of climate change belongs to human activities (Kızmaz, 2021). It is claimed that the impact of human activities on the occurrence of climate change is strengthened in a positive direction by 95% (Erk, 2017). The reasons for the increase in carbon dioxide (CO_2) concentration and other atmospheric gases are due to human activities, such as fossil fuel use, deforestation, industrialization, increase in human population, and change in land cover (Justus & Fletcher, 2006).

In the Climate Change Mitigation Strategy and Action Plan report, it is mentioned that global warming has increased by 1.1°C from 1850 to 2020 as a result of the increase in CO_2 and other gases in the atmosphere and that this rate will inevitably reach 3°C in the future (Climate Change Presidency, 2024a).

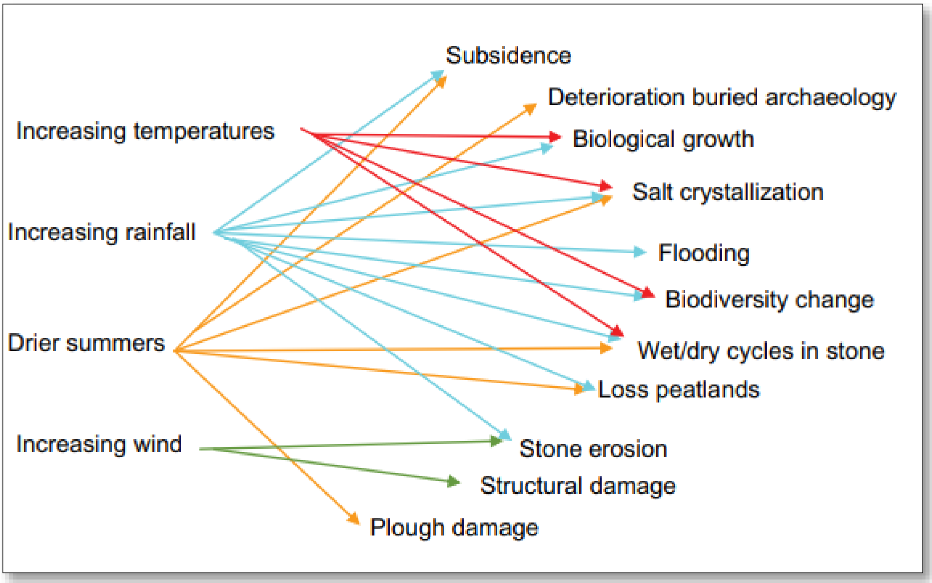

Figure 1. Climate change factors and impacts (Daly, 2014)

Nowadays, increasingly frequent heat waves along with droughts, melting glaciers and permafrost, heavy rains and floods, hurricanes, etc. are seen as an inevitable end of climate change (Somuncu, 2021).

Our natural resources such as surface and underground water resources, marine systems, soil, biodiversity, ecosystems, and forests are affected by sudden weather events seen in climate change. In particular, the seasonal distribution and amount of precipitation and the change in the average annual precipitation flow cause changes and decreases in surface and underground water resources and marine ecosystems, and scarcity of usable water. Sudden heat waves and droughts decrease biodiversity, change ecosystems, decrease fertile soils, and forest fires. Severe weather events such as sudden winds, tornadoes, and hurricanes cause loss of fertile soil through erosion, changes in biodiversity and ecosystems, etc. (Figure 1).

1.2. Global Climate Change Challenge and Climate Agreements

In 1988, the First Assessment Report of the IPCC dated 1990 was prepared by the World Meteorological Organization and the UN Environment Program for the development of scientific evaluation and combat strategies regarding the effects of climate change. According to the report, it was determined that the amount of gases in the atmosphere has changed significantly as a result of human activities (İklim Değişikliği Başkanlığı, 2024a).

Preventing, adapting to, and mitigating the effects of climate change caused by human activities has become a duty for people. Many studies have been carried out to raise environmental and climate awareness around the world. In addition, states have determined many agreements and policies to fulfill their responsibilities (Selçuk, 2023; Akten & Akyol, 2018).

In 1992, the United Nations Framework Convention on Climate Change (UNFCCC) was signed by 194 countries for the first time in Rio de Janeiro to solve the climate change problem (Selçuk, 2023).

This agreement has brought different obligations to countries to minimize the negative effects of climate change. However, the obligations are not legally binding (Türkeş & Kılıç, 2004).

The contract has been discussed based on four principles. These principles;

• The principle of equality,

• The principle of common but differentiated responsibilities,

• The principle of precaution,

• The right and obligation to support sustainable development (Talu & Kocaman, 2018).

The UNFCCC divided the parties into three different groups, based especially on the principles of equality and common but differentiated responsibilities and powers according to countries. These are countries in the Annex-I list, countries in the Annex-II list, and non-Annex-I countries. Annex-I includes European Union (EU) member countries, Organization for Economic Development and Cooperation (OECD) member countries, and Countries in the Transition Process to a Market Economy (Eastern Bloc Countries). Annex II consists of EU countries and OECD members. Non-Annex I countries are underdeveloped countries and are the countries that have been and will suffer the most from climate change (Türkeş, 2001; Selçuk, 2023).

The UNFCCC stipulates 3 conditions regarding the goal of stopping greenhouse gas emissions in the atmosphere at a certain level;

• Ecosystems naturally adapt to climate change,

• Food production is not threatened,

• The existence of a period sufficient to allow economic development to be carried out sustainably (Türkeş, 2021b).

The fact that countries fall behind their greenhouse gas reduction obligations and put their financial interests ahead of global problems has made the fight against climate change very weak. The UNFCCC has been found insufficient to meet greenhouse gas reduction targets because it is not legally binding and does not set clear obligations (Selçuk, 2023).

The Kyoto Protocol is the first international agreement signed on 11 December 1997 (United Nations Environmental Convention on Climate Change (UNFCCC) to determine and reduce the greenhouse gas emissions of major industrial countries with legally binding rules (Fletcher, 2006). This agreement was the first to specify a quantified emission reduction target for Annex-I parties (Climate Change Presidency, 2024b). It was made suitable for the approval of the parties at its conference in 2001 was accepted and approved by the Russian Federation in 2004 and entered into force on February 16, 2005 (Kartal & Akıllı, 2018).

The Kyoto Protocol is an important step for member countries to combat climate change, embodied by the numerical limit. The fact that the USA, which is the first country with the highest greenhouse gas emissions, was excluded from the agreement in its second responsibility period (USA President G. W. Bush period), and the second country, China, and the fifth country, India, did not sign the protocol, caused a big problem. In addition, developing countries have argued that greenhouse gas emission reduction obligations should be undertaken by countries with historical responsibility, and have not taken the mitigation obligation because it would negatively affect the development processes of their economies (Selçuk, 2023).

The Paris Agreement is an important turning point in the climate change process. This Agreement covers all countries for the first time and brings them together to combat climate change and adapt to its current impacts. Under the agreement, countries must work on a five-year climate action cycle called a National Declaration of Contribution (NDC). Parties are obliged to submit their NDCs to the UNFCCC Secretariat every five years. Each NDC submitted to the UNFCCC Secretariat is intended to reflect a higher degree of ambition compared to the previous NDC (İklim Değişikliği Başkanlığı, 2024a).

1.3. Türkiye's Climate Change Struggle and Studies

Türkiye became a Party to the Kyoto Protocol on 26 August 2009, following the Council of Ministers Decision No. 2009/14979. Türkiye which is not a party to the UNFCCC, is not included in the ANNEX-B (list of developed countries) list of the Protocol, where the quantified greenhouse gas emission limitations or reduction obligations of ANNEX-I Parties are defined. The Doha Amendment, which was adopted for the reduction in the second obligation period of the Kyoto Protocol (2012-2020) (The Doha Amendment includes changes or regulations for the second period of the Kyoto Protocol, but has not entered into force) does not impose an obligation on Türkiye (İklim Değişikliği Başkanlığı, 2024b).

The Paris Agreement has accelerated Türkiye's climate change efforts. Türkiye's first Climate Council was held on 21-25 February 2022. At this meeting, 217 recommendations were adopted to create a vision for Türkiye's 2053 Net Zero Emission Target, and 76 of them were prioritized. These decisions formed the basis for the preparations of the Climate Law, NDC, Climate Change Mitigation and Adaptation Action Plans and Long-Term Climate Change Strategy (İklim Değişikliği Başkanlığı, 2024a, İklim Değişikliği Başkanlığı, 2024c).

The most distinctive feature of the Paris Agreement compared to the UNFCCC is that it envisages a system that will be based on the contributions of all countries. The agreement is based on the understanding that developed/developing countries assume responsibility in the fight against climate change in line with the principle of "common but differentiated responsibilities and relative capabilities" of all countries (T.C Dışişleri Bakanlığı, 2024).

In Türkiye; Dated 29/10/2021, the duties of "determining policies, strategies, and actions at national and international levels within the scope of Türkiye's fight against and adaptation to climate change, carrying out negotiation processes, ensuring coordination with institutions and organizations" were given to the Presidency of Climate Change (İklim Değişikliği Başkanlığı, 2024a).

Preparatory work for the Climate Change Mitigation Strategy and Action Plan (2024-2030) has been initiated within the framework of the Climate Council Decisions, the 12th Development Plan, and the MTP 2024-2026. Action plan; It is structured on seven main mitigation sectors, namely "Energy, Industry, Buildings, Transportation, Waste, Agriculture and Land Use, Land Use Change and Forestry (LULUCF)", defined as the basic mitigation sectors, and 2 horizontally cutting theme areas: "Just Transition and Carbon Pricing Mechanisms" yapılandırılmıştır (İklim Değişikliği Başkanlığı, 2024a).

2. Material and Method

In this study, firstly, national and international literature research was conducted on the subject of the study, such as books, articles, theses, internet sources, official institution reports and sites, etc. The causes of global climate change, international and national studies against global climate change, and the problems experienced by rural settlements due to global climate change are discussed.

In the second stage, it tried to reveal the importance of the Village Design Guide, which is an important tool for rural settlements, and its importance in the fight against global climate change. In this regard, suggestions for spatial strategies and actions have been developed for the Village Design Guide in line with climate change, taking into account the findings of official institution reports and theses, articles, etc. literature. It is thought that the proposed strategies and actions will be guiding for decision-makers and practitioners by integrating the suggestions presented in climate change mitigation and adaptation processes

3. Findings

3.1. Rural Settlements and Climate Change

The phenomenon of settlement consists of two basic approaches: rural and urban. Rural settlements appear as settlements where natural and environmental areas come to the fore and are the main centers of agriculture and animal production (Yenigül, 2017). If we give a more detailed definition of rural settlements, they are settlement areas that differ from urban settlements in many aspects, such as population density, economic resources, social and cultural structure features, relationship with the environment, etc. (Aydemir & Gül, 2023). It stands out by being distinguished from urban settlements, especially with its natural and cultural landscape values (Gül et al., 2019).

Today, urban settlements are responsible for 75% of global greenhouse gas emissions with their production and consumption rate, structural mass increase, human-induced activity intensity, transportation, buildings, and energy sectors (UNEP 2019). Although cities, directly and indirectly, increase the effects of climate change, greenhouse gas emission rates vary depending on the size of cities, planning dynamics, lifestyle of the population, and energy consumption (Aşıcı, 2023).

Urban settlements are the main spatial areas in the emergence of climate change. Rural settlements are places that are more affected by climate change than urban areas and face many problems. According to IPCC Rural Areas reports, rural settlements stated that they face certain vulnerabilities to climate change due to their relative deficiencies in investment, service access, management, etc. compared to urban settlements (Table 1) (Morton et al., 2014). Reasons why rural settlements are vulnerable compared to urban areas:

• Even though there is an increase in migration from rural settlements to urban settlements, 3.3 billion people still live in rural areas. This accounts for almost half (47.9%) of the world's total population (UN DESA Population Division, 2013).

• The majority of the world's rural population (3.1 billion people or 91.7% of the rural population or 44% of the world's total population) lives in less developed countries (UN DESA Population Division, 2013).

Table1. Poverty indicator in rural areas of developing countries. (IFAD, 2010; Morton et al., 2014).

	Incidence of proverty (%)		Incidence of rural proverty (%)		Incidence of extreme proverty (%)		Incidence of extreme rural proverty (%)		Rural people as % of those in extreme poverty	
	1988	2008	1988	2008	1988	2008	1988	2008	1988	2008
Developing world	69.1	51.2	83.2	60.9	45.1	27.0	54.0	34.2	80.5	71.6

• Rural people make up approximately 70% of the world's poor people. IFAD (2010) stated that approximately 70% of the extremely poor in developing countries lived in rural areas in 2005 (Morton et al., 2014).

• Rural areas are associated with specific patterns of human activity, but today they are spatial settlements where these relationships are subject to constant change (Morton et al., 2014).

• Rural areas are defined with their differences compared to urban areas, but these differences are seen more as problems today (Morton et al., 2014).

• The rural population has various sources of income, including animal husbandry, farming, and agriculture. Today, although income sources originating from natural resources are privileged, they are the non-dominant source of income in the world (Morton et al., 2014).

Observing the effects of climate change on rural settlements includes basic questions regarding documentation, detection, and attribution. The main reasons for this situation are the numerical abundance and spatial dispersion of rural settlements, low education level, small number of young population, etc. causes (Aydemir, 2022). This situation strengthens the rural community's access to infrastructure and superstructure opportunities and makes public investments difficult (Erdem, 2012; T.C Kalkınma Bakanlığı, 2018).

In rural settlements, the effects of climate change on the structure of settlements, livelihoods, and incomes will be the result of multi-step causal impact chains. These chains will typically be of two types. The first of these will include extreme events such as floods, storms, and droughts that affect rural infrastructure and directly cause loss of life.

The other type would involve impacts on ecosystems on which agriculture or rural people depend (Morton et al., 2014).

The category of extreme events that negatively affect rural settlements includes storms, floods, and drought. Saldaña-Zorrilla, (2008) Hurricane Stan flash floods and river floods in October 2005 affected approximately 600,000 people along the Chiapas coast. Drought, decreased employment and migration also cause serious economic consequences for rural settlements (Gray & Mueller, 2012). Ericksen et al. (2013) investigate various animal mortality rates due to drought in Africa. The number of livestock deaths has increased by 80% since 2009.

3.2. Climate Change Adaptation Strategies and Actions of the Village Design Guide

Design policies are a tool that regulates the justifications of designs and the content of applications and sanctions. Design guides are special application tools that contain the goals and objectives of design policies (Eminağaoğlu & Çevik, 2007).

Design guides protect natural and cultural landscape values, highlight the socio-cultural values of local life, guide development, determine spatial and functional usage diversity, adopt visions and strategies that protect locality but adapt to the future, offer strategic solutions to problems in the field, are flexible, adaptable to change. and are tools open to development (Gül & Bostan, 2018).

Today, compared to urban settlements where similar and monotonous structures are seen, rural settlements have cultural and natural landscape values, ecosystems, biodiversity, social values, etc. They are settlements with rich features and unique values. However, the fact that the current laws and regulations for rural settlements cannot meet today's needs and are insufficient and complex in terms of content is an alarming situation (Aydemir & Gül, 2023). With the Law No. 6360 of 2012, the legal personality of village and town municipalities within the territorial borders of the districts of 30 provinces was abolished, the villages turned into neighborhoods, and the municipalities joined the municipalities to which they were affiliated under the name of town (Eroğlu, 2013). Rural settlements have become an important issue that requires a separate planning and design approach from urban development plan policies. In our country, Village Design Guides (KyTR) entered the legislation with an article added to Zoning Law No. 3194 in 2013 (Aydemir, 2022). In the current legislation, the content, details, and relationship of KyTR with planning have not yet been defined and there is no regulation or directive. Rural settlements are in a much more fragile position than urban settlements due to deficiencies and inadequacies in many areas such as laws and policies, economy and development, infrastructure and superstructure, etc. This situation is getting even worse, especially with the many problems caused by global climate change today.

Türkiye has entered a period of combating climate change. Rural settlements and the climate change adaptation process, which are handled only in the field of agriculture and animal husbandry in terms of rural development, are very inadequate. In this respect, the fight against climate change can be addressed with spatial analyses and this scope can be expanded by taking advantage of the local, flexible, and open-to-development structure of village design guides. The starting point was the question of what should be the strategic action plans for rural settlements in line with Türkiye's Net Zero Emission Target with the Paris Agreement and what role KyTR should play in this study. The strategies and action recommendations that should be included in the KyTRs of rural settlements regarding the fight against climate change are given in Table 2.

Table 2. Recommended strategies and actions for KyTR in the fight against climate change (adapted from the study of Aydemir, 2022)

Strategies	
Actions	**General information**
S.1. Expanding the use of renewable energy resources	
S.E.1.1. Expansion of renewable energy systems in small settlements	-To identify lands that are not used for agriculture and settlement purposes. To make these lands available for renewable energy systems (solar energy, wind energy, etc.). -Encouraging solar energy production in residences. -Identifying the hydroelectric potential in water resources and making the necessary investments. -Carrying out geothermal energy potential determination studies in the settlement.
S.2. Development of physical ınfrastructure	
S.E.2.1. Establishment or maintenance and repair of the drinking water infrastructure in the settlement.	-Improvement of existing infrastructure. Carrying out necessary maintenance and repair work. -Carrying out necessary infrastructure repair and maintenance works to ensure healthier, more hygienic, and sufficient water access. -Supporting the necessary work to prevent clean water leaks-Raise awareness of local people through training programs.
S.E.2.2 Establishing the sewer network or carrying out maintenance and repairs.	-Preventing the mixing of wastewater with clean water and soil and supporting the necessary infrastructure works. - Ensuring the connection of wastewater treatment plants and the sewerage network. - Establishment of sustainable wastewater management should be supported. - Improvement of existing infrastructure. Supporting maintenance and repair works of buildings in poor condition.
S.E.2.3. Establishing electrical infrastructure or carrying out maintenance and repairs.	- Improvement of power lines. Carrying out necessary maintenance and repair work. - Awareness should be increased about energy efficiency in electricity use.
S.E.2.4. Supporting clean-emission energy infrastructure.	-Conducting the necessary feasibility studies and creating the required infrastructure for transmission and distribution through natural gas pipelines. -Using fuels with high sulfur content, such as coal, dung, etc., should be prevented, and using clean fuels such as natural gas should be encouraged. -Solar and wind energy systems should be supported and their usage areas in residences should be increased.

Table 2. Recommended strategies and actions for KyTR in the fight against climate change (adapted from the study of Aydemir, 2022) (continued)

S.E.2.5. Improving existing transportation systems and accessibility.	- Renewal and improvement of the existing transportation network, carrying out necessary repairs and maintenance works. - Public transportation should be expanded between urban and rural settlements. -Smart card systems that allow fare collection/charging to encourage the use of public transportation should be expanded. -Micromobility/walking options should be strengthened. More reliable walking networks should be created for individuals. - The use of low/zero emission vehicles should be supported in public transportation or individual vehicle use. -Planning and development of charging station infrastructure in the required number and location in the transportation network should be supported for the widespread use of electric vehicles.
S.E.3. Making risk planning for natural disasters	
S.E.3.1. Conducting earthquake risk analysis and determining the necessary measures.	- Providing first aid and civil defense basic training to individuals in the settlement. -Identification studies of buildings at risk of earthquake and collapse in the settlement -Carrying out structural strengthening, maintenance, and repair works of buildings at risk of collapse. -Designing first response areas in the settlement (emergency meeting areas, etc.)
S.E.3.2. Conducting flood and erosion risk analysis and taking necessary precautions.	- Individuals in the settlement should be given first aid and intervention training in case of flood and erosion. -Determining residential areas that will be affected by natural disasters such as floods and landslides and taking the necessary precautions. Supporting the relocation of structures in identified dangerous areas to different areas.
S.E.3.3. Conducting risk analyses for weather events such as high winds, tornadoes, etc., and taking necessary precautions	- In sudden and severe weather events, local people should be given first aid and intervention training. - Spatial organization studies should be carried out to minimize loss of life and property.

Table 2. Recommended strategies and actions for KyTR in the fight against climate change (adapted from the study of Aydemir, 2022) (continued)

<table>
<tr><th colspan="2">S.E.4. Protecting and ensuring the sustainability of traditional civil structures against the risk of climate change.</th></tr>
<tr><td>S.E.4.1. Determination of typologies and preparation of surveys of traditional civil architectural structures.</td><td>-Conducting and supporting building typology studies of local architecture.
-Preventing the construction of new and modern buildings other than local architectural structures in the settlement.
- Building approach zones (ecological sensitivity buffer zones) to forest, agriculture, and water resources should be created and the construction of new buildings should be prevented.
-Carrying out an inventory of local materials used in the building. Its use in new buildings should be encouraged.</td></tr>
<tr><td>S.E.4.2. Supporting and encouraging maintenance, repair, renovation, and restoration of traditional and idle buildings against climate change.</td><td>-Carrying out maintenance, repair, and restoration works for the protection and sustainability of registered buildings, if any, in the settlement. Typological studies of the buildings should be carried out.
- Maintenance and repair works of idle, damaged, and about to collapse houses in the settlement should be supported.</td></tr>
<tr><td>S.E.4.3. Training masters and apprentices for local architecture, and providing support and encouragement for training and practice.</td><td>- Organizing training, courses, etc. workshops on building materials, maintenance, and repair specific to the location of the settlement.
-Supporting the training of craftsmen who know the local materials and carry out the necessary maintenance, repair, and renovation works.</td></tr>
<tr><th colspan="2">S.E.5. Making a zoning plan to protect against the risk of climate change</th></tr>
<tr><th colspan="2">S.E.6. Establishment of the Advisory Board to combat climate change.</th></tr>
<tr><td>S.E.6.1. Establishing an Advisory Board for permission, approval, monitoring and control for every activity to be carried out in the village.</td><td>-Establishing an Advisory Board to perform duties such as permission, approval, monitoring, control, etc. for all kinds of activities to be carried out in the settlement.</td></tr>
</table>

Table 2. Recommended strategies and actions for KyTR in the fight against climate change (adapted from the study of Aydemir, 2022) (continued)

S.E.7. Reducing the use of chemical fertilizers, pesticides, and anti-microbials.	
S.E.7.1. Preventing excessive use of chemical fertilizers, especially nitrogenous fertilizers, to reduce carbon emissions from agricultural soils.	-Establishment of inspection and monitoring systems for the use and application of fertilizers and pesticides after existing agricultural activities in the settlement. -Local people should be made aware of the conscious use of pesticides and fertilizers and training programs should be provided. - The use of organic, organomineral, compost, green manure, etc. alternative fertilizers to chemical fertilizers should be supported. - The use of pesticides and anti-microbials should be reduced, and the use of registered and licensed alternative products should be supported. - Dissemination of biological control. Establishing institutions related to biological control and providing support to farmers.
S.E.7.2. Supporting organic agriculture.	-Ensuring the promotion of organic agriculture and food production. Providing farmers with financial support for organic agriculture. -Providing farmers with a training, consultation, and monitoring-evaluation system by authorized units and institutions on organic agriculture. -Establishing cooperatives in organic production and food settlement and supporting farmers.
S.E.7.3. Supporting the use of local seeds.	-Supporting and encouraging the use of local seeds. -Supporting the creation of local seed banks specific to the settlement. - Establishing local seed cooperatives and supporting farmers.
S.E.8. To support the conservation of agricultural areas for environmental purposes (ÇATAK) project.	
S.E.8.1. To support the ÇATAK project in the fight against climate change.	"ÇATAK project, protecting soil and water quality, sustainability of natural resources, preventing erosion and reducing the negative effects of agriculture". - Minimum tillage in agricultural practices, protecting soil and water structure, preventing erosion, and supporting environmentally friendly agricultural technical and cultural practices.

Table 2. Recommended strategies and actions for KyTR in the fight against climate change (adapted from the study of Aydemir, 2022) (continued)

S.E.9. To enable land and soil management.	
S.E.9.1. Supporting and encouraging land consolidation.	- Integration of scattered small pieces of land in the settlement, which are very fragmented, dispersed, and distorted.
S.E.10. Reducing methane emissions from livestock.	
S.E.10.1. Increasing studies on genetic-based animal breeding that takes methane emissions into account.	- Planting forage crops to ensure the sustainability of meadow-pasture areas. -Meadow-pasture areas should be left fallow periodically for their sustainability.
S.E.10.2. Supporting meadow-pasture forage plant production.	- Encouraging the production of forage plants that will increase the quality of animal feed, meat, and milk production and quality.
S.E.10.3. Supporting the protection and development of meadow-pasture areas.	- Carrying out and supporting the necessary procedures and studies to protect the soil from erosion and increase soil fertility.
S.E.11.To ensure the protection and sustainability of water resources.	
S.E.11.1. Determination of ecological protection buffer areas for water resources protection and conservation.	- Creating a protection buffer zone for water resources in the settlement and prohibiting activities such as human intervention, construction, mining, etc. within this buffer zone.
S.E.11.2. Maintenance and repair of the water network and prevention of water leaks.	- Carrying out necessary maintenance and repair works to prevent water leaks in water networks connected to water sources in the settlement.
S.E.11.3. Supporting innovative approaches to agricultural irrigation systems and carrying out existing maintenance, repair or renewal works.	- Encouraging drip irrigation or sprinkler irrigation systems instead of traditional flood irrigation in agricultural lands. - Promoting innovative approaches in agricultural irrigation and supporting the creation of cooperatives.
S.E.11.4. Detection and protection of underground and surface water resources.	- Determining the quality and capacity of the settlement's underground and surface water resources and controlling their use.

4. Conclusion and Suggestions

Rural settlements are places where cultural and social values are in harmony with all aspects of nature and need to be protected and developed with their natural attractions, unique settlement styles, and unique identity values (Aydemir, 2022). Reasons such as the conceptual confusion seen in our country in this field, deficiencies, gaps, and lack of up-to-dateness in the planning hierarchy and current legal dimension have left rural settlements facing multifaceted problems. The main factors of global climate change are the negative effects of anthropocentric approaches on the environment/nature. Industrialization, urbanization, industrial agriculture-food systems, and increasing human-effect greenhouse gas emissions are among the most obvious reasons (Hazar Kalonya, 2022). In addition to these problems observed in rural settlements, these settlements are going to a more serious point with many problems created by global climate change today.

Village design guides (KyTR) are guides that define and analyze the natural, cultural, ecology, and biodiversity of rural settlements and local identity and create a holistic and systematic spatial organization of common and private spaces for the future, where actions and options for conservation and use are created.

KyTR is not a single content but is an innovative tool that sustainably provides optimal use opportunities, taking into account the demands and needs of the people living there for each settlement, and enables joint decision-making by ensuring the cooperation of all actors and participating stakeholders when necessary (Aydemir, 2022). In addition, village design guides are not only a tool for organizing space but also have a structure that provides social equality and justice for every individual living in rural settlements, sustains economic vitality, expands awareness of environmental responsibility, addresses rural policies as a whole, and turns them into action.

KyTR, an important tool for rural settlements, is a very new concept, and studies were first started in 2015 with the example of Kastamonu Küre Ersizlerdere Village Design Guide (Demirel et al., 2020). Ensuring sustainability, protecting, repairing, developing, and developing rural settlements, which have been neglected until now, with the aim of "Rural settlements are the insurance of today and the future" is an issue that should be given importance and priority.

The climate change problem requires necessary studies and investments in rural settlements. KyTR can offer spatial analyses and more detailed solution suggestions in the fight against climate change. It enables the creation of more detailed strategies and actions on many issues such as the local architecture of the settlement, public spaces, agricultural activities, animal husbandry, economic production, ecological and biodiversity, etc. It should not be forgotten that KyTR is an important tool in the fight against global climate change, and it should take its place in the planning hierarchy in our country and be included in a regulation or a directive as soon as possible.

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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 Declaration Information

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

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Design Proposals for the Greenway Multipurpose Trail

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1. Introduction

Today, the features that add identity to cities are being damaged due to reasons such as the occupation of urban open and green areas by construction, wrong land uses and the negative effects of environmental pollution. In solving these problems, planning and management of urban open and green areas in a connected manner has an important place (Salıcı, 2009). The necessity of planning open and green areas in cities in a way to form a system has been revealed in many studies. The common idea advocated in these studies is that the continuity to be provided between urban open and green areas will not only create an easily perceivable and reliable system for users but also contribute to improving the quality of urban life by providing different recreational activity opportunities and ecological benefits (Viles & Rosier 2001; Viñals, Morant & Alonso-Monasterio, 2012; Hellmund & Smith, 2013; Kurt, 2013; Carlier & Moran, 2019).

The basic component required for the creation of green infrastructure by establishing a connection between urban open and green areas is the establishment of connections to connect these areas. The studies carried out in this context paved the way for the development of the concept of greenways (Ahern, 1995). While greenways are the integrity of linear open spaces planned and managed for ecological, recreational and cultural purposes, the concept of greenway network refers to the use of qualified green areas with a conservation/use balance (Arslan et al., 2004). Based on the sustainable planning approach, greenways have important functions such as protecting biodiversity, protecting water resources, providing recreational opportunities, contributing to the protection of historical and cultural resources, and keeping urban development under control (Fabos, 1995; Asakawa, Yoshida & Yabe, 2004; Bryant, 2006; Bentrup, 2008; Bai et al., 2017; Ekren & Arslan, 2022).

Greenway planning studies, which focus on linear elements in the landscape and the network systems to be created with them, offer a strategic approach to landscape planning, but are not a model for landscape planning (Ahern, 1995). Greenway planning generally consists of three interconnected phases. These stages are inventory and analysis, preparation of concept or draft plan and preparation of implementation plan. The first stage, inventory and analysis, is the assessment of the natural and cultural resources of the selected area or corridor. While the preparation of the concept or draft plan includes the determination of goals and objectives, the preparation of the implementation plan, which is the last stage, covers issues such as selecting the most appropriate alternative and determining usage decisions, making cost analysis and determining implementation strategies (Flink & Searns, 1993; Arslan et al., 2004).

In addition to the upper-scale planning decisions developed to address the greenway system and existing problems, it is also important to go down to a lower scale and draw a general framework for the design of the greenway system. In this context, this study aims to propose some design standards for the greenway to gain identity and/or definition with the idea of “design for implementation”. These design standards will contribute to identifying the tools to implement the planning decisions and transfer them to implementation projects. Implementation of greenways within the scope of certain standards is also very important for the sustainability of the works.

2. Material and Method

The main material of this study, which was carried out to establish design standards for multi-purpose trails created within the scope of greenways, is greenways. In this context, design details of multi-purpose trails to be created along railways, roadways and watercourses in rural and urban areas, as well as design recommendations on the intersection of the trails with roadways, the slope of the trails, the surface of the trails, the planting design of the trails and the drainage systems in the trails are given. The design suggestions obtained from the literature on the subject were visualized using the Adobe Photoshop CS3 program, and original suggestions were developed for issues not included in the literature.

3. Findings and Discussion

The design standards for multi-purpose trails on greenways are detailed below.

3.1. Greenway Application Following the Railroad

Greenways planned parallel to an active railroad should be designed in such a way that separation of uses is ensured and users can enjoy the area in safety. There should be a minimum 4.5 m. space between the multi-purpose trail and the railroad. A minimum of 90 cm. of this area should be reserved as a buffer zone and a minimum 120 cm. high barrier should be placed at the end of the buffer zone. Between this barrier and the multi-purpose trail, an area of 60 cm. should be left empty for security purposes (Figure 1). There should also be directional signs and markings along the greenway (Indy Greenways, 2014; Ekren, 2020).

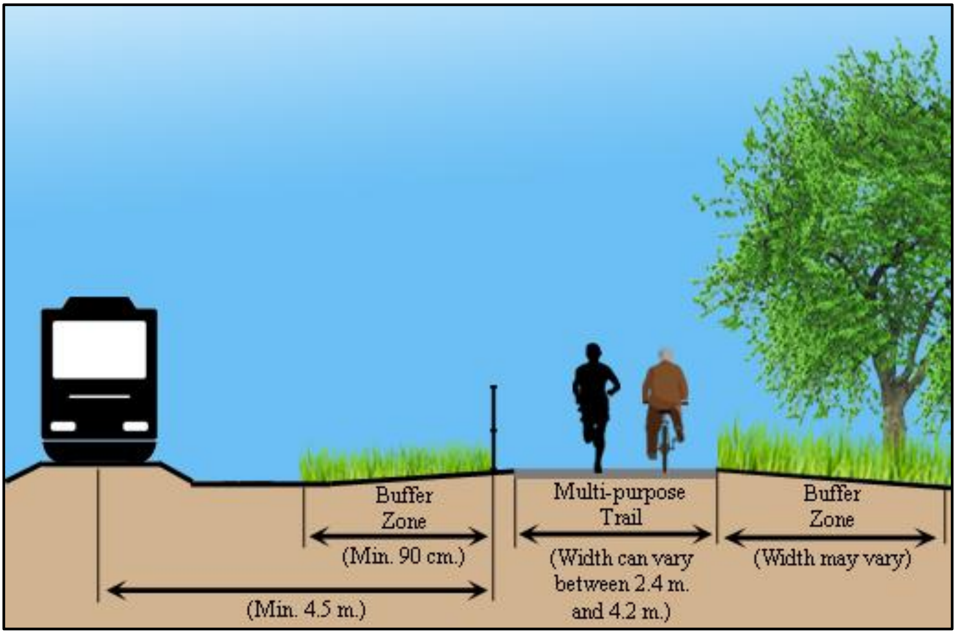

Figure 1. Greenway Application Following the Railroad (Indy Greenways, 2014; Ekren, 2020).

3.2. Greenway Implementation in Rural Areas

Two alternatives are presented for greenways to be created in rural areas. The first of these alternatives is to have buffer zones on both sides of the multi-purpose trail. Buffer zone widths may vary depending on many factors (Figure 2) (Indy Greenways, 2014; Ekren, 2020).

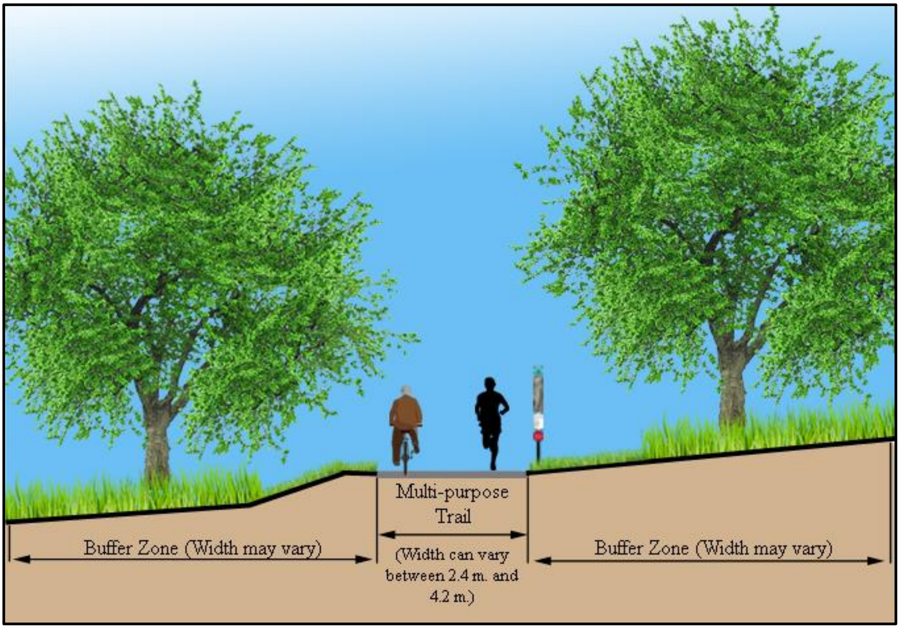

Figure 2. Greenway Implementation in Rural Areas-1 (Indy Greenways, 2014; Ekren, 2020)

On rural greenways planned parallel to roadways, multi-purpose trails should be separated from the roadway by a minimum 1.5 m. buffer zone to ensure the safety of users. The optimal width of the multi-purpose trail is 3 m. while it can be between 2.4 m. and 4.2 m. The corridor width of the buffer zone on the other side of the trail may vary according to habitat continuity, habitat quality and many other factors (Figure 3) (Indy Greenways, 2014; Ekren, 2020).

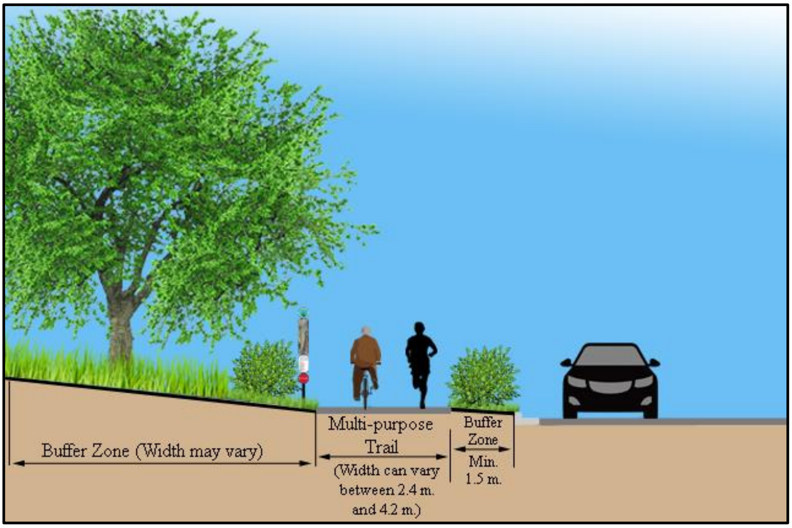

Figure 3. Greenway Implementation in Rural Areas-2 (Indy Greenways, 2014; Ekren, 2020)

3.3. Greenway Implementation in Urban Areas

Two alternatives are presented for greenways in urban areas. The first alternative has a minimum 4 m. wide central refuge and a minimum 1.5 m. buffer zone separating the roadway from the multipurpose trail (Figure 4) (Open Space Seattle: 2100 Project, 2006; Ekren, 2020).

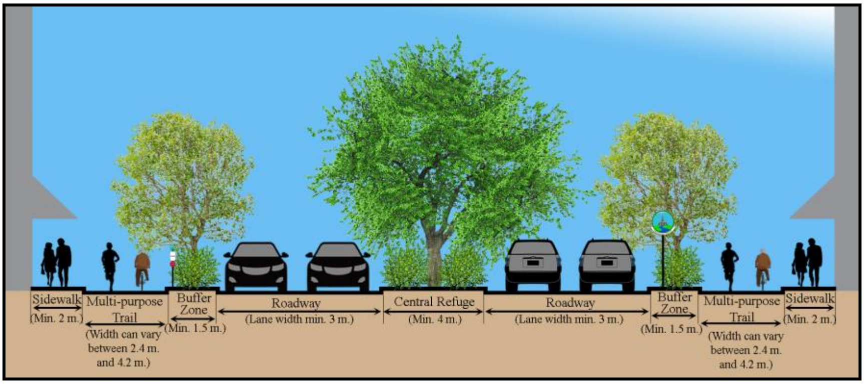

Figure 4. Greenway Implementation in Urban Areas-1 (Open Space Seattle: 2100 Project, 2006; Ekren, 2020)

The second alternative for greenways to be created in urban areas is recommended to be applied in areas where there is no central refuge or where it is very narrow. In these roads, multi-purpose trails are separated from both sidewalks and roadways by a minimum 1.5 m. buffer zone (Figure 5) (Open Space Seattle: 2100 Project, 2006; Ekren, 2020).

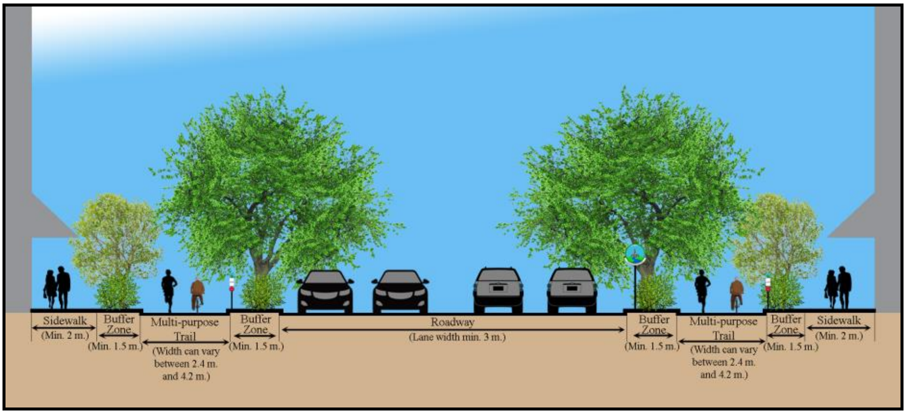

Figure 5. Greenway Implementation in Urban Areas-2 (Open Space Seattle: 2100 Project, 2006; Ekren, 2020)

The common point of both greenway applications designed in urban areas is that, as in rural areas, multi-purpose trail users are separated from the roadway with buffer zones to ensure their safety. There should also be directional signs and markings along urban greenway corridors (Ekren, 2020).

3.4. Greenway Implementation along the Watercourse

Greenways have important functions in the protection, restoration and management of water resources. Multi-purpose trails along the corridors where watercourses are located should be separated from watercourses by buffer zones (Figure 6). Riparian plants used in these buffer zones have important functions. The width of buffer zones may vary (Indy Greenways, 2014; Ekren, 2020).

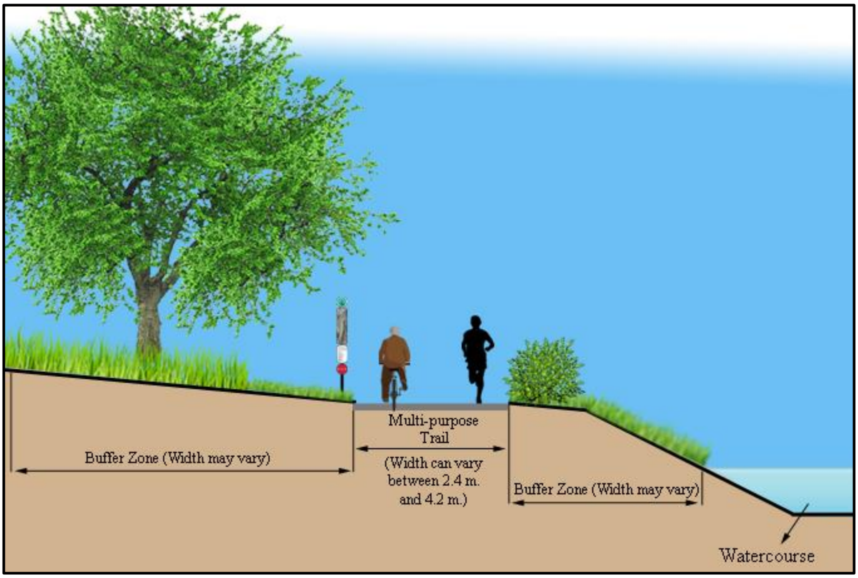

Figure 6. Greenway Implementation along the Watercourse (Indy Greenways, 2014; Ekren, 2020)

Irrigation canals should be included in the greenway system due to their linear characteristics and the fact that they are publicly owned areas, and buffer zones of minimum 1.5 m. should be created on both sides of the multi-purpose trails to be created (Figure 7) (Ekren, 2020).

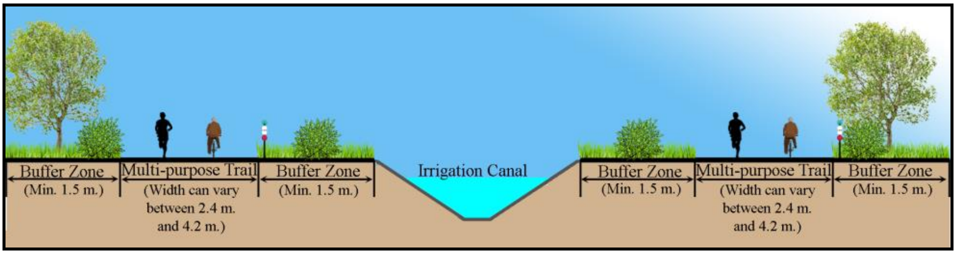

Figure 7. Greenway Implementation along the Irrigation Canal (Ekren, 2020)

3.5. Intersections of Trails with Roadways

Where a multi-purpose trail intersects a roadway, it should be decided whether a level crossing is sufficient or whether a grade crossing (bridge or tunnel) is required. A level crossing should be preferred in areas where motor vehicle traffic is not very heavy or where a traffic signal system can be activated by trail users. In determining the type of crossing, the most intensive use of the roadway, the times when vehicle traffic is at its lowest, as well as the travel speed and visibility at the intersection should be evaluated (Jestico et al., 2017).

Signs and markings are extremely important to ensure the safety of both trail users and road users at the points where trails intersect with the roadway (Figure 8) (Schneider et al., 2021).

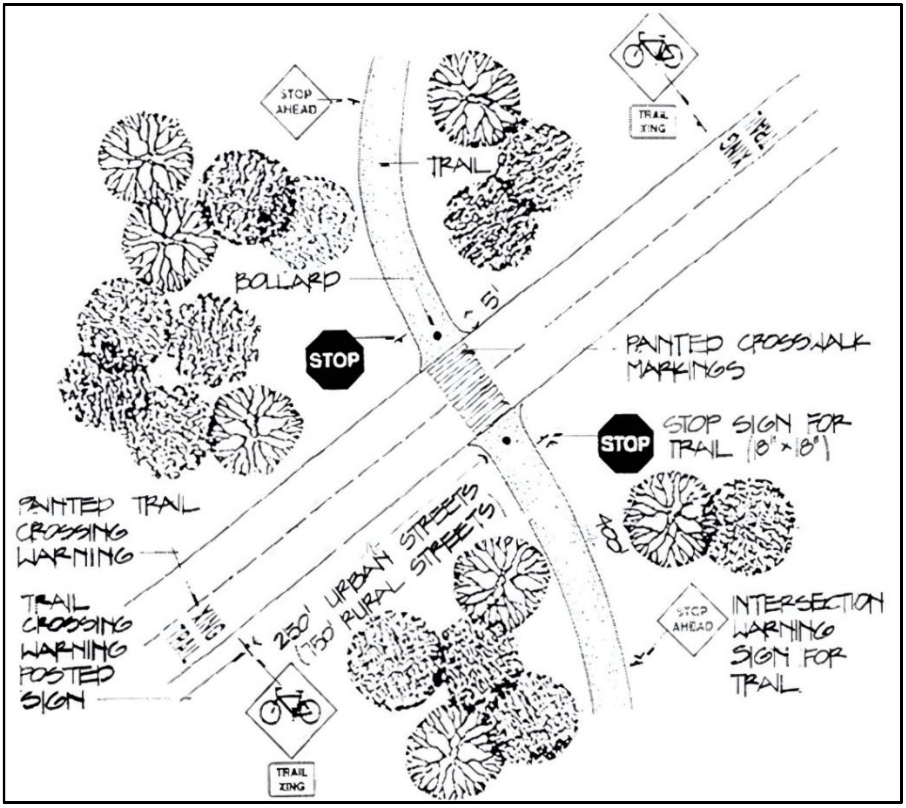

Figure 8. Intersections of Trails with Roadways (Flink, Olka & Searns, 2001)

3.6. Slope of Multi-purpose Trails

In order for people with disabilities to benefit independently from the multi-purpose trails created within the scope of greenways, the trails should be designed and implemented as accessible. The slope of an accessible trail should not exceed 5%. Ramps that rise higher than 15 cm. should have handrails on both sides and these handrails should be 90 cm. above the ramp surface. For ramps with a width of more than 3 m., in addition, there should be a railing in the middle of the ramp and a handrail on the railing at two different heights, 70 cm. and 90 cm.. The railing should start at least 30 cm. before the beginning of the ramp and continue at least 30 cm. from the end (Figure 9). In addition, ramp surfaces should be hard, non-slip and smooth (World Disability Union, 2013; Tuğluer & Ekren, 2022).

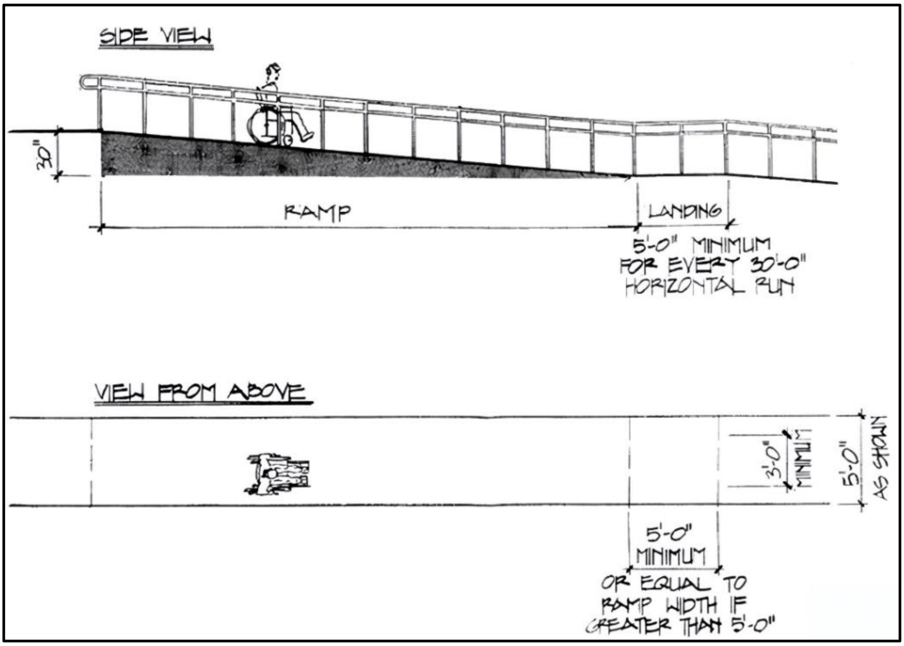

Figure 9. Accessible trail section and plan view (Flink, Olka & Searns, 2001)

The longitudinal and transverse slope percentages of multi-purpose trails differ according to user groups (Table 1) (Flink, Olka & Searns, 2001). Accordingly, as seen in Table 1, the maximum longitudinal slope for pedestrians is 15% and the maximum transverse slope is 4%. For cyclists, the maximum longitudinal slope is 8% and the maximum transverse slope is 4%.

Table 1. Maximum Longitudinal and Transverse Slope Percentages for User Groups (Flink, Olka & Searns, 2001; Ekren, 2020)

User Group	Longitudinal Slope	Transverse Slope
Pedestrians	Maximum: %15	Maximum: %4
Wheelchair users	Maximum: %5	Maximum: %2
Cyclists	Maximum:%8	Maximum: %4
Horse riders	Maximum:%10	Maximum: %4
Rollerbladers	Maximum: %5	Maximum: %2

3.7. Surface of Trails

For the surface of multi-purpose trails, there are options such as granular stone, asphalt, concrete, cement stabilized soil, bark or natural surface (Figure 10). Of these surface options, natural surface and bark are referred to as soft surfaces, while the others are hard surfaces. Soft surfaces are generally used to create hiking and equestrian trails and are not suitable for intensive use and severe weather conditions. Hard surfaces are more resistant to intensive use and external factors. However, it should be kept in mind that the degree of hardness will vary between hard surfaces (Flink, Olka & Searns, 2001; Stevenson et al., 2022).

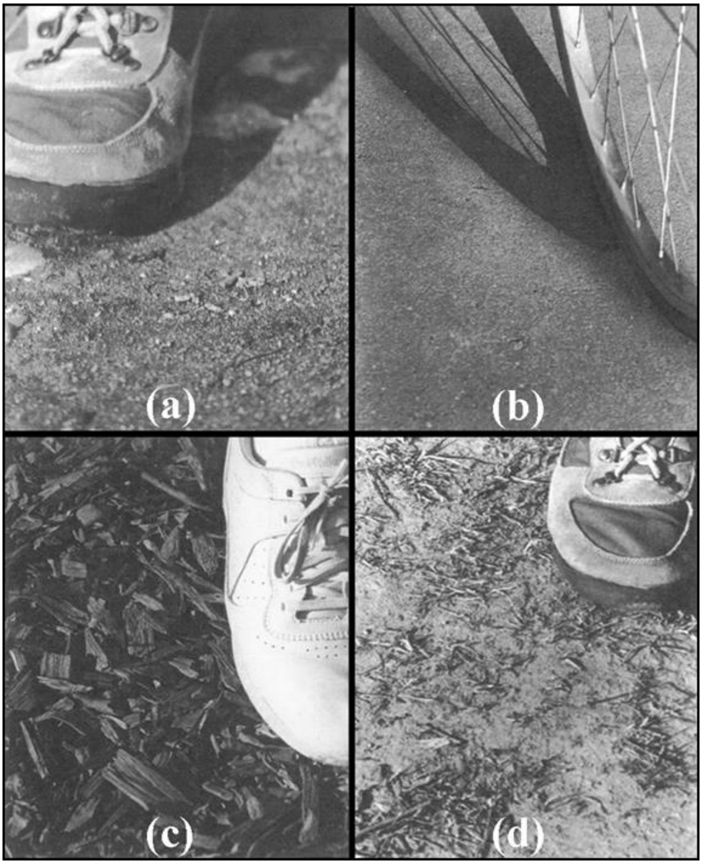

Figure 10. a) Granular Stone, b) Cement Stabilized Soil, c) Bark, d) Natural Surface (Flink, Olka & Searns, 2001; Ekren, 2020)

The advantages and disadvantages of trail surfaces are evaluated in Table 2. Accordingly, the concrete surface has the longest durability time, while the cement stabilized soil surface has the shortest durability time. In terms of application cost, asphalt and concrete surfaces are more costly than other surfaces. In terms of suitability for use, it was found that natural surfaces and surfaces composed of tree bark do not support some uses, while other surfaces are suitable for multiple uses (Flink, Olka & Searns, 2001; Ekren, 2020).

Table 2. Evaluation of Trail Surfaces (Flink, Olka & Searns, 2001; Ekren, 2020)

Trail Surface (Durability Period)	Advantages	Disadvantages
Cement stabilized soil (3-5 years)	It is more durable and has a smoother surface than natural soil. Suitable for multiple use. Low cost.	It wears unevenly. Not resistant to all weather conditions. Difficult to get the right mix.
Granular stone (7-10 years)	It is softer than other hard surfaces. It is a solid surface. Suitable for multiple use and moderately cost-effective.	Heavy rainfall can cause erosion. Replacement of stones requires extra costs. Not suitable for steep slopes and places at risk of flooding.
Asphalt (7-15 years)	Supports most uses in all weather conditions. Withstands intensive use. Low maintenance cost.	The cost of application is high. It is not a natural surface. Repair work requires access to heavy construction vehicles.
Concrete (20 years and more)	Can be shaped according to field conditions. It is the hard surface suitable for multiple use and requiring the least maintenance. Resistant to weather conditions and flooding.	The cost of application is high. It is not a natural surface. Repair work requires access to heavy construction vehicles.
Natural surface (Duration may vary widely depending on usage and conditions)	Includes natural materials such as soil and existing vegetation. Low cost. Maintenance costs are also low. Can be easily replaced for improvements. Allows volunteers to work.	Not suitable for use in all weather conditions. Surfaces may be uneven and bumpy. Not very suitable for disabled use.
Bark	It is a soft surface. Suitable for walking. Natural material. Moderately costly.	May deteriorate under high temperature and humidity. Requires constant refilling. Does not allow all uses. Not suitable for disabled use and flood risk areas.

Trail surfaces can be used as an important way to encourage or discourage use. Hard surfaces are preferable where it is desirable to encourage as many users as possible, while softer surfaces are preferable where it is desirable to limit use to certain groups. In addition, the speed of users can be controlled by the chosen track surface. The softer the surface, the slower the speed of the users (East Coast Greenway, 2019; Ekren, 2020).

When designing trail surfaces for use by people in wheelchairs, it is important to ensure that the surface is firm and stable (Tuğluer, 2019). As an alternative to concrete or asphalt surfaces, more permeable surfaces such as crushed stone are suitable for wheelchair use as long as they remain firm and stable.

Factors to be considered when deciding on the surfaces of the trails are given below (Flink, Olka & Searns, 2001; Ekren, 2020);

- Availability of surface material,
- Cost of purchasing and applying the material,
- Lifetime,
- Accessibility,
- Maintenance cost,
- User acceptance and satisfaction.

3.8. Planting Design in Multi-Purpose Trails

Trees and shrubs provide a visual definition of the space in which they are used. In addition to directing users on multi-purpose trails, successful planting design can also provide shade, screen views, protect from wind and emphasize views (Figure 11 and Figure 12) (Robinson, 2004).

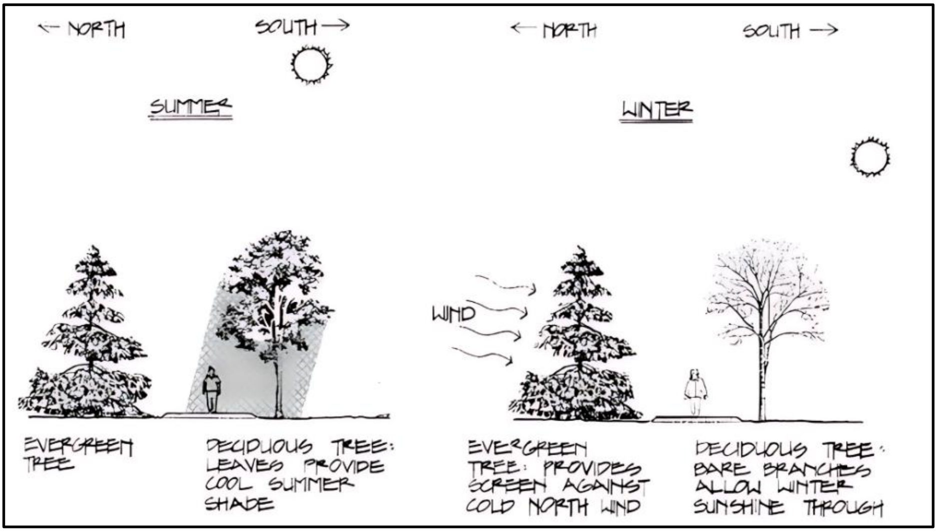

Figure 11. Planting to Provide Shade and Wind Screening (Flink, Olka & Searns, 2001)

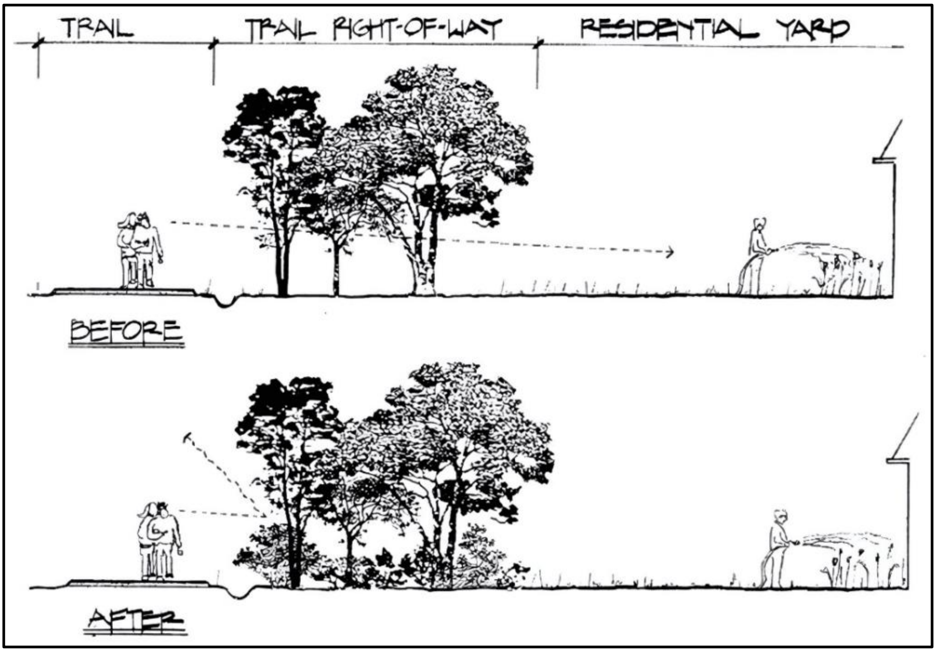

Figure 12. Planting for Image Screening (Flink, Olka & Searns, 2001)

Planting along the multi-purpose trails should be done at a sufficient distance from the trails so as not to obstruct passage, and regular maintenance and pruning should be carried out. Branches extending up to the trails may pose a danger to users. For this reason, it is important to determine the vertical clearance distances according to the user groups that the trails address (Figure 13) (Adams & Bowman, 2001).

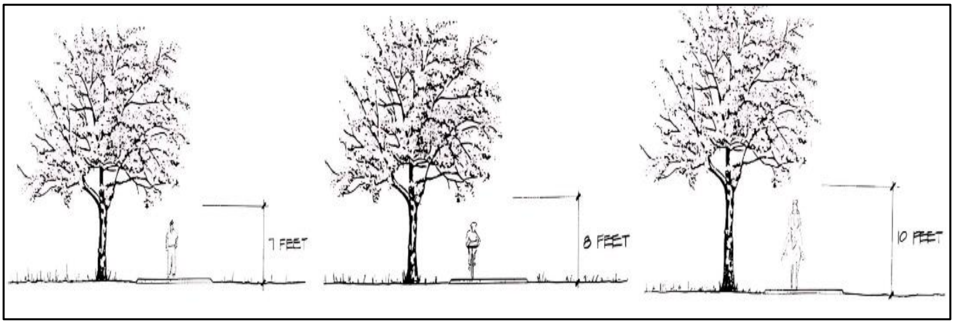

Figure 13. Vertical Clearance Distances for Pedestrians, Cyclists and Equestrian Users (Flink, Olka & Searns, 2001)

In greenway applications, in order for the planting design works to affect the user throughout the year, care should be taken in the selection of plant species as well as the correct planting design. The use of natural plant species from the region where the work will be carried out will ensure the continuity of the application and prevent diseases and pests that may be carried to the area with exotic plants (Çorbacı & Ekren, 2021). If it is necessary to include exotic plant species in the applications due to planting design or other conditions, it should be investigated whether the specimens of those species in the region can show appropriate development in the face of climatic conditions (Çorbacı, Ekren & Usta, 2023).

3.9. Drainage in Multi-Purpose Trails

A properly planned and implemented drainage system ensures that excess water is removed from the site. Proper drainage of surface and groundwater is one of the most important issues in the design, construction and management of multi-purpose trails. Improper drainage will damage the trails and reduce their use (Ritzema, 2006).

Drainage has benefits such as preventing erosion by regulating surface runoff, preventing flooding or reducing the effects of flooding by naturally removing rainwater, preventing the destruction of percolation areas so that aquifers can recharge, and protecting wildlife (Hoang & Fenner, 2015).

There are two types of drainage flow: surface and subsurface flow. Surface flow is water that moves over the ground and eventually flows into streams, rivers and lakes. Subsurface flow is water that moves horizontally or vertically through the soil, depending on soil type and permeability (Ritzema, 2006). The objective of drainage in the implementation of greenway corridors is to maintain or improve the level of water flow that existed before the corridor was developed.

Drainage systems are classified into three groups: open systems (surface drainage systems), closed systems (subsurface drainage systems) and mixed drainage systems (a combination of open and closed systems) (Figure 14) (Flink, Olka & Searns, 2001).

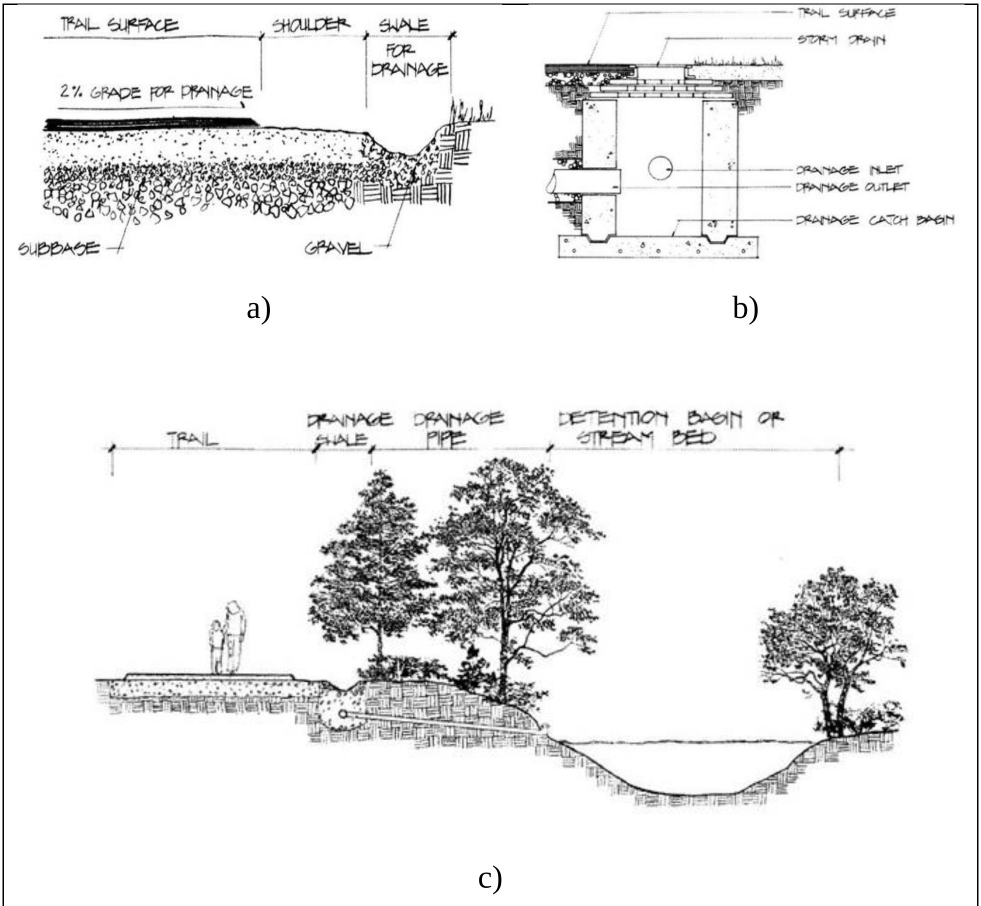

Figure 14. a) Open Drainage, b) Closed Drainage, c) Mixed Drainage (Flink, Olka & Searns, 2001)

The most appropriate time for drainage assessments in greenway corridors is during or immediately after heavy rainfall. Maintenance of drainage systems should also be considered in regular maintenance works (Arslan et al., 2004).

4. Conclusion and Suggestions

Greenways, which can be planned at different scales, help to improve the quality of life of city dwellers by reducing the impact of the problems brought about by the urban ecosystem when they are implemented at the urban scale. When they are implemented in rural areas, they contribute to the socio-economic development of rural settlements by acting as rural development projects.

Greenways are a planning strategy that requires multidisciplinary work. In addition to the contribution of many professional disciplines, it is a process that requires public participation in the planning, implementation and management stages. Presenting three-dimensional visuals of the multi-purpose trails created within the scope of design standards to users before implementation will facilitate public perception of future conditions. The feedback received at this stage should be considered as an opportunity for designers and managers to improve the applications.

It should be noted that designing a multi-purpose trail can be a long and complex process that may require many iterations before the best design emerges. It should also be recognized that multi-purpose trails should be designed with both the safety of users and the integrity of the landscape in mind.

One of the most important issues in the design of multi-purpose trails is their accessibility for all users. If a landscape design is created without taking into account people’s accessibility to amenities offered or their motivations to participate in the designed landscape, only a limited number of individuals may benefit from the landscape (Kordon, Miller & Bohannon, 2022). This may threaten the success of the project in the long term due to a lack of sufficient support from the broader community (Kordon & Miller, 2023). Therefore, trails should be designed multifunctionally in such a way that people with disabilities have the right to benefit from these areas and move freely like all city dwellers. In this context, it is recommended to make use of the "Universal Standards Guide for Persons with Disabilities" prepared by 120 relevant and competent organizations that are members of World Disability Union (WDU) in order to ensure that multi-purpose trails comply with accessible design standards.

In addition to providing many environmental benefits, greenway implementations are works that enable various recreational activities with multi-purpose trails. For this reason, it should be determined which user groups the multi-purpose trails will serve and which activity opportunities will be offered on the trails from the planning stage and the designs should be realized accordingly.

These design standards proposed for multi-purpose trails to be created within the scope of greenways are a guide for greenway applications to be made in Türkiye, where the concept of greenway has become increasingly important in recent years.

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Author Contribution and Conflict of Interest Declaration Information

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Cultivating Benefits: A Review of the Types of Community Gardens Enhancing Urban Life

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1. Introduction

Urban green systems have generally focused on parks, greenways, and natural reserves to provide services such as recreational areas, improve air quality, and manage stormwater (Liu & Russo, 2021). However, the social and environmental challenges of cities became more apparent due to rapid and dense urbanization (Qureshi, 2010). This uncontrolled growth of cities has expanded the role of vacant lands and green spaces in cities to mitigate the negative impacts on social life and environmental quality (Kim, Miller, & Nowak, 2015; Tan & Kordon, 2024).

In recent years, community gardens have increasingly become an integral part of urban green systems, reflecting a change in how cities approach open space usage, sustainability, community engagement, and environmental stewardship (Tan & Kordon, 2024). As a part of the green infrastructure system, community gardens have evolved into essential components of cities thanks to their multiple benefits such as addressing food insecurity, beautifying neighborhoods, and fostering social cohesion (Kordon & Miller, 2023; Tan & Kordon, 2024).

Community gardens may be in various forms and serve for different purposes. However, studies discussing the types of community gardens are very limited in the literature (Kordon, Miller, & Bohannon, 2022). The review of different types of community gardens is important because cities are facing challenges related to limited green spaces, environmental degradation, and lack of community engagement (Kaiser, Hand, & Pence, 2020). A detailed discussion of different types of community gardens and their benefits can provide insights into how these spaces can be optimized to address these issues in cities. Therefore, this study reviews different community garden approaches along with their benefits and highlights how they address specific community needs. This review can also provide valuable knowledge for designers, urban planners, and local authorities for more effective planning, implementation, and support of community gardens in different contexts.

Before communicating the methods and the findings of the study, it is considered that a brief history of community gardening can provide insights regarding their changing role throughout history.

1.1. A Brief History of Community Gardens

Although the concept of community gardens is a global phenomenon where people come together to grow food and plants, these gardens are known by different names in various countries (Samkova, 2013). For example, while they are called ‘Community Gardens’ in the United States, Canada, and Australia (Pascoe & Howes, 2017), they were named ‘Allotment Gardens’ in the United Kingdom (Dobson, Edmondson, & Warren, 2020), ‘Citizen Farms’ in Japan (Harada et al., 2021), ‘Urban Gardens’ in most European cities, ‘Food Gardens’ in Africa (Wills, Chinemana, & Rudolph, 2010), and ‘Hobby Gardens’ in Türkiye (Şolt & Heinz, 2017).

Before becoming an essential part of the cities, community gardens had different roles in their history. The first modern examples of community gardens started to appear in the 19th century during the Industrial Revolution in Europe (Keshavarz et al., 2016). As cities grew rapidly, rural populations moved to urban areas in search of work, resulting in overcrowded living conditions and poor access to fresh food (Acton, 2011). As a result, the gardening concept in urban vacant lands emerged in European cities, where plots were allocated to urban workers to grow their food (Acton, 2011). These allotments were seen as a way to improve public health, provide access to nutritious food, and offer a productive outdoor space for the working class (Iaquinta & Drescher, 2010).

In the United States, community gardening began to take shape mainly by cultivating vacant lots and establishing school gardens during the late 19th century, particularly in urban areas like Detroit, New York, and Philadelphia (Kordon, 2022; Lawson, 2005). During the economically challenging period, rising urban migration and economic difficulties heightened the need for affordable and accessible food (Birky & Strom, 2013). Community gardening, often referred to as vacant lot gardens, emerged as a strategy to enhance the availability of inexpensive local food (Ohmer, Meadowcroft, Freed, & Lewis, 2009).

The use of vacant lands for cultivation and food production from community gardens declined after the economic crisis subsided (Hanna & Oh, 2000). However, the number of community gardens rose during World War I, when they were named “War Gardens” or “Liberty Gardens” (Kurtz, 2001).

These gardens helped alleviate economic hardships and food shortages during the war, supplying households with food (Hanna & Oh, 2000; Lawson, 2005). Over 5 million people took part in this gardening initiative, utilizing any available space to grow fruits and vegetables for their own use and to assist those impacted by the economic crisis and the war (Kordon, 2022; Lawson, 2005). As a result, this gardening movement was seen as both a food initiative and a national act of patriotism (Kurtz, 2001).

The popularity of vacant lot gardens waned after the economic challenges and the impact of World War I diminished (Birky, 2009). However, the number of gardens surged again following the Great Depression in 1929, aiming to address economic and employment problems. These gardens focused on individual and family survival by creating jobs and ensuring sufficient food for citizens (Kordon, 2022; Kurtz, 2001; Lawson, 2005). During this period, they were known as "subsistence gardens" and "relief gardens" (Birky, 2009).

After the U.S. entered World War II, the National War Garden Commission launched the Victory Garden Program to boost domestic food production, support citizens' morale, and conserve canning metals and railroad services for the war effort (Kurtz, 2001). At its peak in 1943, Victory Gardens supplied more than 40 percent of the vegetables in the U.S. (Bentley, 1998; Kordon, 2022). Although community gardens declined and nearly vanished after the war crisis eased, their numbers surged again during major national recessions or crises in U.S. history (Birky, 2009). Consequently, community gardens have served various purposes for communities over the years.

Briefly, community gardens, once seen primarily as a source of food and economic benefits during difficult times for citizens, recently began to be recognized for their multifaceted contributions to urban life. They serve a variety of purposes beyond food production, including environmental education, community building, and cultural preservation (Datta, Kayira, & Datta, 2022; Hill, 2020; Kordon, 2022). Modern community gardens are often supported by local governments, non-profit organizations, and neighborhood volunteers, reflecting their potential for a wide range of social, environmental, and economic benefits for urban residents (Kordon, 2022).

2. Material and Methods

For this study, a systematic literature review was conducted in two phases. In the first phase, keywords related to the types of community gardens were searched using databases such as PubMed, Web of Science, EBSCOhost, Scopus, and Google Scholar. For the second phase, keywords related to the benefits of community gardening were searched in the same databases. A total of 97 references were downloaded for the initial review. A total of 66 references were excluded from the detailed review because they were considered irrelevant or lack of desired information. A total of 31 references including 23 Journal articles, 3 technical reports, and 5 theses were included in the in-depth review.

3. Findings

The study findings are provided in two sections, “Benefits of Community Gardens” and “Types of Community Gardens”.

3.1. Benefits of Community Gardens

The inclusion of community gardens in urban green systems has become popular because of their ability to enhance biodiversity, improve local food security, and create resilient communities (Reis & Ferreira, 2015). With the increase of these gardens, it has been possible to transform unused urban vacant spaces into productive landscapes, contributing to the social life and ecological health of cities (Pearson & Hodgkin, 2010). In the literature, social benefits, environmental benefits, economic benefits, and health benefits are the most commonly mentioned positive outcomes of community gardens. The following sections briefly describe each benefit.

3.1.1 Social benefits

As discussed in the brief history of community gardens, they are commonly recognized as places for food production. However, the increasing body of knowledge has shown that they also serve as gathering spaces for events, picnics, workshops, and educational programs (McGonagle, 2020). Hence, community gardens also play an important role in increasing social interaction and fostering community building (Abi-Nader et al., 2009), by providing a shared space for individuals from diverse backgrounds. Participants of these gardens commonly work collaboratively, share grown foods, and exchange knowledge and labor which all strengthen their ties and support the sense of community and belonging (Glover, Parry, & Shinew, 2005). Community events held in these gardens create opportunities for community engagement and help to reduce the feeling of social isolation. (Alaimo, Reischl, & Allen, 2010). Community gardens have more diverse roles, especially in multicultural neighborhoods. People from different cultures have a chance to come together in these gardens and perform their cultural differences by growing and cooking foods using their traditional recipes and methods (Holland, 2004). This practice allows individuals to maintain a connection to their cultural roots and promotes cultural exchange between community members which results in increased mutual understanding and respect. These outcomes are also important for building safety and prosperity in neighborhoods because a close relationship was found between the sense of safety and connectedness of people and their intercultural relationships (Ohmer et al., 2009; USGPO, 2000).

3.1.2. Environmental benefits

Community gardens provide numerous environmental and ecological benefits in several ways. The most commonly mentioned environmental benefit is the creation of productive urban green spaces, especially in neighborhoods with limited public green areas. The increase in green areas has important positive outcomes. For example, the transformation of unused vacant lands into vibrant green areas supports urban green systems and improves the visual appearance as well as the overall aesthetic quality of neighborhoods (Stewart et al., 2019). Additionally, with the increase in the number and variety of plants grown in community gardens, they enhance biodiversity and provide habitats for plants, insects, and small animals (Martin, Clift, Christie, & Druckman, 2014). Pawelek et. al. (2009) also found that community gardens also support pollinators, which are essential for the overall health of urban ecosystems (Pawelek, Frankie, Thorp, & Przybylski, 2009). Another important role of community gardens is related to the connectedness and sustainability of habitats. For example, community gardens connect fragmented urban green spaces and habitats which helps to create urban-scale ecological corridors (Di Pietro, Mehdi, Brun, & Tanguay, 2018).

In addition to supporting biodiversity and habitats, community gardens also play a role in mitigating the negative effects of climate change (Clarke, Davidson, Egerer, Anderson, & Fouch, 2018). The concentration of concrete surfaces of buildings and pavements results in higher temperatures that increase the heat island effect in cities. Community gardens help to mitigate this effect by increasing green areas, providing shade, and cooling the surrounding area through the evapotranspiration of plants (Humaida, Saputra, & Hadiyan, 2023). This process also improves air quality and reduces the energy demand for cooling buildings which contributes to the efforts against climate change (Ellison, Bakshi, Fletcher, & Vale, 2021).

Moreover, community gardens have obtained increasing attention in reducing the carbon footprints of cities. The plants in these gardens absorb and store carbon dioxide and release oxygen which helps to reduce greenhouse gas levels and lessen overall carbon footprint (Koriesh & Abo-Soud, 2020).

Several studies revealed that community gardens play a crucial role in stormwater management. They reduce stormwater runoff by infiltrating rainwater into the soil which helps to decrease the risk of flooding and water pollution. Also, these gardens are generally equipped with water storage tanks to capture and reuse rainwater (Corrêa, Tonello, & Nnadi, 2021; Gittleman, Farmer, Kremer, & McPhearson, 2017). All these positive attributes are critical, especially in dense cities with poor infrastructure and limited water resources.

Another challenging issue is the waste management in landfills in growing cities because of their negative impacts on the surrounding environment and groundwater. Community gardens contribute to waste reduction through composting. Community gardeners usually store their organic waste such as food scraps and yard trimmings in composting bins and use them to improve soil fertility in community gardens (Carvalho, Más-Rosa, & Ventura, 2022). This practice helps to reduce the amount of waste carried to landfills and improves soil fertility without using chemicals and synthetic fertilizers (Wang & Clark, 2017).

Last but not least, community gardens revitalize vacant lots by transforming them from neglected spaces into productive gardens (Alon-Mozes & Heller, 2022). This transformation improves the neighborhood’s visual appeal and enhances cities' environmental and aesthetic quality (Kordon, 2022).

3.1.3. Economic benefits

The presence of community gardens is more critical, especially in low-income neighborhoods suffering from the impacts of food insecurity. These gardens have the potential to offer substantial economic benefits for their residents (Carney, 2012). Generally, for example, the price of locally grown, fertilizer-free, and healthy fresh produce is more expensive in the market compared to mass-produced goods (Burt, Mayer, & Paul, 2021). However, these gardens support their participants with access to fresh, nutritious produce, which is valuable, especially for low-income families who may otherwise struggle to afford healthy food options (Smith, Miles-Richardson, Dill, & Archie-Booker, 2013). In many US cities, therefore, they are recognized as a source of affordable food and income. This access to fresh produce is critical in urban food deserts, where affordable and nutritious food is often scarce (Kordon, 2022; Wang, Qiu, & Swallow, 2014).

In addition to economic benefits through food production, community gardens also enhance opportunities for job creation and skill development (Armstrong, 2000). These gardens can serve as sites for agricultural training, workshops, internships, and cooking skills which equip their participants with valuable skills in horticulture, sustainable farming, cooking, and entrepreneurship (Andrews, 2001). These skills increase individuals' employability and, the chance of higher salary while supporting the goal of building a sustainable urban economy.

Beyond individual advantages, community gardens can have broader economic benefits by supporting local economies. For example, community gardeners can sell their produce at local farmers' markets or to local restaurants. It is important to keep the income circulation locally rather than being spent on produce transported from outside (George et al., 2016). Furthermore, community garden organizations often attract funding and resources from sponsors for neighborhood improvement projects, which can lead to increased employment, higher property values, and economic revitalization of the area (Voicu & Been, 2008). As a result, community gardens contribute to the economic resilience and sustainability of cities by increasing affordable food and supporting local production, job creation, skill development, and local investment.

3.1.4. Health benefits

In the literature, the most common health benefits of community gardens are related to gardeners' physical and mental well-being (Lampert et al., 2021). Because gardening requires several activities such as digging, planting, weeding, and harvesting, it improves individuals' physical activity and promotes physical fitness, strength, and flexibility (Mükerre (Arslan & Ekren, 2017). Hence, gardening is considered to be a form of physical activity. Corrigan (2011) states that in the long term, regular participation in these activities can help to reduce the risk of chronic diseases such as obesity, heart disease, and diabetes (Corrigan, 2011).

In addition to physical health, according to Kingsley et al., (2009), community gardens encourage the consumption of fresh fruits and vegetables leading to increased vegetable intake and better nutrition which improves participants' overall health (Kingsley et al., 2009; Litt et al., 2011).

Another health outcome of community gardens is related to people's mental health and well-being. Research has revealed that gardening has a therapeutic effect because it provides a sense of accomplishment and fosters a connection to nature which reduces stress, anxiety, and depression (Hayashi et al., 2008). Also, a survey study conducted by Kordon (2022), showed that people participate in community gardening to escape from the crowd and stresses of urban life, allowing them to relax and enjoy nature (Kordon, 2022). According to Hoag (2011), people come together at community gardens to participate in fitness activities for their physical health and meditation sessions for their mental health (Hoag, 2011).

In general, the combination of benefits including physical activity, connection to nature, and stress relief makes community gardens important places for promoting holistic well-being in urban environments.

Given the variety of benefits and opportunities, community gardens have an increasing popularity in developing more affordable, environmentally friendly, socially vibrant, and culturally accepted food systems for the residents of cities (Feenstra, 2002; Kordon & Miller, 2023). The integration of community gardens into urban planning and development strategies can support the creation of resilient, inclusive, and sustainable communities that thrive economically, socially, and ecologically.

3.2. Types of Community Gardens

In recent years, research has shown that the increasing popularity of community gardening and the rise of participation have resulted in more diverse gardener profiles, varied age groups, and different garden typologies. This diversification, along with the evolving roles of community gardens, has prompted different organizations and community groups to adopt varied definitions for these gardens in practice (Kordon, 2022). Therefore, community gardens can be seen in a variety of forms and functions in urban environments, to address specific community and spatial needs. Understanding these different types helps to highlight how they can be effectively integrated into diverse urban landscapes, from small backyard plots to larger shared urban environments. Otherwise, the wide range of garden types might lead to misunderstandings among both laypeople and professionals (Kordon, 2022). To gain a clearer understanding of the role of community gardens in contemporary cities, it is useful to examine the various types of community gardens discussed in the literature. Typically, the primary factors used to categorize these gardens are their intended purpose and location (Lawson & Drake, 2012).

As described by Kordon (2022), in this review, community gardens were classified according to their main functions and the types of community groups involved in gardening (Table 1).

3.2.1. Neighborhood gardens

Neighborhood gardens are typically described as public or private areas where community members collaboratively gather to grow fruits, vegetables, or ornamental plants (Bauermeister, Swain, & Rilla, 2010; Kordon, 2022). Typically, the land in neighborhood gardens is divided into individual plots, with gardeners paying an annual fee for the use of their plots. In some neighborhood gardens, however, gardeners may work together on a single, larger plot without designated individual plots. The produce from these gardens is usually consumed by the gardeners themselves or shared with others, and selling the produce is generally not allowed. Additionally, these gardens often feature amenities such as picnic or barbecue areas and communal tool storage (Ferris, Norman, & Sempik, 2001; Kordon, 2022). In this review, the “Community Garden” term primarily denotes the neighborhood gardens as described by Kordon (2022) (Table 1).

3.2.2. Youth/school gardens

School gardens, another popular type of community garden, integrate gardening into the educational curriculum and function as outdoor learning laboratories (Bradley & Baldwin, 2013; Wansink, Hanks, & Just, 2015).

School gardens often integrate nutrition education into science classes through the use of schoolyards (Morris & Zidenberg-Cherr, 2002). Their main goals are to teach children about plants, nature, and science, as well as to promote healthier eating habits (Morris, Koumjian, Briggs, & Zidenberg-Cherr, 2002; Nowak, Kolouch, Schneyer, & Roberts, 2012). These gardens can accommodate students from elementary through high school. Typically, a designated area of the schoolyard is used for the gardens, often featuring raised beds (Wansink et al., 2015). While a teacher who aims to enhance the educational curriculum usually manages the garden, some are overseen by volunteers or paid coordinators funded by grants (Bauermeister et al., 2010) (Table 1).

3.2.3. Entrepreneurial/farmers' market gardens

The goals of entrepreneurial gardens can vary, but they often aim to reduce poverty and social exclusion, particularly in low-income communities (Ferris et al., 2001). These gardens are sometimes referred to as farmer's market gardens because they are typically linked to a farmer's market. They can be set up on either private or public land, with the primary objective of generating income by selling produce, thereby helping unemployed residents develop job skills (Ferris et al., 2001; Lawson, 2005). Unlike most neighborhood gardens, which typically prohibit the sale of harvested produce, farmer's market gardens allow gardeners to sell their crops to local markets and restaurants. Additionally, participants in these gardens gain knowledge of basic business principles as well as techniques for growing and selling their produce (Bradley & Baldwin, 2013) (Table 1).

3.2.4. Residential gardens

Home gardening is a widely used method for food production, particularly for individuals who lack access to a community garden. Residential gardens can be divided into two categories: home gardens and apartment gardens. Home gardens are typically established in the backyards of single-family homes, while apartment gardens are usually created in the courtyards of affordable housing complexes and are shared by the apartment residents (Kordon, 2022). The costs associated with these gardens, such as tools and water, are also distributed among the residents (Bauermeister et al., 2010). The landscape design and layout are quite similar to other types of gardens; however, the main distinction is that these gardens are usually reserved for the residents of the specific housing community and are not open to outsiders (Kordon, 2022) (Table 1).

3.2.5 Healing/therapeutic gardens

Another emerging but less widely recognized type of community garden is the healing and therapy garden (Ferris et al., 2001). These therapeutic gardens are designed to emphasize the healing effects of plants on individuals' social learning, as well as their psychological and physical well-being (Arslan, Kalaylıoğlu Akyıldız, & Ekren, 2018). Typically, therapeutic gardens are affiliated with public or private institutions, including hospitals, nursing homes, churches, senior centers, retirement communities, outpatient treatment centers, and job training programs (Bauermeister et al., 2010; Bradley & Baldwin, 2013). Their primary goal is to offer services such as mental and physical rehabilitation, job training and skill development, landscape design, and cooking classes (Bauermeister et al., 2010). These gardens are thoughtfully designed to accommodate wheelchair users, individuals with visual impairments, and those with limited physical strength (Bradley & Baldwin, 2013) (Table 1).

3.2.6. Demonstration gardens

Demonstration gardens come in various sizes and serve multiple purposes, including food production, land restoration, and youth education (Chalker-Scott & Collman, 2006). These gardens can also be incorporated into other types of gardens and tailored for specific educational objectives, such as showcasing native plants, natural wetlands, or composting methods (Chalker-Scott & Collman, 2006; Kordon, 2022). They are valuable tools for public education, offering workshops and training sessions on topics like composting, organic gardening, water conservation, irrigation, beekeeping, garden design, and carpentry (Ferris et al., 2001). These sessions are often led by master gardeners who provide expert instruction on particular subjects (Kordon, 2022). Furthermore, universities and other educational institutions may use demonstration gardens as outdoor classrooms to enhance their teaching programs (Bradley & Baldwin, 2013) (Table 1).

It's important to recognize that a garden type categorized under one classification may also exhibit characteristics of other garden types found in different categories. For instance, while the literature often distinguishes between neighborhood gardens and demonstration gardens as separate types of community gardens, a neighborhood garden might also fulfill demonstration functions for its residents. Therefore, in practice, it can be challenging to clearly distinguish one garden type from another with a straightforward definition. The primary aim of this study is to outline the various types of community gardens and offer a general understanding of the different garden types observed in urban environments and discussed in the literature.

Additionally, community gardens are typically characterized by two distinct layout features: plot gardens and communally managed gardens, also known as cooperative gardens. Representing these layout models is crucial for a clearer understanding of how these gardens function.

3.2.7. Plot gardens

One common operating method for community gardens involves dividing a garden parcel into individual plots assigned to each gardener or family (Bradley & Baldwin, 2013). These plots can be either ground-level or raised beds, depending on the soil conditions of the area (Drake & Lawson, 2015). Plot gardens are often situated in inner-city areas and are allocated to gardeners through monthly or yearly contracts and aim to offer personal green space. Gardeners are responsible for maintaining their plots (Bell et al., 2016).

3.2.8. Communally managed gardens

In contrast to plot gardens, communally managed gardens are designed more holistically, with the entire space being managed collectively by multiple gardeners, rather than assigning specific sections to individual gardeners (Kordon, 2022; Napawan, 2015). These gardens are also referred to as urban farms, as they lack subdivided plots and are treated as a unified agricultural field (Napawan, 2015).

The diverse types of community gardens reflect the wide range of potential participants and illustrate the various roles and layouts that community gardens can have within an urban environment (Table 1).

Table 1. Summary of the Types of Community Gardens (Kordon, 2022).

Garden Type	Participant Groups	Land Type	Garden Space	Use of Products	Primary Purpose
Neighborhood Gardens	• People in the community	• Public land • Private land	• Individual • Communal single-plot	• Personal • Give away • Selling is not allowed	• Gardening • Gathering • Socializing
Youth School Gardens	• Students • Teachers • Families	• Private • Government • Schoolyards	• Raised beds • Individual plot	• Products are used in the school kitchen	• Education • Curriculum • Nutrition education • Outdoor learning • Science classes
Farmers Market Gardens	• Unemployed people • Residents in disadvantaged neighborhoods	• Public land • Private land	• Individual plots	• Sell to local markets, restaurants, and farmers markets	• Income generation • Lessen poverty and social exclusion • Improve growing and selling techniques
Residential Gardens	• Individuals or people in housing groups	• Private land • Government-supported housing yard	• Individual plots	• Personal • Share with residents	• Gardening • Gathering • Socializing
Therapeutic Gardens	• Patients • Seniors • Retirement communities • Church participants	• Public or private organizations (hospitals, churches, senior centers, outpatient treatment centers)	• Individual plots • Communal single-plot	• Used in institution kitchen • Donated	• Social Education • Psychological and physical well-being • Mental or physical rehabilitation • Job training • Skill development
Demonstration Gardens	• Public people • Students • Job and skill learners	• Part of botanical gardens • Education institutions	• Individual plots • Communal single-plot	• Used in institution kitchen • Donated	• Outdoor classroom • Public education programs (composting, organic gardening, water conservation, irrigation, beekeeping, garden design, and carpentry)

4. Conclusion

The different types of community gardens play an important role in fostering social cohesion, promoting environmental sustainability, and enhancing food security across urban communities. Whether they are neighborhood parcels, school gardens, or therapeutic gardens, each type offers multiple purposes and addresses various community needs. These green spaces not only provide opportunities for individuals to engage with nature and produce fresh food but also serve as areas for education, cultural expression, and community empowerment. It is important to recognize and support the richness of community garden types to maximize their benefits and ensure their continued contribution to healthier, more resilient, and sustainable cities worldwide.

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Author Contribution and Conflict of Interest Declaration Information

There is no conflict of interest.

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Development of City-Specific Resilience Index

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1. Introduction

The rapid increase in population and socio-economic development globally has started to significantly impact landscapes and their resources. However, the impact of these transformations became particularly visible in the mid-20th century (Chen et al., 2016; OECD, 2016). With the increasing population, existing settlements have expanded and new settlement areas have formed (Kaba, 2020; Yüksel ve Karaçor, 2021). The increase in the rate of urbanization has increased the pressure on the natural environment and resources and brought about the problem of climate change.

The interaction between climate and cities should be viewed as a reciprocal action-reaction process (Erell, 2011). While cities host sectoral activities such as energy, transportation, and industry, which are part of urban life, they also cause greenhouse gases that cause climate change to be released into the atmosphere. This has brought about risky situations for humans and nature. Climate change is among the causes of global landscape and ecosystem change. This situation is attracting great attention at all institutional levels from local to global and with short-term and long-term strategies as it threatens socio-environmental security. Although climate change is a global problem affecting various human settlements, its effects are more severe in cities. Therefore, due to the changes in natural disaster regimes caused by global climate change, it has become important for communities to determine their actions in order to increase their current resilience (IPCC, 2018; UNCCS, 2019).

The capacity of a city to respond to, cope with and organize various variables against climate variability is defined by the concept of resilience (Meerow, Newell, & Stults, 2016; Florin & Linkov, 2016; Eren & Parihar, 2022). The term “urban resilience” varies across the environmental and social sciences (Meerow et al., 2016). Resilience, which is affected by climate variability and changes at global and local levels, is accepted as a concept that covers and tries to organize the ability of a city to respond to and cope with different changes.

Resilience is derived from the definition of resilience, a technical term based on biology and ecosystem sciences. Holling (1973) defined resilience as "the ability of systems to persist and absorb change and disruption, while maintaining relationships among populations or state variables". Initially, resilience was primarily embraced by environmental and social sciences, based on the notion that ecological system principles could be applied to understand societal dynamics. Over time, this perspective expanded into fields such as psychology, sociology, geography, and planning (Meerow et al., 2016; Boon et al, 2012). Nowadays, resilience is brought to the agenda more with studies on adaptation to climate change, sustainability and disaster risk reduction.

Resilience is commonly approached through three key perspectives: socio-ecological systems, sustainable livelihoods, and disaster risk reduction. According to Berke et al. (2009), resilience is a systems-based concept, where socio-ecological systems function as complex adaptive structures. Rose (2007) and Frazier et al. (2013) define resilience as a community's ability to manage crises effectively with minimal reliance on external aid.

Tiernan et al. (2019) defined resilience as; determination, recovery, responsiveness to disturbances with the help of the latest technology and adaptation. Tiernan et al. (2019) also touched on the role of mechanisms that enable social responsibility, risk management and public-private partnerships for resilience. The necessity of a holistic approach to social resilience has been frequently brought up in studies (Cutter et al., 2008; Paton, 2007; Kesici et al., 2010; Paton et al., 2013; Tierney & Bruneau, 2007; Paton & Johnston, 2017). However, studies on how these mutual relations can be effectively expressed and found a place in practice are extremely few.

Ali & Jones (2013) explored the connections between vulnerability, resilience, and adaptive capacity, alongside the intricate socio-political environment that shapes community resilience. They stated that awareness of the impacts of disaster events should be increased. They also stated that instead of investing in protective measures against natural disasters, decisions should be made to reduce the effects of the built environment in cities against disasters.

Cavallo (2014) adopted a command-and-control approach (engineering resilience). He also suggested that it is crucial to examine whether community resilience can truly be attained in the face of disaster events and that community resilience should be regarded as a dynamic, adaptive system (socio-ecological resilience). He argued that it is important to recognize and prepare for a series of critical thresholds in such a system. However, he argued that community resilience is important rather than trying to measure the disaster event.

Understanding a community's level of resilience is crucial for disaster preparedness, recovery, and estimation of potential losses. However, measuring resilience is difficult due to the nature of resilience indicators. Studies have attempted to identify and characterize the baseline conditions for community resilience to natural disasters. Many studies have attempted to create a resilience index and measure resilience (Bruneau et al., 2003; Simpson, 2006; Rygel et al., 2006; Rose, 2007; Mayunga, 2007; Cutter et al., 2008, 2010; Razafindrabe et al., 2009; Chen et al.,2016; Sherrieb et al., 2010, 2012; Jeorin et al., 2012; Orencio & Fujii, 2013; Kusumastuti et al.,2014; Kaba, 2020; Karabakan, 2020; Xu et al., 2020; Yüksel & Karaçor, 2021; Hurlimann et al., 2021). However, in all urban resilience studies, it has been stated that resilience criteria and indicators should be determined specifically for countries and even cities.

2. Review of Factors Affecting Community Resilience

While the factors influencing community resilience are widely acknowledged, there is less understanding of how to integrate these factors into explanatory models and practical tools for assessing resilience and pinpointing areas for improvement (Sharif, 2016; Jones et al., 2020). Is it possible to create reliable, robust, and consistent measures for each resilience factor? What techniques can ensure the secure combination of these factors? Could a robust and context-sensitive scorecard that accurately reflects local conditions be developed? Numerous studies have explored these questions in search of answers (Ainuddin & Routray, 2012; Bruneau et al., 2003; DPRAP/CoBRA, 2013; Menoni et al., 2012; Kellett & Mitchell, 2014; IFRC, 2012;

Resilience Alliance, 2010; GOAL, 2015; Jones et al. 2020; Sharif, 2016). Although the details may vary, the process begins with system modeling and hazard definitions in the form of domains, components, factors and indicators in the proposed toolkits. In this way, after the system is contextualized, indicators are developed according to their scales by scoring according to the components, characteristics and threat of the domain. The indicators are then scored. After scoring, they are collected using the weighting method (simple sum of factors).

The resilience score of each indicator is created by summing its sub-indicators using the weighting method. (Jones et al., 2020).

Sharif (2016) identified six critical criteria for community resilience tools in his study. These are; "accommodating multiple dimensions of resilience, accounting for cross-scale relationships, capturing temporal dynamism, addressing uncertainties, using participatory approaches, and developing action plans" (Jones et al., 2020).

The Disaster Resilience Report Card for Cities (UNDRR, 2017) has all these criteria and is a preferred option for assessing community resilience (Cutter et al., 2010; Burton, 2015; Morga et al., 2020).

3. Resilience Indicators

Resilience has been explored in both international and national academic research across several dimensions, including social, community capacity, economic, institutional, infrastructure/physical, and natural/ecological aspects. Interpretations of economic and natural/ecological resilience differ among researchers. Rose (2007) described economic resilience as the inherent or adaptive capacity of individuals, markets, and the overall economy to handle hazards. In contrast, Cutter et al. (2010) viewed it as the economic vitality and stability of a society. Similarly, Razafindrabe et al. (2009) linked natural resilience to the frequency and severity of hazards. Moreover, Cutter et al. (2008) noted that ecological resilience is influenced by factors such as biodiversity and spatial characteristics (Kusumastuti, 2014).

The OECD (2016) assessed the resilience framework in four key factors. The four key factors are not sequential stages (Figure 1). One may precede or be stronger than the other, but they are mutually reinforcing.

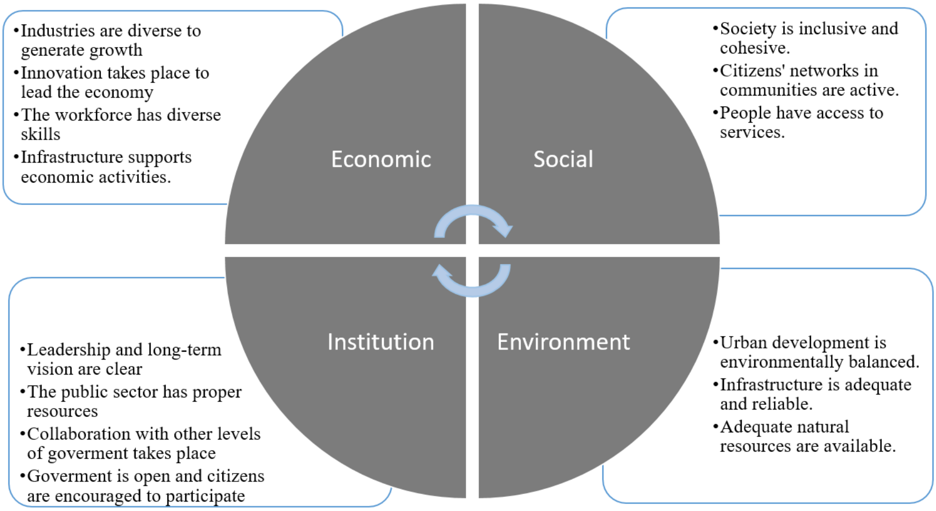

Figure 1. Resilient City Resilience Dimension (OECD, 2016).

The economic aspect of resilience demands diversification within industries and fostering innovation. The social aspect necessitates an inclusive and cohesive society, active citizen networks, and equitable access to opportunities. The environmental aspect focuses on urban sustainability, the provision of safe and adequate infrastructure, and the availability of natural resources. The institutional aspect calls for forward-thinking leadership, access to public resources, collaborative governance, and a transparent and participatory government.

Bruneau et al. (2003) proposed four interrelated dimensions of resilience: technical, organizational, social and economic. Simpson (2006) stated that demography, community assets, social capital, infrastructure/system quality, planning, social services and population are dimensions of resilience. Mayunga (2007) proposed a capital-based approach to examine resilience to natural disasters.

Rose (2007) examined resilience from an economic perspective. He proposed five dimensions of resilience: social, economic, human, physical and natural, which can contribute to reducing vulnerability and increasing community resilience. Norris et al. (2008) stated that community resilience depends on a number of networks, including economic development, social capital, information and communication, and community competence.

Razafindrabe et al. (2009) suggested that resilience to climate disaster has five dimensions: physical, social, economic, institutional and natural (hazard frequency and hazard intensity). Cutter et al. (2008) proposed community resilience indicators that include various dimensions such as ecological, social, economic, institutional, infrastructure and community capacity. Again, Cutter et al. (2010) suggested that ecological resilience is affected by factors such as biodiversity and spatiality.

It is seen that resilience indicators are categorized under 6 headings: social, community capacity, economy, institutional, infrastructure/physical and natural/ecological/environmental (Cai et al., 2018; Galantini, 2018). In addition, Cai et al. (2018) investigated the frequency of use of resilience performance indicators in the literature.

Yüksel & Karaçor (2021) examined 25 different international resilience studies and methods in their study titled "Methodological Review of Urban Resilience Studies Related to Disaster Risks".

In the Environmental Indicators booklet of the Ministry of Environment, Urbanization and Climate Change, resilience indicators are discussed under three headings: Driving Force Indicators, Status Indicators and Pressure Indicators (URL- 3).

4. Disaster Risk Reduction and Sendai Framework

The United Nations has implemented the "Sendai Framework for Disaster Risk Reduction" (UNDRR) to reduce disaster risks and significantly reduce losses. This framework replaced the Hyogo Framework for Action. While the basic goals of Hyogo and Sendai are similar, their approaches differ. While the Hyogo Framework emphasizes the need for disaster risk management, the Sendai Framework identifies four key priority areas for managing disaster risk over the 15-year period from 2015 to 2030. These areas are: understanding disaster risk in all its dimensions, strengthening disaster risk management at all levels, investing in disaster preparedness and recovery, and focusing on recovery, rehabilitation and reconstruction.

The United Nations has identified the "Disaster Resilience Report Card for Cities" (UNDRR), which includes ten basic principles to support the implementation of the Sendai Framework (Jones et al., 2020). The Resilience Report Card aims to develop a common understanding of both local resilience and disaster risk assessment according to local hazard characteristics.

“The UNDRR Disaster Resilience Report Card for Cities” consists of 118 disaster resilience assessment criteria grouped under “10 Core Principles” (Figure 2). These are divided into the main groups of governance and financial issues (items 1–3), planning and disaster preparedness (items 4–8), and disaster response and recovery (items 9–10) (URL-1; URL-2; Jones et al., 2020).

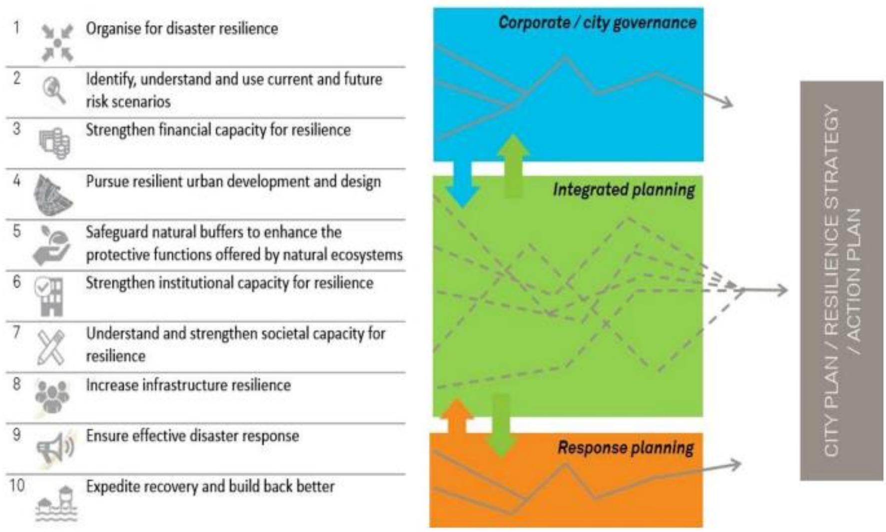

Figure 2. UNDRR Disaster resilience scorecard for cities (UNDRR, 2017; Jones et al., 2020; URL-1).

“The UNDRR Disaster Resilience Scorecard for Cities” has a wide range in terms of social scale and hazards. It can be used easily and provides high convenience in terms of public services. It is a tool that provides outputs for resilient planning (Yüksel & Karaçor, 2021).

Details of the issues addressed in the “UNDRR Disaster Resilience Scorecard for Cities (10 Core Principles)”;

- Organize for resilience

- Plan
- Organize, Coordinate and Participate
- Integrate
- Capture, publish and share data

- Identify, understand and use current and future risk scenarios

- Hazard assessment
- Exposure and consequences information
- Cascading effects and interdependencies
- Hazard maps
- Update scenario, risk, vulnerability and exposure information

- Strengthening financial capacity for resilience

- Knowledge of approaches to attracting new investment to the city
- Resilience budgets within the city financial plan, including emergency funds
- Insurance
- Incentives and financing for businesses, community organizations and citizens

- Monitor resilient urban development

- Land use zoning
- New urban development
- Building codes and standards
- Implementation of zoning codes and standards

- **Maintain natural buffers to enhance the protective functions provided by natural ecosystems**
- Health of existing natural systems and ecosystems
- Integration of green and blue infrastructure into city policy and projects
- Transboundary environmental issues
- **Strengthening institutional capacity for resilience**
- Skills and experience
- Public education and awareness
- Data capture, publication and sharing
- Educational delivery
- Languages
- Learning from others
- **Understand and strengthen societal capacity for resilience**
- Community or “grassroots” organizations
- Social networks
- Private sector/employees
- Citizen engagement techniques
- **Increase infrastructure resilience**
- Protective infrastructure
- Water sanitation
- Energy-electricity
- Energy-gas
- Transportation
- Communications
- Healthcare
- Education

- Prisons

- Management and operations

- Computer systems and data

- Ensure effective disaster response

- Early warning

- Incident response plans

- Personnel/responder needs

- Equipment and relief material needs

- Food, shelter, essential goods and fuel supply

- Interoperability and interagency working

- Accelerate recovery and build back better

- Pre- and post-event recovery planning

- Lessons learned/learning cycles

5. Association of Basic Disaster Resilience Indicators and UNDRR Disaster Resilience Report Card for Cities

In this study, the "UNDRR Disaster Resilience Report Card for Cities" was used. This is a planning tool that attempts to explain the areas of a city that are least resilient or cannot be adequately intervened in the event of a disaster due to climate change. The assessment of basic disaster resilience indicators was made and associated with the "UNDRR Disaster Resilience Report Card for Cities".

5.1 Development of the UNDRR Disaster Resilience Scorecard for Cities

The "UNDRR Disaster Resilience Scorecard Card", based on the "Ten Essential Elements for Making Cities Resilient" developed within the Sendai Framework, is the most widely accepted community resilience toolkit today. (Jones et al., 2020; Yüksel & Karaçor, 2021). The resilience report card is a practical tool that determines the disaster resilience of cities for each of the Essential Principles. The "Resilience Scorecard" was also developed to identify areas in need of disaster resilience improvement or areas in need of mitigation interventions (UNISDR, 2017). The "Urban Resilience Scorecard" developed within the framework of the "UNDRR Disaster Resilience Scorecard for Cities" was prepared within the scope of the study.

The scorecard is a tool to initiate interaction between cities and various stakeholders in the city, to identify their actions and provide analysis, and to plan for the future. It has been widely accepted. This is largely because it increases stakeholder participation in cities (Schofield & Twigg, 2019). The scorecard should not have evaluation criteria that are not specific to the city. The scorecard has the potential to provide a general picture of the city, allowing for tracking of long-term progress.

Within the scope of this study, the three main headings of the "Urban Resilience Scorecard" are divided into components as "Resilience, Governance and Financial Issues, Disaster Response and Post-Disaster Recovery" (Figure 1). Resilience consists of the components "Readiness" and "Vulnerability". The indicators of the Readiness component consist of the subheadings "Social", "Economic", "Institutional", "Infrastructure/Physical", "Environment". The indicators of the vulnerability component consist of the subheadings "Social", "Economic", "Institutional", "Infrastructure/Physical", "Hazard".

Indicators and sub-indicators were created based on national and international data (Cutter et al., 2008; Cutter et al., 2010; Meerow et al., 2016; Razafindrabe, 2009; OECD, 2016; UNISDR, 2017; Morga et al., 2020; Jones et al., 2021; URL-4).

-Planning and Disaster Preparedness = Resilience

-This main heading consists of Social, Economic, Institutional, Infrastructure/Physical, Environment and Hazard headings.

-Social

-High population growth rate

-High urban population area area

-Low rural population area area

-High land used as residential area

-High number of houses

-Low number of houses that pass local building inspection

-High unemployment rate

-High migration rate

-High literacy rate

-High number of settlements with high dependent population rate (elderly and children)

-Low population covered by community health services

-High population with vehicles

-High population with landline telephone

-Low population with communication barriers (those without telephones)

-High number of transportation alternatives (airports, bridges, highways, railways, seaways)

-High number of villages/neighborhoods in cities

-High number of evacuation signs per km²

-Existence of early warning systems

-High number of health services (acute care, long-term care, specialization)

-High number of compulsory earthquake insurance

-The number of urban settlements in floodplains is low

-The number of registered civil society organizations is high

-The number of active participants in civil society organizations programs is high

-The participation in community development programs is high

-Economy

-The number of regions with high domestic material consumption per capita is low (city budget per capita)

-The sectoral distribution of Gross Domestic Product is high (cash budget in the annual fund)

-The number of large enterprises is high (more than 250 employees)

-The number of working families is high

-The number of homeowners is high

-The share of municipal taxes in municipal revenues is low

-Environmental expenditure expenses are low

-Social expenditure expenses are high

-The debts in the budget are low

-Institutional

-Existence of disaster management institutions at the municipality level

-Large share of disaster management in the municipal budget

-Existence of disaster response plans in the municipal regulation

-Existence/number of disaster information centers

-Large number of disaster management/training activities

-Large population receiving disaster management/training

-Large number of companies participating in disaster mitigation

-Large number of emergency shelter stock/critical facilities

-Large number of volunteers in disaster mitigation activities of civil society organizations

-Existence of coordination between the community leader and civil society organizations and other leaders

-Physical/infrastructure

-Low water usage (m3/year)

-High number of households with access to clean water

-Low amount of wastewater discharged from the network according to the treatment status (thousand m3/year)

-Low amount of wastewater treated in wastewater treatment facilities according to the treatment plant type (thousand m3/year)

-High ratio of municipality population receiving waste service to total municipality population (%)

-Low hazardous waste (ton/year)

-High density of highway and railway network

-High road length (per km^2)

-High freight transportation (ton-km) according to type

-High number of households with electricity

-Existence/extent of gross electricity generation resources

-Low average number of power outages per year

-Low death rate due to traffic road injuries

-Existence of building code applications

-Environment

-High total agricultural land

-High total forest area

-High wetlands

-High water bodies

-High presence/number of coastal defense structures

-Danger

-Diversity

-Frequency

-Intensity

-Governance and Financial Issues

-Existence of emergency response and rescue plans

-Existence of emergency services

-Existence of cooperation with institutions and stakeholders

-Ensuring good governance

-Existence of municipal fire and emergency management expenditures

-Existence of disaster prevention plans

-Existence of scenarios regarding possible disasters

-Existence of disaster inventory

-Existence of social awareness and education in large numbers

-Existence/number of civil society organizations

-Existence and number of non-profit organizations

-Existence of annual cash budget of municipalities

-Low debt in the budget

-Excessive municipal budget per capita

-Excessive municipal social expenditure budget

-Disaster Response and Post-Disaster Recovery

-High number of doctors per 1000 people

-High number of hospital beds per 1000 people

-High number of fire department personnel per 1000 people

-High number of emergency personnel/groups

-High number of emergency personnel/groups

-Existence and number of shelters

-Existence of emergency evacuation plans

-Existence and number of emergency offices

-Existence of municipal emergency regulations

-Existence of accessible emergency assembly areas

During the implementation phase of the scorecard, face-to-face, multi-stakeholder and multi-sector workshops are held. These workshops are carried out with a broad participatory approach from government departments, academic institutions and civil society organizations. In the workshop, stakeholders are informed about the basic topics of the scorecard, indicators and sub-indicators of the topics.

The participants in the workshop are grouped according to the sectors related to each indicator and sub-indicator and their own topics and authority issues and are asked to score.

The results are verified by the participants at the end of the meeting. The verification process is repeated by discussing the scorecard results that emerge after the workshop with focus group interviews and institution representatives.

5.2. Improving the Resilience Index

Many studies have developed methods for determining indices related to disaster risk management. Cardona (2005) developed an indicator system for disaster risk management using four indicators: “Disaster Vulnerability Index, Local Disaster Index, Widespread Vulnerability Index and Risk Management Index”.

Simpson (2006) introduced the Individual Disaster Resilience Index, a model designed to gauge a community’s resilience. This index is derived from the interplay between a region's preparedness score and its vulnerability score. The resilience measures are quantified and assigned weights based on these scores. The "preparedness score" includes factors such as social, economic, institutional, infrastructure/physical, and environmental aspects, while the "vulnerability score" encompasses social, economic, institutional, infrastructure/physical, and hazard indicators, along with their measurement (Kusumastuti et al., 2014).

Rygel et al. (2006) created a social vulnerability index using the Pareto ranking technique. They began by identifying indicators of vulnerability and performing principal component analysis on these indicators' representative values. The Pareto ranking was then applied to these principal components to compute overall social vulnerability. Additionally, they assessed preparedness and vulnerability dimensions through seventeen interviews with representatives from disaster management agencies.

Mayunga (2007) suggested a disaster resilience index that is derived from the average of the weighted sums of various capital indices. Each capital index was determined by aggregating the weighted values of its specific indicators.

Chen et al. (2016) employed the Delphi method to identify factors influencing urban and regional disaster carrying capacity. They integrated qualitative and quantitative data by organizing structurally weak issues into systematic hierarchies.

Cutter et al. (2010) utilized composite indicators to evaluate disaster resilience across counties in the southeastern United States. They developed a place-based model from a literature review, resulting in a resilience index with 30 indicators categorized into five subcomponents: social resilience, economic resilience, institutional resilience, infrastructure resilience, and community capital.

Sherrieb et al. (2012) conducted an online survey of school principals to evaluate community resilience in coastal U.S. schools. The survey addressed various topics including community competence, disaster management, social capital, economic development, and information and communication.

Joerin et al. developed an alternative framework to assess community resilience to climate-related disasters, which was applied via a household survey in Chennai, India (Joerin et al., 2012).

Orencio & Fujii (2013) introduced a disaster resilience index utilizing the Analytical Hierarchy Method to evaluate coastal communities. Their criteria were categorized into environmental and natural resource management, human health and well-being, sustainable livelihoods, social protection, financial instruments, physical protection, structural and technical measures, and planning frameworks. The resilience of these communities was assessed using a composite index derived from the weighted linear average of all indicators.

Balta (2013) examined index studies on disasters and stated that when index studies are evaluated from an interdisciplinary perspective, different indicators can be diversified by applying them to different areas. It is seen that various methods such as survey, indicator combination, “Analytical Hierarchy Process” and “Delphi” are used in the development of indexes in many studies. Different indexes have been developed to evaluate disaster resilience and relatively the same criteria have been used. However, it has been stated in many studies that different countries have made new arrangements in resilience indicators and sub-indicators and that this is necessary.

The resilience of a city is the result of comparing its preparedness with its vulnerability (disaster exposure) (Simpson, 2006). The aim here is to maximize the preparedness potential and minimize the level of vulnerability. Preparedness and vulnerability scores are evaluated and scored separately with the Analytical Hierarchy Method. Then, the ratio of the resilience score and the preparedness score to the vulnerability score is calculated. A value less than 1 indicates that the capacity to cope with disasters is low, a value equal to 1 indicates that the city has the capacity to eliminate vulnerability problems, and a value greater than 1 indicates that it is resilient to natural disasters (Mayunga, 2017; Bruneau, 2003; Cutter et al., 2010; Orencio & Fujii, 2013; Kusumastuti et al., 2014).

6. Conclusion and Recommendations

A single scorecard is not expected to fit cities of different sizes and contexts and provide healthy results. Indicator and sub-indicator sets should be developed according to the characteristics of the cities themselves (City Resilience Index, 2016; UNISDR, 2012; Frazier et al. 2013; Kusumastuti et al., 2014; Jorerin & Shaw, 2016; Morga et al. 2020; Jones et al., 2020). In resilience studies, countries and even cities should determine resilience criteria and indicators in their own way (Bruneau et al., 2003; Simpson, 2006; Rygel et al., 2006; Rose, 2007; Mayunga, 2007; Cutter et al., 2008, 2010; Razafindrabe et al., 2009; Chen, 2009; Sherrieb et al., 2010, 2012; Joerin et al., 2012; Orencio and Fujii, 2013; Kusumastuti et al.,2014; Kaba, 2020; Karabakan, 2020; Duo Xu et al., 2020; Yüksel & Karaçor, 2021; Hurlimann et al., 2021). To give an example, cities prone to earthquakes must develop strong and tailored risk assessment strategies and response capacities. In contrast, cities less frequently affected by earthquakes are less likely to prioritize this risk in their plans and programs. Additionally, it is challenging to determine whether one city is "more" or "less" resilient than another, given the varying causes and risks they face. The goal of creating a disaster resilience scorecard for a city is not to compare it with other cities, but to monitor its own progress over time.

Therefore; developing sets of indicators and sub-indicators for each city by their own special local committee would be much more effective to monitor the resilience process.

"The Disaster Resilience Scorecard for Cities" measures a city's ability to cope with disasters over time and its progress in doing so. By this way, resilience of city could be comparable to its own past conditions, not to other cities' resilience indicators.

Developed to make cities more resilient and understand the local context, the "Disaster Resilience Scorecard for Cities" could be used as a tool and could be developed for each city.

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Determination of Biomass and Carbon Sequestration Capacity of Urban Trees: Rize Province Ziraat Botanical Park

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1. Introduction

Industrialization, increasing population and unconscious use of natural resources negatively affect the world. Endless and ever-increasing uncontrolled consumption demands on natural resources cause partial or complete disruption of the natural balance or the destruction of some ecosystems (Oğuztürk & Bayramoğlu, 2020; Çorbacı & Ekren, 2022). As a result of the warming of the atmosphere due to anthropogenic factors, carbon emissions have increased and global disasters have increased.

Urban green areas not only provide interaction between humans and nature, but also increase the quality of urban structure and improve living conditions (Ekren & Çorbacı, 2022; Ercan Oğuztürk & Pulatkan, 2023). Therefore, urban green areas stand out as an indicator of urban comfort and the quality of life of the society. Urban comfort is directly related to green areas and their harmony and sustainability as well as the structural units they contain. In this context, developed countries have made efforts to plan and design urban areas that take more into account the mental and physical needs of people (Gül & Küçük, 2001; Oğuztürk & Murat, 2023). On the other hand, cities, which have a large share in energy and resource use, should be planned as places that are in harmony with nature, environmentally sensitive, where natural resources are protected and developed while they are being used (Surat et al., 2023).

Plants, especially trees, have the capacity to sequester CO_2 through photosynthesis. Plants are considered as the most important carbon sinks that store carbon in their biomass and under the soil (Tuğluer & Gül, 2018; Gül et al., 2009). For more livable cities: Reducing CO_2 emissions, increasing the amount of stored carbon, improving the urban ecosystem and aesthetics, etc. urban green spaces and trees are of great importance due to their versatile services and contributions (Tuğluer & Çakır, 2019; Gül et al., 2021; Ariluoma et al., 2021). More scientific research is needed to reveal the effects of urban green spaces and the plant taxa within them on carbon storage and sequestration (Fares et al., 2017). One of the most important factors in the inability to determine the amount of carbon storage of plants is the lack of a standardized method for calculating biomasses using dendrological characteristics that vary depending on different growing conditions (Chave et al., 2005). The characteristics of taxa used in urban areas also affect the amount of carbon storage. Leafing rate, crown width, age, and rapid growth of the taxon increase the amount of carbon storage (Gül et al., 2021). The roots of the plant play an important role in carbon storage as well as the carbon stored in the upper part of the plant.

In his study, Büyüktürkmen (2021) determined the carbon sequestration values of recreation areas using the KARBİYOSİS program in order to evaluate it as an important criterion in vegetative designs by considering the amount of carbon sequestration in landscape design areas.

Remote sensing and geographic information systems are one of the most effective methods to determine changes in land cover in large areas where data information is insufficient (Wu et al., 2018; Chowdhury et al., 2020; Gülçin, 2021). In areas where inventory information is lacking, global values based on empirical assumptions can be used for estimation purposes to calculate the amount of carbon (Myeong et al., 2006).

In our country, many studies have been conducted to determine carbon sink capacities both in natural forests and in rehabilitation and afforestation areas by using equations developed by using local measurement methods (Tolunay & Çömez, 2008; Yıldız et al., 2010; Çömez, 2010; Güner et al., 2012; Yüksek, 2012; Sivrikaya & Bozali, 2012; Özdemir et al., 2013; Yaşar Korkanç, 2014; Değermenci & Zengin, 2016; Karataş et al, 2017; Güner et al., 2021; Yüksek & Yüksek, 2021) and many studies have been carried out to determine carbon sink capacities with the help of ArcGIS program as well as Landsat satellite images using remote sensing methods (Myeong et al., 2006; Altınbaş, 2006; Aydoğdu et al., 2009; Düzgün, 2010; Ashraf et al., 2011 Gülçin, 2021). Therefore, although there are many studies in the literature on carbon storage in forests and rehabilitation areas, studies on carbon storage in urban green areas and urban trees (Gül et al., 2021) are limited.

The carbon storage of urban open green spaces in specific cities needs to be analyzed in detail on a map-based basis and the appropriate spatial scale needs to be considered in the urban carbon storage spatial mapping process. Appropriate or minimum spatial mapping of urban carbon storage is considered a prerequisite for both accurate urban carbon storage estimation and scaling of the study area as well as urban and regional climate impact simulation. Nowadays, most studies are focused on carbon mapping and, based on this, the carbon storage capacity of taxa in different ecosystems. These initiatives necessitate the development of a GIS-based mapping infrastructure focused on estimating the advantages of urban open green spaces in terms of carbon storage and sequestration (Li et al., 2024; Liu et al., 2024; Rachid et al., 2024).

In our world, which is rapidly urbanizing and experiencing serious problems in its natural resources, the carbon cycle, one of the most important issues of the modern era, is a concept in which plant material plays a very important role and which landscape architects should definitely know a lot about as part of their professional responsibility. Especially in studies carried out in ecologically “problematic” places such as urban areas, it is stated that a landscape architect's concern about the contribution of the product to the carbon cycle will both strengthen the professional discipline and produce extremely correct results in terms of professional ethics (Akkuş, 2014).

The aim of this study is to determine the biomass and carbon sequestration capacity of trees in Ziraat Botanical Park in Rize province. Determining the carbon storage capacities of plants in urban open green areas and conducting studies to overcome the deficiencies in this field may be useful for combating global climate change on the one hand and sustainable urban management on the other.

2. Material and Method

This study was conducted in the Ziraat Botanical Park of the General Directorate of Tea Enterprises (ÇAYKUR) located in the city center of Rize. [2]The study area (Figure 1) is 28481.80 m^2 and is located between latitudes 41° 1´ 15´´- 41° 1´ 18´´ N and longitudes 40° 30´ 35´´- 40° 30´ 45´´ E and between 96-110 m elevation (Figure 1). The total annual precipitation of the study area is 2302 mm, the average annual temperature is 14.5 °C, the average highest temperature is 26.5 °C in August and the average lowest temperature is 3.7 °C in February (Table 1).

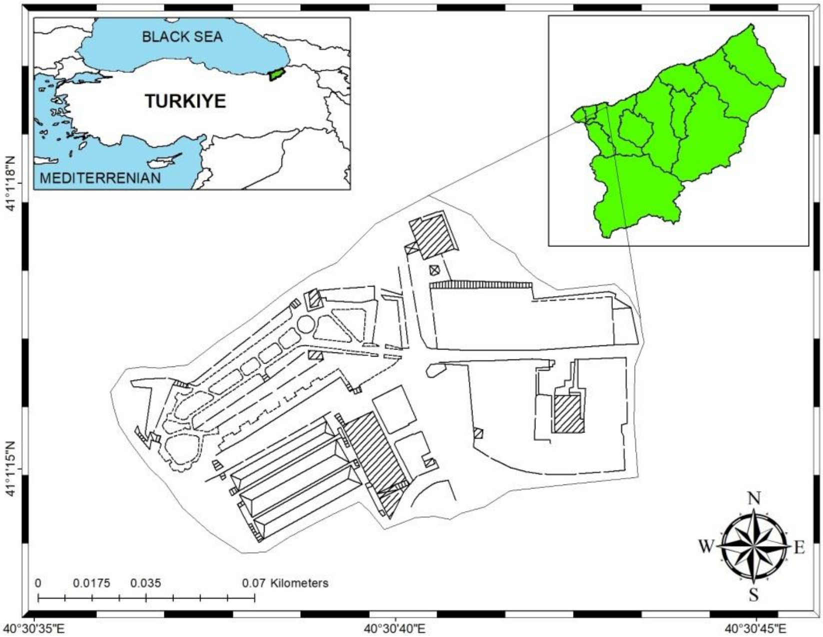

Figure 1. Research Area

Table 1. Monthly Variation of Some Climate Elements in Rize Province (Measurement Period: 1928 - 2022) (Anonymous, 2024)

RİZE	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Average Temperature (°C)	6.8	6.8	8.1	11.7	16.0	20,3	22.9	23.3	20.3	16.4	12.3	8.8	14.5
Average Highest Temperature (°C)	10.7	10.8	11.9	15.4	19.4	23.6	26.0	26.5	24.0	20.4	16.5	12.9	18.2
Average Lowest Temperature (°C)	3.8	3,7	4.9	8.4	12.7	16.7	19.6	20.1	16.9	13.1	9.1	5.7	11.2
Average Sunshine Duration (hours)	2.2	3.1	3.6	4.6	5.7	6.6	5.4	5.2	5.0	4.2	3.0	2.2	4.2
Average Number of Rainy Days	14,72	14.27	15.77	14.52	14.20	14.08	13.69	14.25	14.62	14,82	13.55	14.14	172.6
Monthly Total Rainfall Average (mm)	232.6	185.7	161.6	95.4	96.5	134.2	150.7	196.0	258.2	294.5	253.4	243.2	2302.0
Highest Temperature (°C)	26.6	28.1	32.6	35.8	38.2	36.1	35.6	35.6	35.0	33.8	30.4	26.7	38.2
Lowest Temperature (°C)	-6.5	-6.6	-7.0	-2.8	4.0	7.8	12.0	13.4	4.6	2.5	-2.6	-4.0	-7.0

The annual number of rainy days in the study area is 172.6. According to the seasons, although the number of rainy days is high in spring, the amount of precipitation is at the lowest level. According to the seasons, the highest precipitation occurs in the fall. Rize's climate type is A B'1 r a': very humid, medium temperature (mesothermal), no or very little water deficit, oceanic (marine) climate type (Yüksek, 2017).

2.1. Material

Tools such as calipers, branch pruning shears, laser meters, penknives, steel tape measures, telescopic branch pruning shears, precision scales, etc. were used during plant inventory and sampling. ArcGIS 10.5 was used for the preparation of maps and attribute tables and the KARBİYOSİS program developed by Tuğluer (2019) was used as material for calculating the amount of carbon storage on leaf surfaces.

2.2. Method

The method consists of three stages; the first stage is plant sampling in the trial areas, the second stage is the analysis of plant samples and the third stage is the density analysis of the data. In 57 areas within the urban open green space system of Rize province, 305 plant taxa belonging to 103 families were identified (Çorbacı et al., 2020). Based on the study conducted by Çorbacı et al. (2020), a total of 30 plant taxa were identified from 10 taxa, 5 broad-leaved and 5 coniferous plants, and 3 from each taxon (Figure 2). The distribution of plant taxa according to their Latin name, family, abbreviation, leaf type and naturalness are presented in Table 2; plant taxa sampled in Ziraat Botanical Park and their geographical locations are presented in Figure 3.

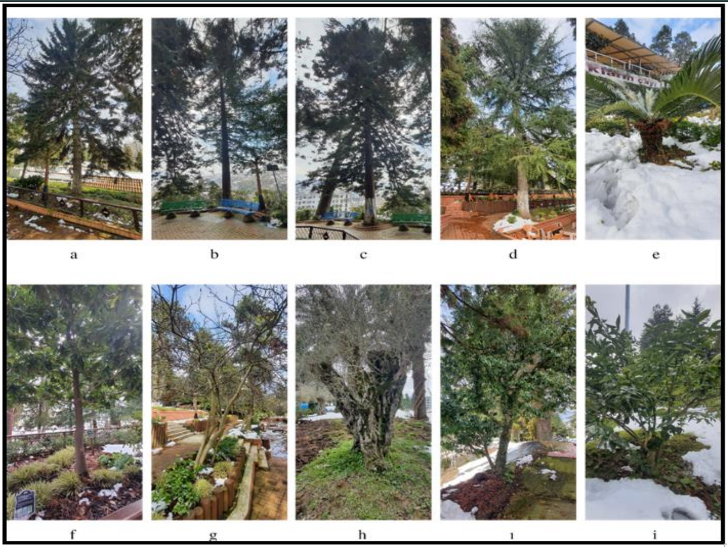

Figure 2. Plant taxa of the study area (a) *P. orientalis*, (b) *S. sempervirens*, (c) *C. japonica*, (d) *C. deodora*, (e) *C. revoluta*, (f) *M. grandiflora*, (g) *M. soulangeana*, (h) *O. europaea*, (i) *L. officinalis*, (i) *C. Reticulata*

Table 2. Taxa Sampled in Ziraat Botanical Park

Latin Name	Abbreviation	Family	Leaf Type.	Naturalness
Sequoia sempervirens (D. Don) Endl.	Se.sem.	Cupressaceae	Coniferous plants	Exotic
Cedrus deodora (Roxb.) G. Don	Ce.deo.	Pinaceae	Coniferous plants	Exotic
Citrus reticulata L.	Ci.ret	Rutaceae	Broad-leaved	Exotic
Cryptomeria japonica (Thunb. ex L.f.)D. Don	Cr.jap.	Cupressaceae	Coniferous plants	Exotic
Cycas revoluta L.	Cy.rev.	Cycadaceae	Coniferous plants	Exotic
Magnolia grandiflora L.	Ma.gra.	Magnoliaceae	Broad-leaved	Exotic
Magnolia soulangeana Soul.-Bod.	Ma.sou.	Magnoliaceae	Broad-leaved	Natural
Olea europaea L.	Ol.eur.	Oleaceae	Broad-leaved	Natural
Picea orientalis (L.) Peterm	Pi.ori.	Pinaceae	Coniferous plants	Natural
Laurocerasus officinalis M Roem	La.off.	Rosaceae	Broad-leaved	Natural

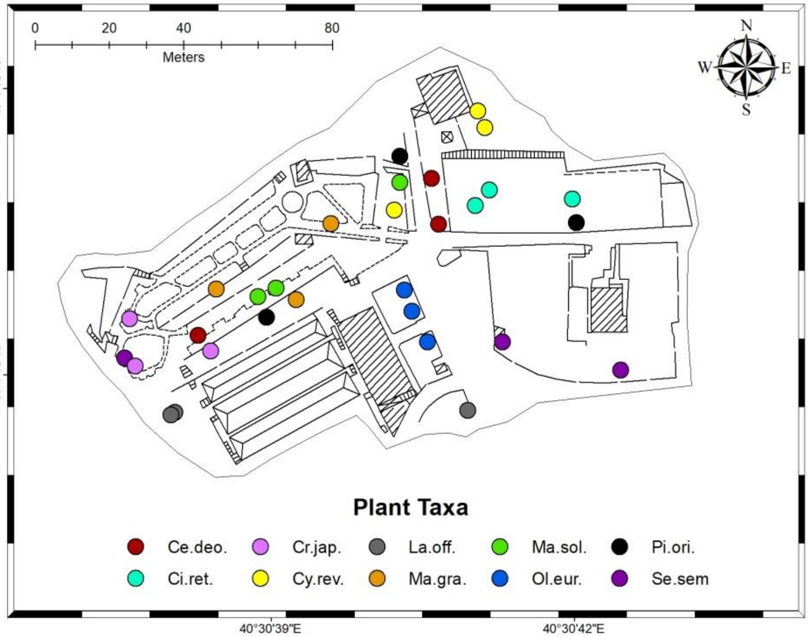

Figure 3. Taxa Sampled in Ziraat Botanical Park and Their Geographical Locations

2.2.1. Plant Sampling in Experimental Areas

The taxa identified in Ziraat Botanical Park were identified in the herbarium of Recep Tayyip Erdoğan University, Department of Landscape Architecture and the trees to be measured were selected. Then, sample number, taxon Latin name, leaf type, stem length, stem base diameter, stem top diameter, bark thickness, percentage of sampled branches, percentage of sampled branches wet weight, percentage of sampled leaves, percentage of sampled leaves wet weight were measured in the selected taxa (Table 3) and transferred to the KARBİYOSİS program.

Table 3. Tree Inventory Information Form for KARBİYOSİS Program Users

Tree Inventory Information Form for CARBIOSIS Users								
Leaf Type (1:Broad-leaved plants) (2:Coniferous plants	Tree Trunk Length (cm)	Tree Trunk Bottom Dıameter h:0 (cm)	Tree Trunk Top Dıameter h:max (cm)	Tree Bark Thıckness (cm)	Tree Branch Sample Percentage (%)	Tree Branch Sample Age Weight(kg)	Leaf Sample Percentage (%)	Leaf Sample Weight (kg)

A code number was given to distinguish the inventoried tree from other trees. Taxon distribution of the trees sampled in Ziraat Botanical Park is shown in Figure 4.

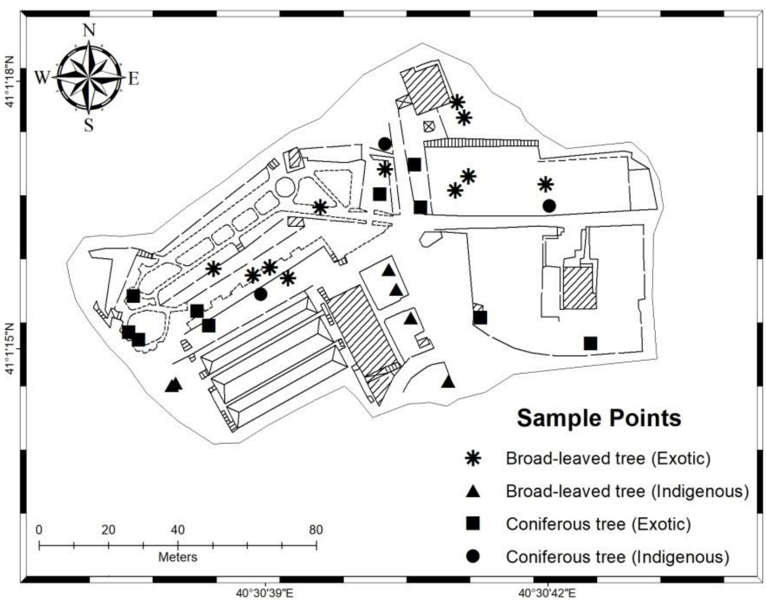

Figure 4. Taxon Distribution of Trees Sampled in Ziraat Botanical Park

Trunk length was calculated in two ways. In broad-leaved taxa, if branching starts by separating from the trunk, the distance between the base and the point where the tree crown starts was determined. In coniferous taxa, it was calculated between the base and the point at the end of the trunk. Trunk base diameter was measured as the width of the diameter from the lowest part of the trunk. The diameter of the uppermost part of the trunk was measured as the trunk top diameter. Bark thickness was taken as the average thickness of the bark pieces taken from 3 points to represent the tree. The percentage of branches sampled was determined as the percentage ratio according to the number of branches in the sampled tree by counting branches from 3 points to represent the branching of the trees. Sampled branch weight was determined as the wet weight of the sampled branch pieces by scraping them from the leaves. Percentage of leaves sampled was estimated as the percentage ratio of the samples on the branch according to the number of branches in the tree. Sampled leaf weight was calculated as the wet weight of the leaves stripped from the branch pieces.

2.2.2. Analyzes of Plant Samples

In the KARBİYOSİS program developed by Tuğluer (2019), above-ground carbon storage and biomass are estimated after the tree inventory study. The tree inventory study required for the program to work was carried out and entered into the inventory form. Then, by entering this form into the KARBİYOSİS program, the biomass and carbon sequestration amounts of the trees were calculated and the final report was issued.

2.2.3. Density Analysis

The data obtained were entered into the ArcGıs10.5 program and an information system was created. According to the carbon storage amounts in the attribute table, density analysis maps were created using ArcGIS10.5 spatial statistics methods.

Looking at the data imported into the program, it was determined that *S. sempervirens* (2400 cm) had the highest stem length and *C. reticulata* (70 cm) had the shortest stem length. *O. europaea* (90 cm) had the thickest stem base diameter, while *M. soulangeana* (10 cm) had the thinnest stem base diameter (Tables 4, 5 and 6).

It is observed that the coniferous taxa in the research area have a higher stem length than the leafy taxa. *C. deodora*, *P. orientalis* and O*. europaea* had the highest base diameters, while *M. soulangeana* and *C.* reticulata had the lowest base diameters. In general, it was observed that leafy taxa had higher top diameters than coniferous taxa. Although the difference between base diameter and top diameter was high in coniferous taxa; this difference was found to be quite low in leafy taxa

This difference was found to be caused by pruning in leafy taxa (Figure 5). In general, the bark of coniferous taxa was found to be thicker than that of leafy taxa. *C. deodora* had the thickest bark while *M. soulangeana* had the thinnest bark (Figure 6).

Table 4. Inventory Data Collected in Section 1 of Ziraat Botanical Park

Sample No	Taxon Latin Name	*Leaf Type	Tree Trunk Length (m)	Tree Trunk Bottom Dıameter h:0 (cm)	Tree Trunk Top Dıameter h:max (cm)	Tree Bark Thıckness (cm)	Tree Branch Sample Percentage (%)	Tree Branch Sample Age Weight(kg)	Leaf Sample Percentage (%)	Leaf Sample Weight (kg)
1a	*S. sempervirens*	2	24	55	8	1.2	0.2	1.5	0.6	0.77
1b	*C.* japonica	2	22	65	5	1.2	0.4	1.58	0.8	1.23
1c	*C. deodora*	2	20	70	4	1.8	0.7	3.75	0.1	1.08
1d	*P. orientalis*	2	18	52	6	0.6	0.4	6.41	0.33	3.00
1e	*M.* soulangeana	1	1.6	11	9	0.2	0.9	4.12	1.2	0.29
1f	*M. grandiflora*	1	1.4	20	16	1.2	0.3	3.47	0.98	1.02
1g	*C. revoluta*	2	1.6	20	15	0.7	0.9	0.23	0.6	0.18
1h	*C.* reticulata	1	0.7	13	10	0.3	0.6	2.29	0.8	0.50
1ı	*O. europaea*	1	1.8	75	70	0.5	0.1	2.69	0.1	0.20
1i	*L.* officinalis	1	1.5	30	25	0.4	0.2	2.62	0.6	1.00

*(1: Broadleaf) (2: Coniferous)

Table 5. Inventory Data Collected in Section 2 of Ziraat Botanical Park

Sample No	Taxon Latin Name	Leaf Type*	Tree Trunk Length (m)	Tree Trunk Bottom Dıameter h:0 (cm)	Tree Trunk Top Dıameter h:max (cm)	Tree Bark Thıckness (cm)	Tree Branch Sample Percentage (%)	Tree Branch Sample Age Weight(kg)	Leaf Sample Percentage (%)	Leaf Sample Weight (kg)
2a	*S. sempervirens*	2	22	60	8	1.5	0.2	0.30	0.6	0.087
2b	*C.* japonica	2	17	60	5	1.5	0.4	0.40	0.8	0.31
2c	*C. deodora*	2	20	70	4	1.3	0.7	0.13	0.1	0.12
2d	*P. orientalis*	2	13	45	6	0.8	0.4	0.43	0.33	0.10
2e	*M.* soulangeana	1	1.75	10	8	0.5	0.9	0.77	1.2	0.06
2f	*M. grandiflora*	1	4.1	80	75	1	0.3	0.50	0.98	0.45
2g	*C. revoluta*	2	1.6	30	40	0.6	0.9	0.10	0.6	0.12
2h	*C.* reticulata	1	0.8	13	10	0.3	0.6	0.30	0.8	0.10
2ı	*O. europaea*	1	1.7	90	85	0.8	0.1	0.43	0.1	0.06
2i	*L.* officinalis	1	1.7	35	30	0.5	0.2	0.67	0.6	0.33

*(1: Broadleaf) (2: Coniferous)

Table 6. Inventory Data Collected in Section 3 of Ziraat Botanical Park

Sample No	Taxon Latin Name	Leaf Type*	Tree Trunk Length (m)	Tree Trunk Bottom Dıameter h:0 (cm)	Tree Trunk Top Diameter h:max (cm)	Tree Bark Thickness (cm)	Tree Branch Sample Percentage (%)	Tree Branch Sample Age Weight(kg)	Leaf Sample Percentage (%)	Leaf Sample Weight (kg)
3a	*S. sempervirens*	2	20	60	8	1.4	0.2	1.07	0.6	0.28
3b	*C.* japonica	2	13.5	60	5	1.4	0.4	0.30	0.8	0.34
3c	*C. deodora*	2	12.5	70	4	1.5	0.7	1.10	0.1	0.16
3d	*P. orientalis*	2	17	82	6	0.7	0.4	0.43	0.33	0.087
3e	*M.* soulangeana	1	1.8	10	8	0.3	0.9	0.43	1.2	0.083
3f	*M. grandiflora*	1	1.8	15	12	0.6	0.3	0.27	0.98	0.53
3g	*C. revoluta*	2	1.65	35	30	1	0.9	0.20	0.6	0.12
3h	*C.* reticulata	1	0.8	13	10	0.3	0.6	0.20	0.8	0.06
3ı	*O. europaea*	1	1.7	65	60	0.5	0.1	0.93	0.1	0.07
3i	*L.* officinalis	1	1.7	30	25	0.4	0.2	0.53	0.6	0.25

*(1: Broadleaf) (2: Coniferous)

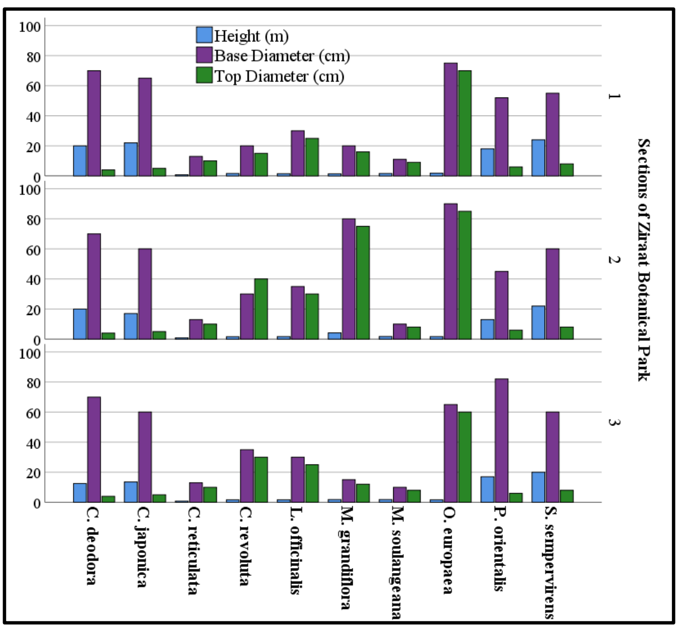

Figure 5. Height (m), Base Diameter (cm) and Top Diameter (cm) Values of Stems of Taxa in Different Parts of the Botanical Park

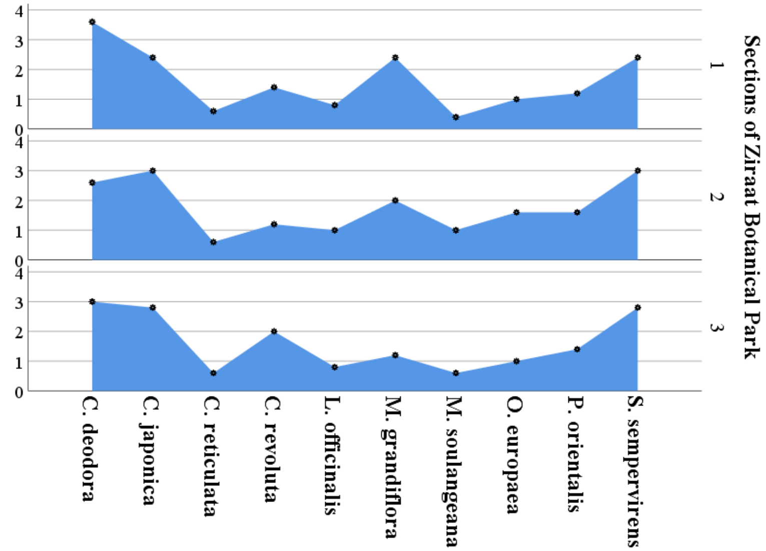

Figure 6. Stem bark thickness of taxa in different parts of the Botanical Park (cm)

Inventory distribution density analyses of the sampled taxa (Figure 7 - 14) were performed on a map-based basis.

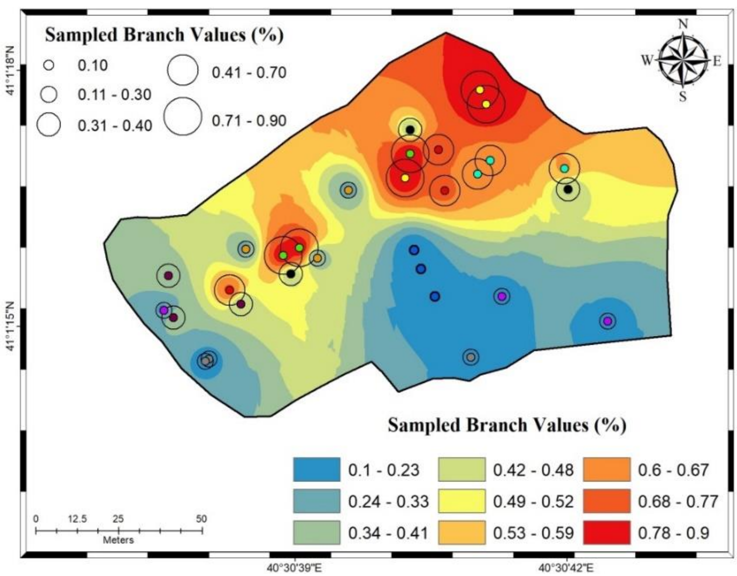

Figure 7. Distribution of Sampled Branch Values

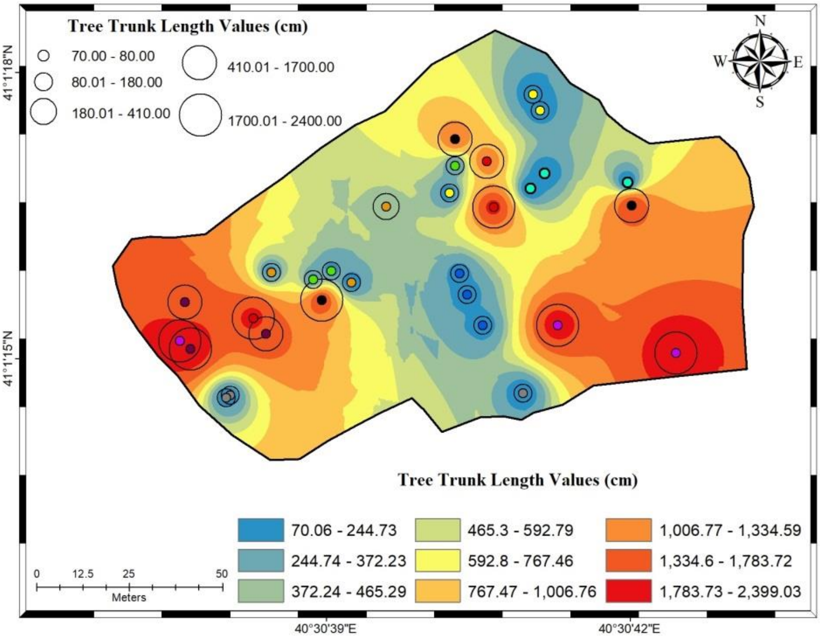

Figure 8. Distribution of Sampled Tree Trunk Length Values

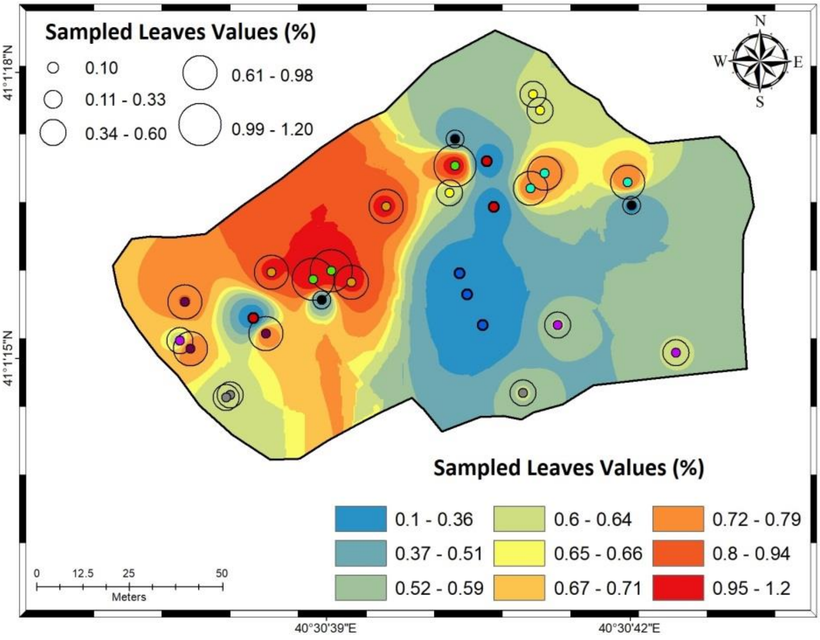

Figure 9. Distribution of Percentage Values of Sampled Leaves

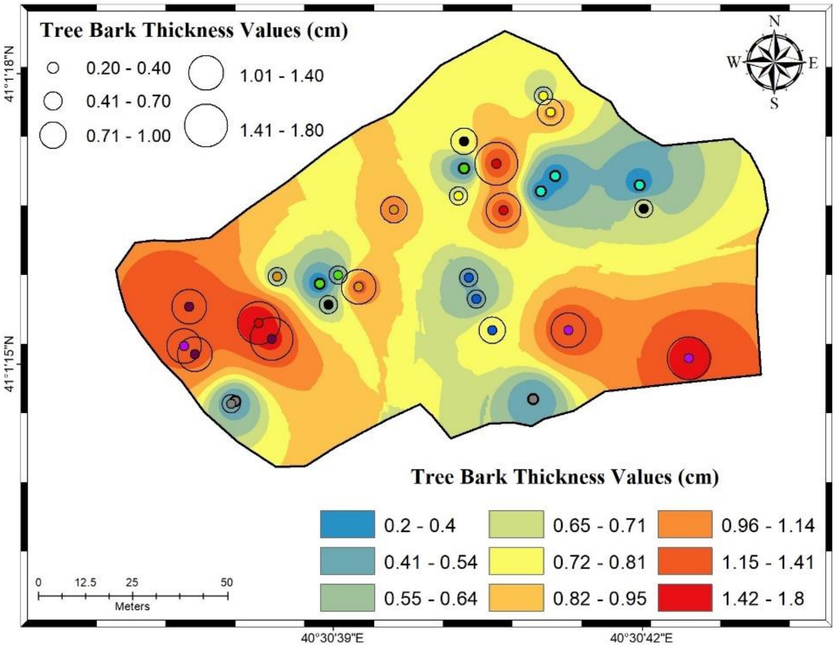

Figure 10. Distribution of Sampled Tree Bark Thickness Values

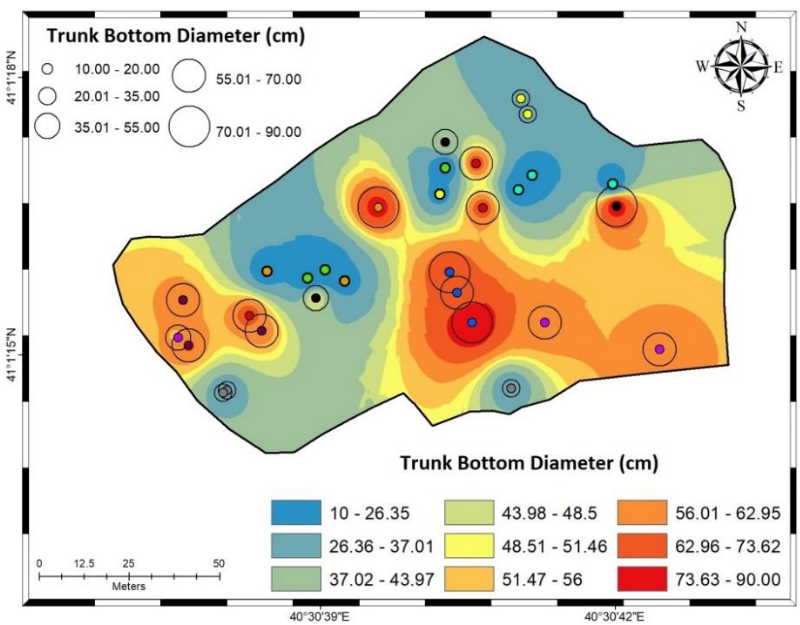

Figure 11. Distribution of the Bottom Diameter Values of Sampled Trunk

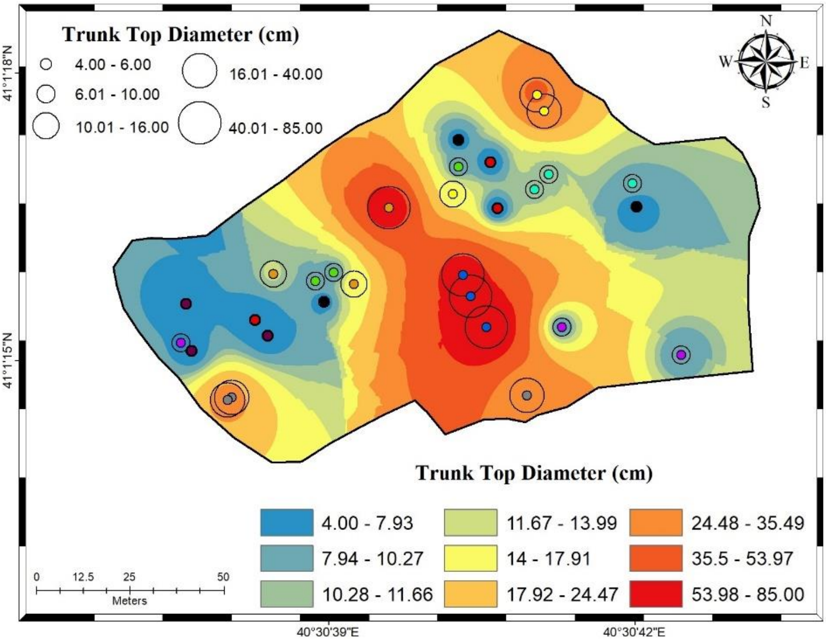

Figure 12. Distribution of Sampled Tree Trunk Top Dıameter Values

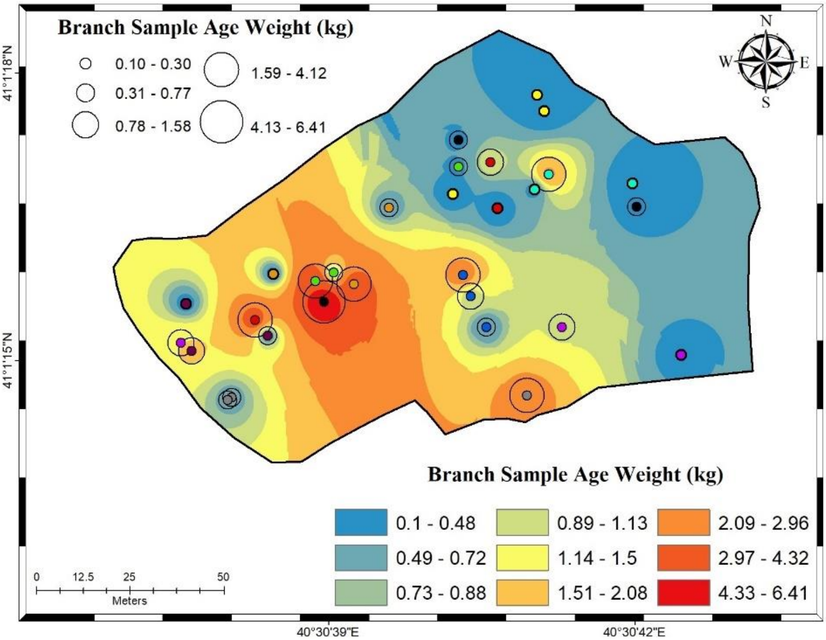

Figure 13. Distribution of Branch Sample Age Weight

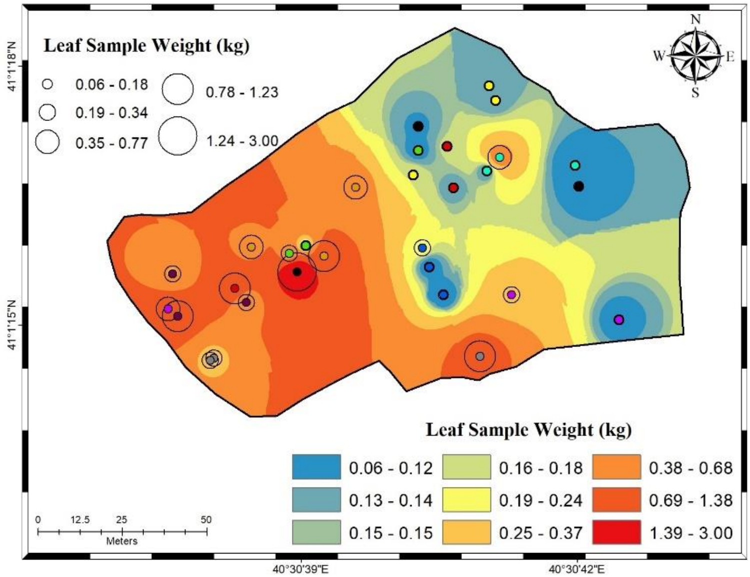

Figure 14. Distribution of Leaf Sample Weight

Total biomass amounts calculated for the study area are given in Tables 7, 8 and 9.

Table 7. Total Biomass Values of Trees in Section 1 of Ziraat Botanical Park

Sample No	Taxon Latin Name	Stem Biomass (kg)	Stem Bark Biomass (kg)	Branch Biomass (kg)	Leaf Biomass (kg)	Total Biomass(kg)	Percentage of Total Biomass
1a	*Se.sem.*	1130.07	109.56	379.25	63.12	1682.00	13.68
1b	*Cr.jap.*	1447.31	111.84	197.38	75.23	1831.76	14.89
1c	*Ce.deo.*	1744.90	192.80	271.13	556.83	2765.66	22.49
1d	*Pi.ori.*	789.09	38.55	801.13	445.80	2074.56	16.87
1e	*Ma.sol.*	6.97	0.55	242.50	10.02	260.04	2.11
1f	*Ma.gra.*	15.42	5.00	612.86	43.63	676.89	5.50
1g	*Cy.rev.*	14.85	2.39	12.94	14.43	44.62	0.36
1h	*Ci.ret.*	3.92	0.41	201.90	24.00	230.25	1.87
1ı	*Ol.eur.*	396.01	10.791	1427.82	83.84	1918.45	15.60
1i	*La.off.*	47.42	2.74	695.10	68.99	814.24	6.62
	Total	5595.96	474.61	4842.03	1385.88	12298.47	100

Table 8. Total Biomass Values of Trees in Section 2 of Ziraat Botanical Park

Sample No	Taxon Latin Name	Stem Biomass (kg)	Stem Bark Biomass (kg)	Branch Biomass (kg)	Leaf Biomass (kg)	Total Biomass(kg)	Percentage of Total Biomass (%)
2a	*Se.sem.*	1209.99	134.55	75.00	7.08	1426.45	19.13
2b	*Cr.jap.*	928.17	99.21	50.00	19.19	1096.57	14.71
2c	*Ce.deo.*	1798.54	141.19	9.61	60.02	2009.36	26.95
2d	*Pi.ori.*	418.05	32.37	54.13	14.36	518.90	6.96
2e	*Ma.sol.*	5.42	1.30	45.17	1.99	53.87	0.72
2f	*Ma.gra.*	1004.91	52.21	88.33	19.19	1164.64	15.62
2g	*Cy.rev.*	38.21	3.25	5.56	9.80	56.81	0.76
2h	*Ci.ret.*	4.48	0.46	26.50	5.26	36.70	0.49
2ı	*Ol.eur.*	538.38	19.61	229.49	25.26	812.75	10.90
2i	*La.off.*	74.22	4.57	176.76	23.39	278.94	3.74
	Total	6020.23	488.67	760.53	185.55	7454.99	100

Table 9. Total Biomass Values of Trees in Section 3 of Ziraat Botanical Park

Sample No	Taxon Latin Name	Stem Biomass (kg)	Stem Bark Biomass (kg)	Branch Biomass (kg)	Leaf Biomass (kg)	Total Biomass(kg)	Percentage of Total Biomass (%)
3a	*Se.sem.*	1108.21	11.,47	266.75	23.14	1512.57	21.62
3b	*Cr.jap.*	742.44	73.76	37.50	21.03	874.73	12.50
3c	*Ce.deo.*	1110.56	101.26	79.47	82.29	1373.57	19.64
3d	*Pi.ori.*	1850.38	64.37	54.12	12.87	1981.75	28.33
3e	*Ma.sol.*	6.10	0.82	25.50	2.92	35.34	0.51
3f	*Ma.gra.*	12.65	2.39	47.17	22.91	85.13	1.22
3g	*Cy.rev.*	52.61	6.52	11.11	10.07	80.31	1.15
3h	*Ci.ret.*	4.48	0.46	17.67	3.16	25.76	0.37
3ı	*Ol.eur.*	277.44	8.79	494.49	29.47	810.19	11.58
3i	*La.off.*	53.75	3.10	141.25	17.78	215.87	3.09
	Total	5218.61	375.95	1175.02	225.64	6995.23	100

When the biomass amount of broad and coniferous leafy taxa belonging to the study area is examined;

- In Section 1, *C. deodora* with 2765.66 kg and 22.49% in coniferous taxa *and O. europaea* with 1918.45 kg and 15.60% in broad-leaved taxa (Table 7)
- In Section 2, *C. deodora* with 2009.36 kg and 26.95% in coniferous taxa and *M. grandiflora* with 1164.64 kg and 15.62% in broad-leaved taxa (Table 8)
- In Section 3, *P. orientalis* with 1981.75 kg and 28.33% in coniferous taxa and *O. europaea* with 810.19 kg and 11.58% in broad-leaved taxa (Table 9) were the plants with the highest biomass capacity.

In general, the biomass values of coniferous taxa were higher than those of leafy species (Figure 15).

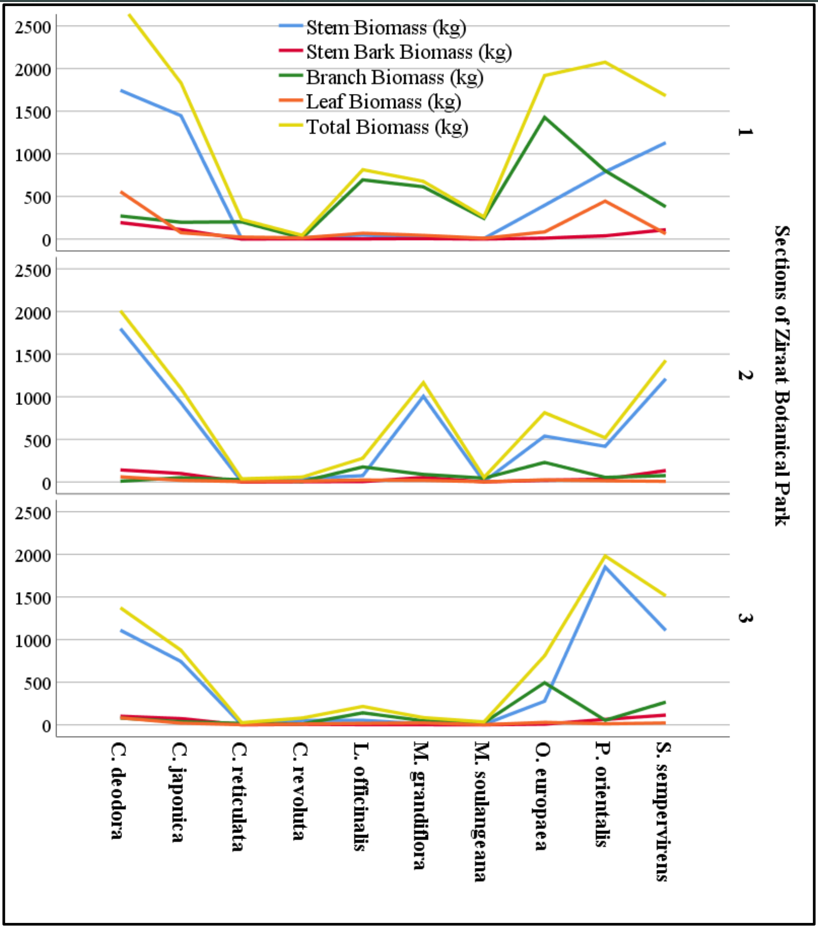

Figure 15. Stem (kg/tree), Bark (kg/tree), Branch (kg/tree), Leaf (kg/tree) and Total Biomass (kg/tree) Per Tree of Taxa in Different Parts of the Botanical Park

In coniferous taxa, the trunk was found to be the highest contributor to biomass, while in leafy taxa, except for M. grandiflora (In Section 2), the contribution of branch wood to biomass was higher (Figure 16).

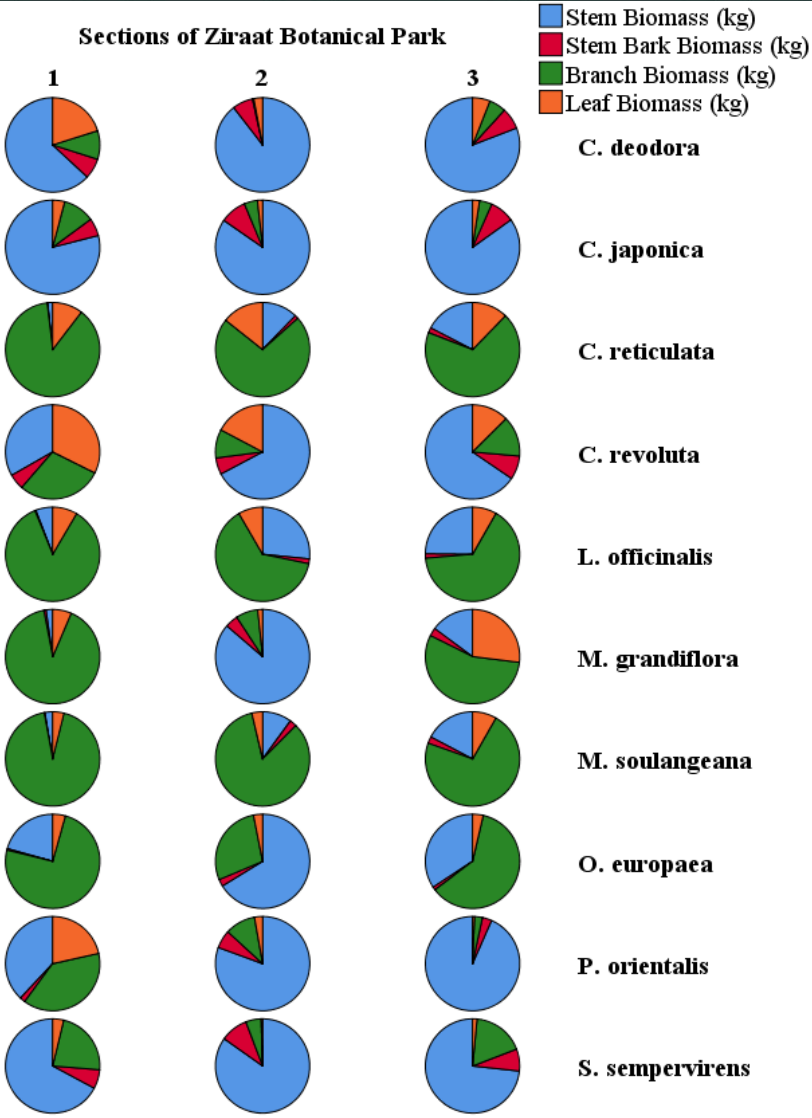

Figure 16. Proportional Distribution of Stem (kg/tree), Bark (kg/tree), Branch (kg/tree) and Leaf (kg/tree) Biomass per Tree in Taxa in Different Parts of the Botanical Park in Relation to Total Biomass

In M. grandiflora, the contribution of branch or trunk to total biomass varied according to pruning status. Figure 16 shows the proportional contribution of tree parts to total biomass. When we look at the graph, we see the effect of tree parts on biomass according to pruning severity in pruned plants. In the pruned taxa, it is seen that there is a significant change especially in branch and trunk biomass according to pruning severity. The most significant changes were observed in M. grandiflora and O. europaea. Density analysis of biomass values of the sampled taxa (Figures 17 - 21) was performed on a map-based basis.

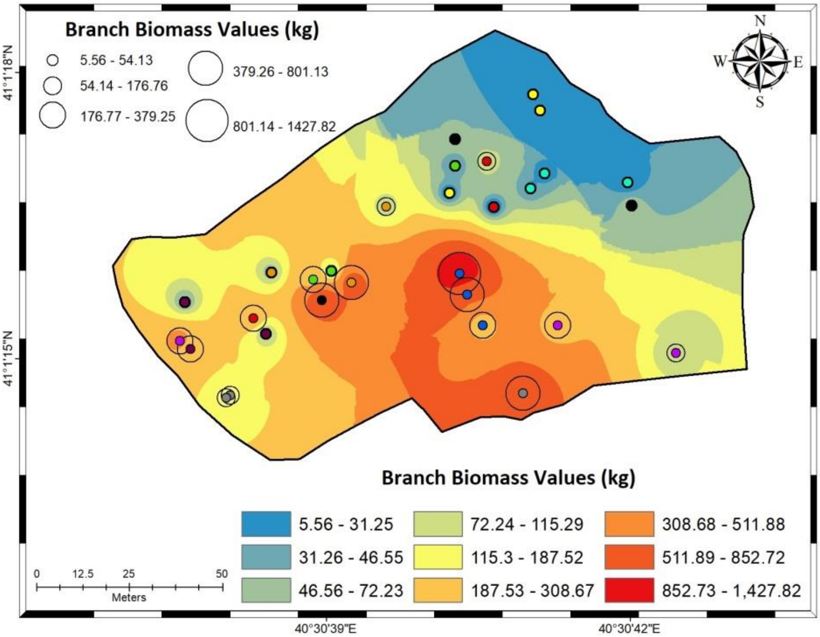

Figure 17. Distribution of Branch Biomass Values of Trees

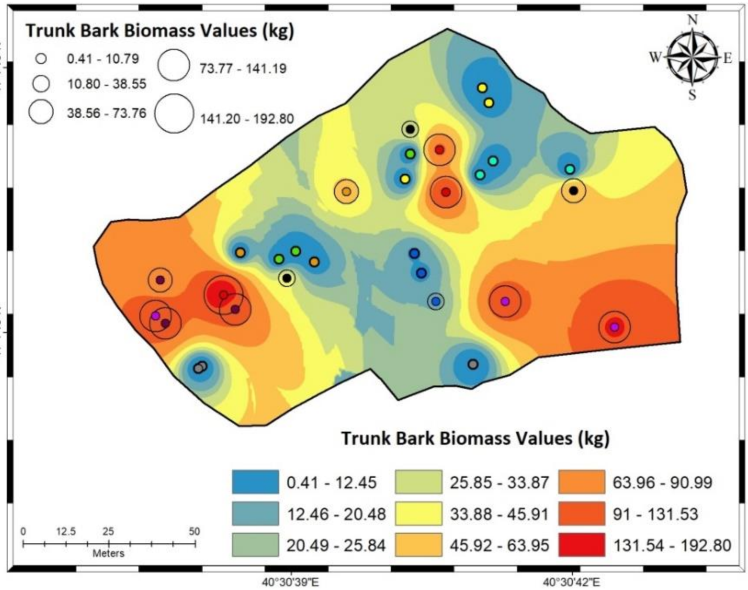

Figure 18. Distribution of Trunk Bark Biomass Values of Trees

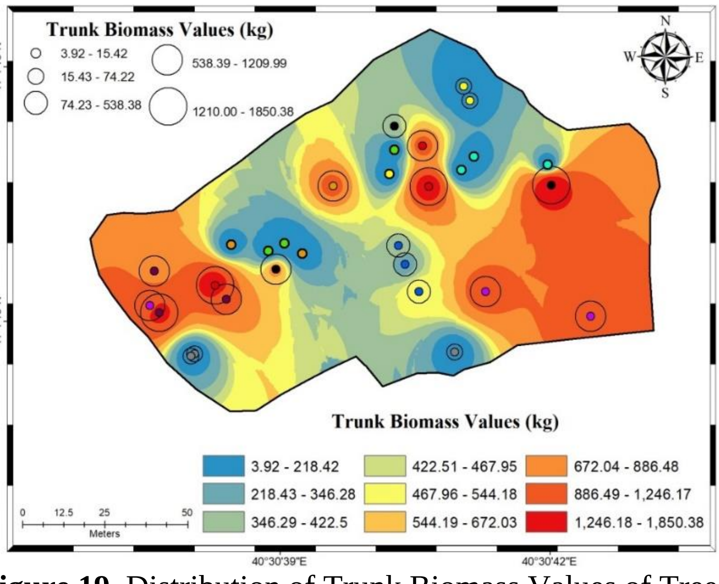

Figure 19. Distribution of Trunk Biomass Values of Trees

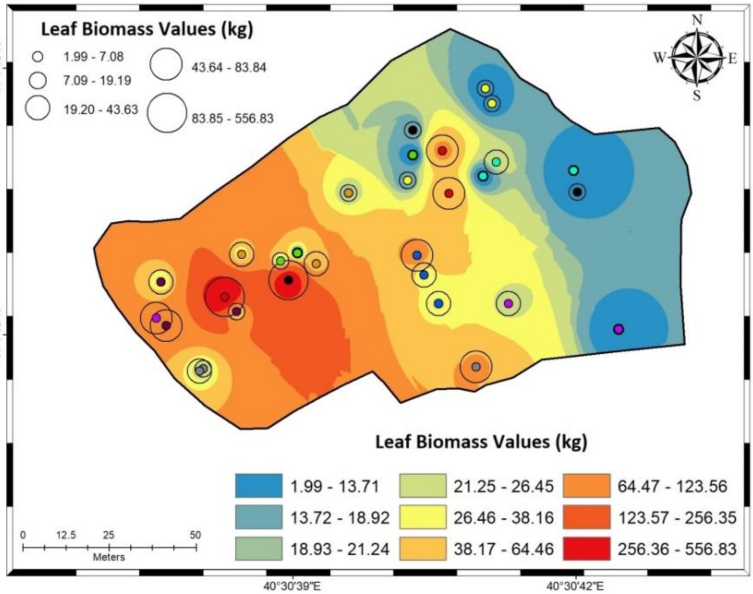

Figure 20. Distribution of Leaf Biomass Values of Trees

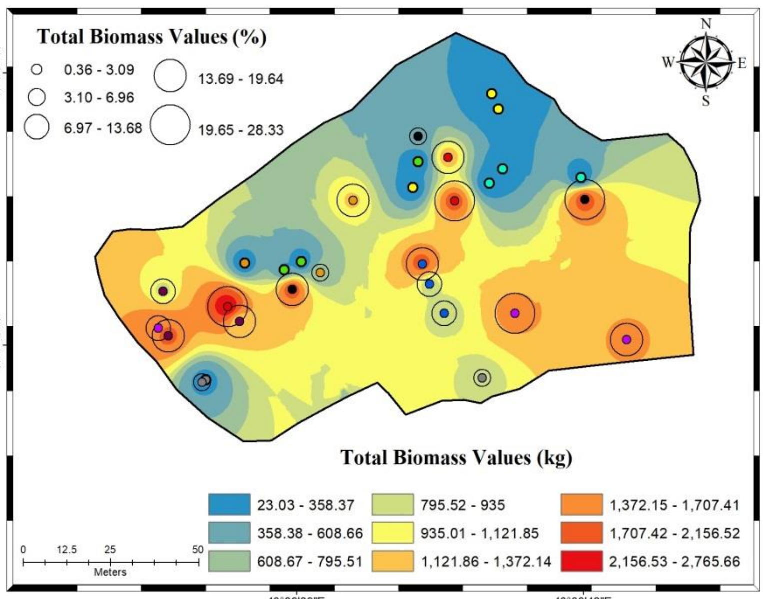

Figure 21. Distribution of Total Biomass Values of Trees

The total carbon sequestration amounts and percentages of the trees belonging to the 1st, 2nd and 3rd sections of Ziraat Botanical Park are given in Tables 10, 11 and 12.

Table 10. Carbon Sequestration Amounts and Percentages of Trees in Section 1 of Ziraat Botanical Park

Sample No	Taxon Latin Name	Body Carbon Sequestration Amount (kg)	Stem Bark Carbon Sequestration	Branch Carbon Sequestration Amount (kg)	Leaf Carbon Sequestration (kg)	Total Carbon Sequestration (kg)	Percentage of Total Carbon Sequestration
1a	*Se.sem.*	539.27	52.88	180.60	29.61	802.36	13.83
1b	*Cr.jap.*	690.66	53.98	93.99	35.29	873.92	15.07
1c	*Ce.deo.*	829.00	96.24	129.44	268.39	1323.08	22.81
1d	*Pi.ori.*	376.55	18.61	381.50	20.12	985.78	17.00
1e	*Ma.sol.*	3.22	0.25	111.84	4.36	119.68	2.06
1f	*Ma.gra.*	7.13	2.27	282.65	19.00	311.04	5.36
1g	*Cy.rev.*	7.09	1.16	6.16	6.77	21.18	0.37
1h	*Ci.ret.*	1.81	0.18	93.13	10.45	105.57	1.82
1ı	*Ol.eur.*	183.23	4.90	658.51	36.50	883.14	15.23
1i	*La.off.*	21.94	1.24	320.58	30.04	373.80	6.45
	Total	2659.92	231.71	2258.40	649.53	5799.57	100

Table 11. Carbon Sequestration Amounts and Percentages of Trees in Section 2 of Ziraat Botanical Park

Sample No	Taxon Latin Name	Body Carbon Sequestration Amount (kg)	Stem Bark Carbon Sequestration	Branch Carbon Sequestration Amount (kg)	Leaf Carbon Sequestration (kg)	Total Carbon Sequestration (kg)	Percentage of Total Carbon Sequestration
2a	*Se.sem.*	577.35	64.92	35.72	3.32	681.31	19.35
2b	*Cr.jap.*	442.92	47.89	23.81	9.00	52.,62	14.87
2c	*Ce.deo.*	854.49	70.48	4.59	28.92	958.49	27.23
2d	*Pi.ori.*	199.49	15.62	25.77	6.74	247.63	7.03
2e	*Ma.sol.*	2.51	0.59	20.83	0.87	24.79	0.7
2f	*Ma.gra.*	464.97	23.70	40.74	8.36	537.76	15.28
2g	*Cy.rev.*	18.23	1.57	2.65	4.60	27.04	0.77
2h	*Ci.ret.*	2.07	0.21	12.22	2.30	16.79	0.48
2ı	*Ol.eur.*	249.11	8.90	105.84	11.00	374.85	10.65
2i	*La.off.*	34.34	2.07	81.52	10.18	128.12	3.64
	Total	2845.48	235.96	353.68	85.28	3520.41	100

Table 12. Carbon Sequestration Amounts and Percentages of Trees in Section 3 of Ziraat Botanical Park

Sample No	Taxon Latin Name	Body Carbon Sequestration Amount (kg)	Stem Bark Carbon Sequestration (kg)	Branch Carbon Sequestration Amount (kg)	Leaf Carbon Sequestration (kg)	Total Carbon Sequestration (kg)	Percentage of Total Carbon Sequestration (%)
3a	*Se.sem.*	528.84	55.25	127.03	10.85	721.97	21.76
3b	*Cr.jap.*	354.29	35.60	17.86	9.86	417.61	12.58
3c	*Ce.deo.*	527.63	50.55	37.94	39.66	655.78	19.76
3d	*Pi.ori.*	883.00	31.07	25.77	6.04	945.89	28.50
3e	*Ma.sol.*	2.82	0.37	11.76	1.27	16.23	0.49
3f	*Ma.gra.*	5.85	1.09	21.75	9.98	38.67	1.17
3g	*Cy.rev.*	25.10	3.15	5.29	4.72	38.27	1.15
3h	*Ci.ret.*	2.07	0.21	8.15	1.38	11.80	0.36
3ı	*Ol.eur.*	128.37	3.99	228.06	12.83	373.25	11.25
3i	*La.off.*	24.87	1.41	65.14	7.74	99.16	2.99
	Total	2482.85	182.69	548.75	104.33	3318.63	100

The trees with the highest carbon sequestration capacity are *C. deodora* and *P. orientalis* in the coniferous taxa, and *M. grandiflora* and *O. europaea* in broad-leaved trees. When the carbon sequestration capacities of broad-leaved and coniferous taxa of the study area are examined;

- *C. deodora* with 1323.08 kg and 22.81% in coniferous taxa and *O. europaea* with 883.14 kg and 15.23% in broad-leaved taxa (Table 10).
- *C. deodora* with 958.49 kg and 27.23% in coniferous taxa *and M. grandiflora* with 537.76 kg and 15.28% in broad-leaved taxa (Table 11).
- In the section, *P. orientalis* with 945.89 kg and 28.50% in coniferous taxa *and O. europaea* with 373.25 kg and 11.25% in broad-leaved taxa (Table 12) were determined as the plants with the highest carbon sequestration capacity.

In parallel with the biomass amounts in the research area, it is generally observed that coniferous taxa store more carbon than leafy taxa (Figure 22).

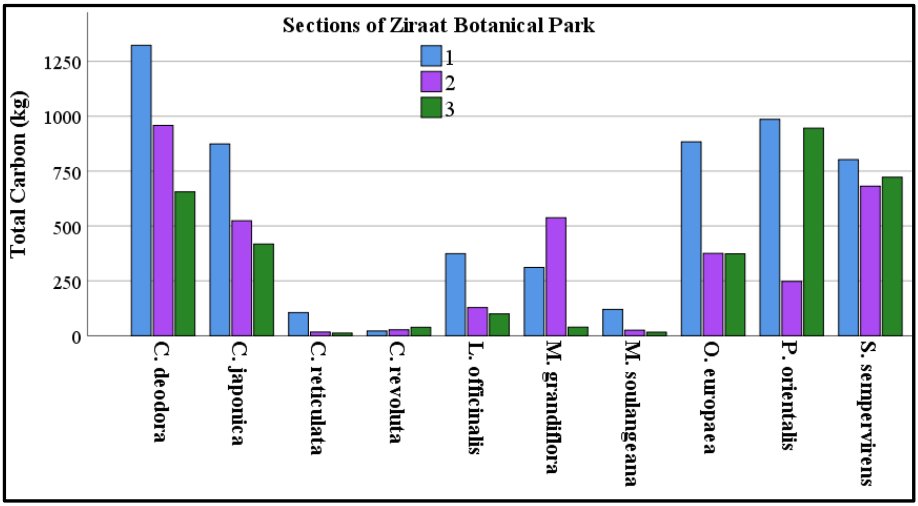

Figure 22. Total Carbon Sequestration of Taxa in Different Parts of the Botanical Park (kg/tree)

In parallel with the biomass, the amount of carbon stored by taxa in the research area varied according to pruning status and species (Figure 23).

In particular, it is clearly seen in the taxa *P. orientalis*, *M. grandiflora* and *O. europaea* how different maintenance treatments (pruning) on the same plant affect the amount of carbon sequestered and the carbon sequestration properties of plant parts (Figure 23).

Carbon densities were found to be at different levels in different parts of the park. Carbon density distributions varied according to biomass distributions. Map based density analysis of carbon storage of the sample taxa was presented in (Figures 24 to 28).

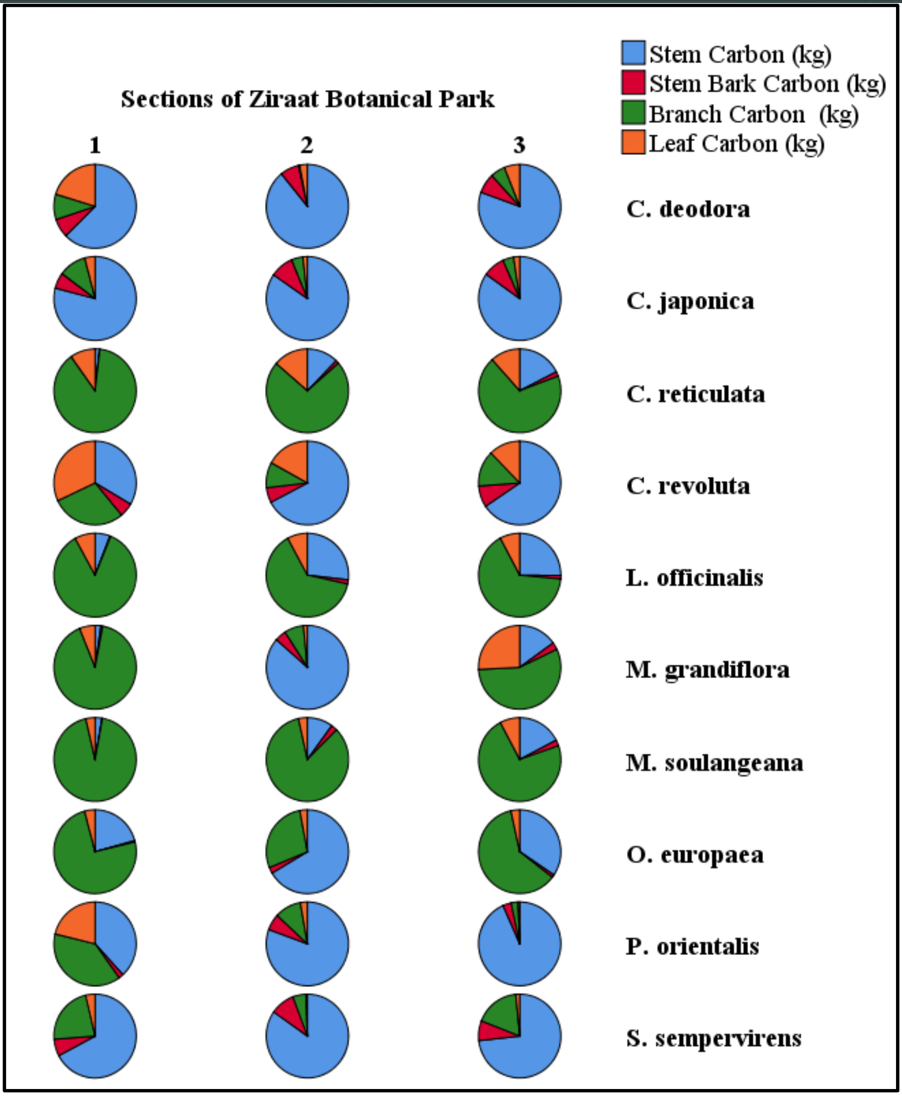

Figure 23. Distribution of Carbon Stored in the Aboveground Biomass of Taxa in Different Parts of the Botanical Park by Plant Parts

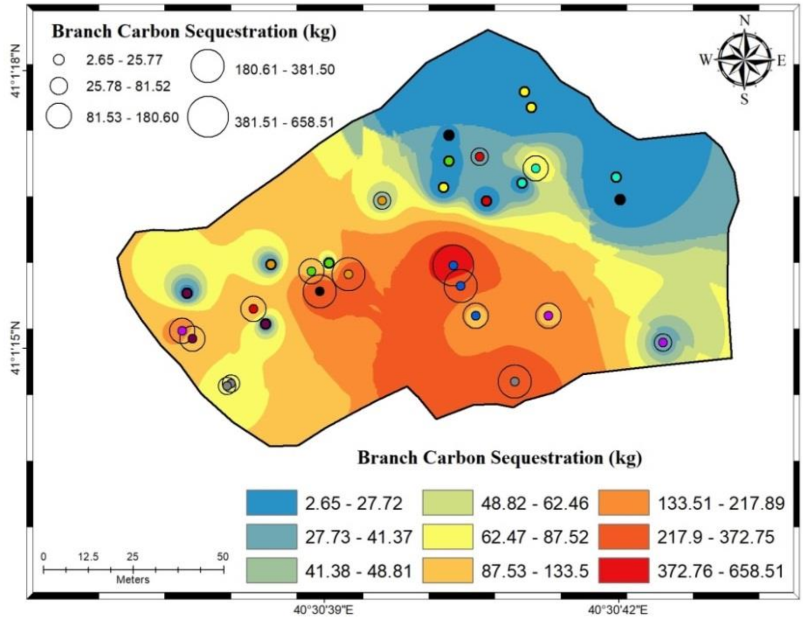

Figure 24. Distribution of Branch Carbon Sequestration of Trees

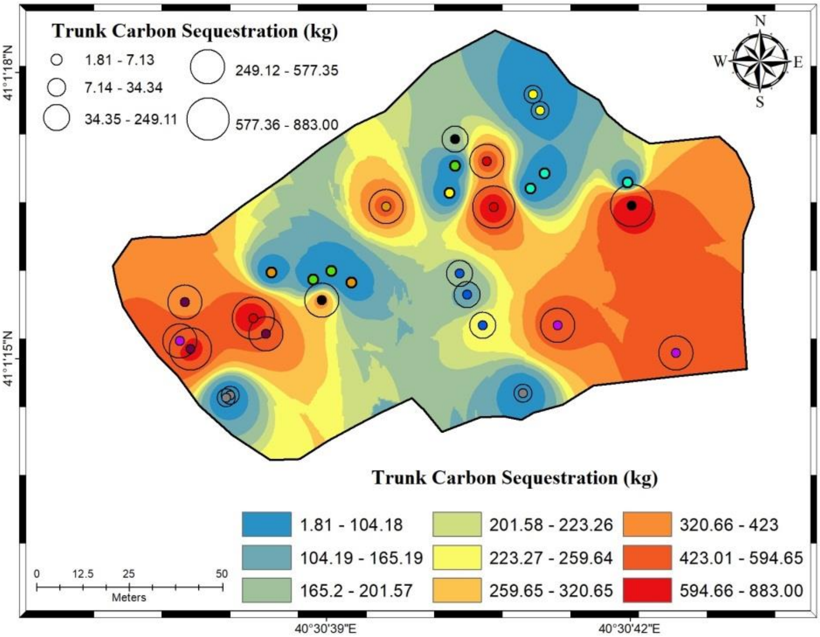

Figure 25. Distribution of Trunk Carbon Sequestration of Trees

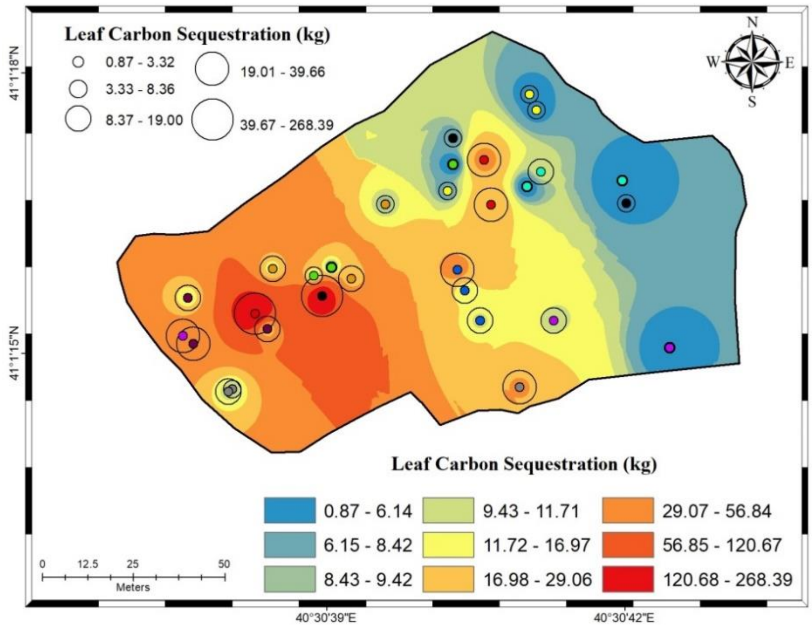

Figure 26. Distribution of Leaf Carbon Sequestration of Trees

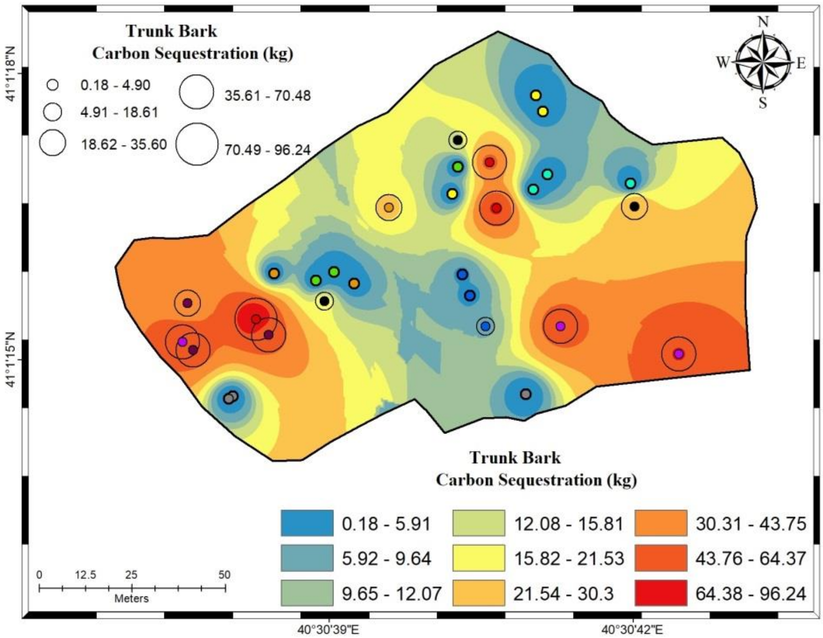

Figure 27. Distribution of Carbon Sequestration Amounts of Trunk Bark of Trees

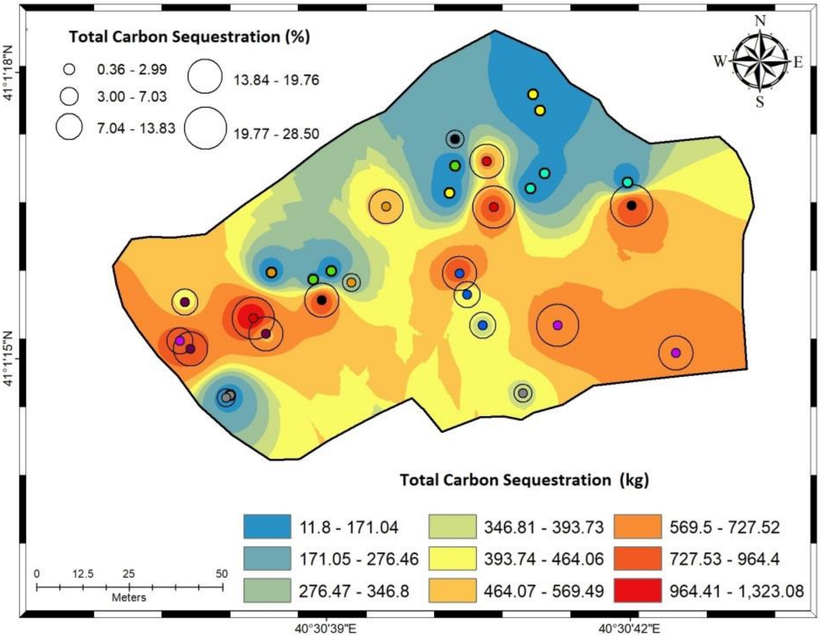

Figure 28. Distribution of Total Carbon Sequestration of Trees

3. Findings and Discussion

Environmental problems caused by global warming continue to increase on a local, national and international scale. In recent years, events occurring as a result of global warming have been encountered more frequently in our country. Increasing the amount of carbon stored in both plants and soil by using plants is the fastest, most effective and economical method that can be used to prevent global warming. Many different properties of plants are taken into consideration in landscape project studies. However, the researches carried out to determine the contribution of plants used in parks and gardens to carbon storage in our country are still at the beginning stage. In his thesis study, Tuğluer (2019) determined that the total biomass amount of 10 taxa in Isparta City Boulevard was 5.11

tons and the total carbon storage amount was 2.4 tons. In the study, it was determined that *Koelreuteria paniculata* Laxm. has the highest carbon storage percentage in broad-leaved taxa and *Pinus pinea* L. has the highest carbon storage percentage in coniferous taxa. Again, in his thesis study, Büyüktürkmen (2021) determined the total biomass of 446 trees identified in Kahramanmaraş Kılavuzlu Park and Recreation Area as 104.8 tons and the total carbon storage capacity as 48.2 tons. *Cupressus sempervirens* var. *horizontalis* (Mill.) Loudon was the taxon with the highest carbon sequestration amount and *M. grandiflora* was the taxon with the lowest carbon sequestration capacity. When the studies are compared; the provinces and the number of taxa sampled are different. It was observed that more carbon was stored in the study with larger area size and higher number of taxa. In Büyüktürkmen (2021) and the study conducted in Rize province, *M. grandiflora* was the common taxon among the sample taxa. In Büyüktürkmen's (2021) study, *M. grandiflora* L. with a stem height of 153 (bottom diameter 14 cm and top diameter 12 cm) cm stored 22.52 kg biomass and 10.23 kg carbon, while in Rize province, stem heights were 180 cm (bottom diameter 15 cm and top diameter 12 cm) in the 3rd section stored 85.13 kg biomass and 38.67 kg carbon. While the stem and bark biomass were found to be similar, the difference was due to the branch and leaf biomass of the plant. This situation is also reflected in the amount of carbon sequestration. In Rize province, when the stem heights were 140 cm in the 1st part, 676.89 kg (5.50%) biomass and 311.04 kg (5.36%) carbon, when they were 410 cm in the 2nd part, 1164.64 kg (15.62%) biomass and 537.76 kg (15.28%) carbon, when they were 180 cm in the 3rd part, 85.13 kg biomass and 38.67 kg (1.17%) carbon were stored. As it is known, changes in growing environment characteristics (climate, soil, etc.) and maintenance operations, especially pruning, have the potential to change the biomass characteristics (stems, branches, bark and leaves, etc.) of taxa. Therefore, in this study, it was revealed that the growing environment characteristics and the biomass characteristics of the taxa were effective in the difference in the amount of carbon storage by taxa. However, it should be noted here that it cannot be said that the effects on carbon storage were taken into consideration when selecting plants in the research area park. When selecting plants in park areas; carbon storage capabilities of the plants to be selected should be taken into consideration as well as other characteristics. Kırteke and Oğuz (2022) found that trees are one of the most economical materials for carbon sequestration in terms of sustainability of urban ecosystems. They also stated that carbon sequestration capacity is an important factor in the selection of trees for urban open green areas. Determining the total carbon storage values of all parks in our country in soil and plants and determining the ecological and economic effects of carbon in urban parks is very important for sustainable urban management.

3.1. Recommendations

The total amount of biomass from 30 trees identified in Ziraat Botanical Park in Rize province was calculated as 26.75 tons and the total carbon storage capacity was calculated as 12.64 tons. When this study and previous studies on this subject were evaluated; it was determined that coniferous taxa have more carbon sequestration capacity than broadleaf taxa. It was determined that pruning in leafy taxa caused a decrease in above-ground biomass. It was observed that this situation both changed the contribution of plant parts to carbon sequestration and reduced carbon sequestration success compared to conifers. As a result of these evaluations, when it is desired to design a green area with a high carbon sequestration capacity, it may be preferable to use plants with a predominance of coniferous taxa suitable for the growing environment. If leafy taxa are preferred, either planting should be designed to require less pruning or pruning methods should be developed to reduce carbon sequestration capacity at an acceptable level.

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Author Contribution and Conflict of Interest Declaration Information

All authors contributed equally to the study.

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Ecological Solutions That Can be Applied to Reduce the Negative Effects of Climate Change in Urban Areas

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1. Introduction

Throughout history, people have survived by settling in areas where the climate is most suitable for living. However, with today's rapid population growth, lifestyles and needs have also changed and increased. This situation has led to increased environmental pollution. Environmental pollution occurs in two ways: natural and human-induced. In natural pollution, nature can clean itself in a short time (U.S. Environmental Protection Agency, 2016). Human-induced environmental pollution occurs especially due to factors such as industrial activities and vehicle exhaust fumes. Such pollutants remain in nature for a long time and harm human health. The changes experienced in the last century have negatively affected living life around the world (Cesur et al., 2021; Koç, 2021). In this process, changes in the climate outside the normal course have occurred on a global scale due to the changes in the structure of the atmosphere. Since these changes are global in scale, they are called "Global Climate Change". As the global climate changes, human well-being, ecosystem function, and even the climate itself are increasingly affected by the changing geography of life (Figure 1) (Pecl et al., 2017).

Figure 1. Global climate change and its effects (Pecl et al., 2017).

The first findings about climate change date back 300 years. Until the 1970s, studies on climate change continued with climate skeptic scientists and came to the agenda at the global level with the 1st World Climate Conference. Although cities cover only 2% of the world's surface, they consume 78% of the world's energy and produce more than 60% of all carbon dioxide (Kahraman & Şenol, 2018).

The world is experiencing rapid urbanization (Grimm et al., 2008), global urbanization is projected to increase to 67.2 per cent by 2050 (United Nations, Department of Economic and Social Affairs & Population Division, 2012). Urbanization has significantly contributed to economic development and improved the quality of life of the population. It also brings with it many environmental challenges such as air pollution, floods and heat waves (Cetin, 2019). Studies have shown that air pollution can kill nearly 1 million people annually in China (Yue et al., 2020), while floods in Southeast Asian cities in 2017 killed more than 1,000 people and destroyed the homes and livelihoods of 45 million residents (Bai et al., 2018) has shown that heat waves can cause heat stress in humans, harming their health (Estoque et al., 2020; Yu et al., 2021). Addressing urban environmental challenges is therefore an urgent issue to achieve urban sustainability.

This study examines the effects and symptoms of climate change in urban areas, initially focusing on the global significance of climate change. Additionally, strategies for coping with climate change are discussed in the context of the model of cities' vulnerability to climate change.

1.1. Climate Change: What Is It?

The climate has changed naturally over the 4.5 billion year history of the earth. However, with the industrial revolution, a new era began in which human-induced factors affected the climate, starting from the mid-19th century (Türkeş et al., 2000). Climate change refers to significant changes in climate measurements over more than the last few decades and long-term changes in the interactions between the atmosphere, oceans, and glaciers around the world. These changes are caused by human activities such as the burning of fossil fuels, deforestation and industrial activities. Climate change can cause many consequences such as temperature increase, drought, floods, sea level rise and imbalances in ecosystems (Kahraman & Şenol, 2018; Yılmaz et al, 2021'a). Changes in climate can alter human health and quality of life by affecting where people live, plant habitats, and the condition of structures and infrastructure (U.S. Environmental Protection Agency, 2016).

1.2. Climate Change: Causes

Climate change can be caused by natural and anthropogenic factors, as well as changes in the composition of the atmosphere and land use. Although there is no apparent change in the climate systems after humanity's transition to a settled system, findings from the past to the present show the opposite (Türkeş, 2008). Throughout human history, the geographical features of the world have changed several times. These changes have caused the disruption of natural balance and major changes in the climate. From the beginning of human history to the present day, there have been periods when glaciers covered the world, and the natural and man-made environment was greatly affected during these periods. It is now known for certain that human activities have had an impact on these changes since the mid-19th century (Demir, 2009; Çevre ve Şehircilik Bakanlığı (ÇŞB), 2017; Yılmaz et al., 2021b). Human-induced activities that cause climate change;

• Deforestation: occurs as a result of the destruction of trees that store carbon in nature. This event contributes to climate change by causing the release of carbon dioxide in the atmosphere.

• Industrial Pollution: Industrial activities accelerate climate change by causing the release of greenhouse gases into the atmosphere.

• Fossil Fuel Use: Greenhouse gases released into the atmosphere as a result of the burning of fossil fuels such as coal, oil and natural gas cause climate change (Çevre ve Şehircilik Bakanlığı (ÇŞB), 2017).

2. Examples of Climate Change in the World

2.1. Global warming

Today, as a result of the increased use of fossil fuels such as coal, oil and natural gas in order to meet the increasing energy need, more greenhouse gases are released into the atmosphere than necessary. As a result, an excessive greenhouse effect occurs in the atmosphere, causing the phenomenon of Global Warming (Türkeş, 2008; Akpınar Külekçi et al., 2022). In Global Warming;

- Extreme heat, drought,
- Excessive rainfall, typhoon, flood,
- Melting of polar ice caps,
- Rising sea levels

It poses a threat to living life by triggering the occurrence of chain natural disasters such as (Atalık, 2006; Ersoy, 2006; Akın, 2007).

2.1.1 Temperature

It shows that the 1983-2012 period in the Northern Hemisphere was the warmest 30-year period of the last 1400 years. It has been warmer than any consecutive decade in 30 years. According to the period 1850-1900, there has been a temperature increase of approximately 0.9°C in the world from the pre-industrial period to the present day, and 0.6°C of this increase occurred after 1950 (IPCC, 2013).

2.1.2. Precipitation

The irregularity in precipitation increases, and the difference between dry and wet periods and dry and wet areas grows. The number, frequency or intensity of heavy rainfall events on land have increased. Since 1950, the number of cold days and nights on a global scale has decreased and the number of hot days and nights has increased. The frequency of heat waves has increased in large parts of Europe, Asia and Australia (IPCC 2013).

2.1.3 Melting of Glaciers

Since the early 1970s, mass loss of glaciers and thermal expansion of the oceans resulting from warming explain approximately 75% of the observed global mean sea level rise (IPCC, 2013). Over the past 20 years, Greenland and Antarctic glaciers have been losing mass, continuing to shrink on a global scale, and Arctic sea ice and Northern Hemisphere spring snow cover have continued to decrease in area (IPCC, 2013).

2.1.4 Sea Level Rise

One of the events caused by Global Warming is the melting of glaciers on earth. Global warming triggers an increase in the temperatures of both the atmosphere and ocean waters, causing glaciers to melt faster than ever before. If the melting of glaciers continues in this way, most of the land

and sea glaciers will melt in a short time and the water levels of the seas and oceans will rise (Atalık, 2006). The global average sea level increased by 19 cm in the period 1901-2010, and this rate is the highest value reached in the last 2 thousand years (URL, 2015).

3. Effects of Climate Change on Rural and Urban Areas

The change process experienced with climate change affects all social, economic, environmental and institutional systems, from the global scale to the rural and urban scale. Determining the degree to which interconnected systems in cities can cope with the effects of climate change and their adaptation capacities is of great importance in terms of their survival today and in the future (Çobanyılmaz & Duman Yüksel 2013). Today, climate change occurring in rural areas is one of the most concretely observable events; Developments such as increasing temperatures, decrease in drinking and irrigation water, and deterioration in soil fertility are coming (Kızmaz, 2021). These negativities cause loss of productivity, especially in the field of agriculture. In addition, these negativities caused by climate change may lead to product shortage, decrease in soil fertility, decrease in income, damage the sectors that provide livelihood in rural areas, lead to poverty and increase the cost of production (Dumrul & Dumrul, 2017).

Another area of impact of climate change has been cities. Another important problem of cities, which have been struggling with the consequences of irregular and rapid urbanization and the problems it has created since the day people settled down, is climate change resulting from global warming. Although rapidly developing industrialization and intense population growth are among the main factors that change the climate in cities by causing an increase in harmful gases in the atmosphere, the most important reason for this situation can be shown as the destruction of natural ecosystems in cities and incorrect land use (Kamer Aksoy & Arslan, 2022).

Recent scientific studies on local and regional climate change have shown that rapid urbanization has a great impact on climate change. The negative effects of urbanization and urban population growth increase the speed of climate change, causing the deterioration of the global climate (Grimm et al., 2008). Espinosa-Paredes et al. (2020) and; According to Liu et al., (2021), the reasons that most cause climate change in urban areas are as follows:

Air pollution: industrial activities and heavy traffic in urban areas cause air pollution problems, accelerating climate change.

Urban Heat Island: Building and asphalt surfaces increase heating in urban areas, causing the urban heat island effect.

Flood Risk: Asphalt and concrete surfaces in urban areas increase the risk of floods by preventing rainwater from being absorbed into the soil.

4. Causes and Consequences of Climate Change Urban Areas

Natural land cover in the world we live in is subject to visible change due to human-induced events and natural events. It is accepted that increasing urbanization has an important role in climate change in the last century, considering its impact on the destruction and change of the natural environment through improper land use (UNFPA, 2007). For this reason, climate change occurs in association with population growth, concretion, greenhouse gas emissions and destruction of natural areas. Researchers emphasize that urbanization leads to changes in local land cover and use, which is an important component affecting local climate parameters (Dale, 1997).

Conducted global climate change studies have accepted urbanization as a factor that generally affects climate change on a local scale through land use and land cover change (Guo-Yu, 2015). While it is observed that the changes observed in the climate are caused by natural areas such as forests and agricultural lands that have been destroyed, on the other hand, the decrease in natural areas due to construction; It can be thought that it occurs as a result of the effects of greenhouse gas emissions resulting from the density of expansion and growth in urban areas (construction caused by industry, transportation, housing and other uses). As a result of these observed changes, it is seen that they cause environmental damage such as loss of biodiversity in urban areas, decrease in water resources and health problems (Moradi & Tamer, 2017).

Urban sustainability has been one of the challenges faced in the last few decades as climate change, anthropogenic activities and increasing urbanization lead to a series of negative environmental consequences such as global warming, air pollution, stratospheric ozone layer depletion, urban heat island (UHI) effect, excessive noise and reduced biodiversity has become one of the major challenges (Cook & Larsen, 2021; Liu et al., 2021). It contributes to the deterioration of human mental, psychological and physical health (Williams et al., 2019). To alleviate these problems, energy efficient buildings, use of renewable energy sources, air and water pollution reduction techniques, urban green spaces, expansion of green infrastructure, etc. Many sustainable approaches, nature-based solutions, practices, methodologies and algorithms have been designed and implemented, including (Shafique et al., 2018). Nature-based solutions include mitigation and adaptation strategies that aim to create and maintain a balance between biotic and abiotic ecosystem components, primarily by increasing biodiversity, expanding green infrastructure, and supporting the sustainability transition of cities by creating a livable built environment (Demuzere et al., 2014; Raji et al., 2015; Susca, 2019).

5. How Can The Impact of Climate Change Occurring in Cities Be Reduced?

Traditionally, technical and engineering approaches have often been used to address urban environmental challenges (Jing et al., 2022; Kim & Kang, 2023). For example, using air conditioning to cope with urban heatwaves (Guo et al., 2022) and building dams to prevent urban floods (Du et al., 2020). In recent years, the role of ecosystem-based approaches (EDA) in addressing urban environmental challenges has been increasingly recognized (Wu, 2014; Chakraborty et al. 2022). In some cases, EDA is a more effective and cost-effective alternative to engineering or technology-based approaches (Keeler et al. 2019; Cura et al. 2022). However, EBAs often provide more than one function and benefit (Raymond et al. 2017). For example, wetlands constructed to reduce urban flooding can also provide recreational areas for residents. However, technology- or engineering-based approaches tend to be monofunctional (Fang & Ma, 2023).

With an ecological approach, open green areas are one of the most important components of the urban structure. Today, rapid urbanization and dense construction cause a decrease in green areas in cities.

Infrastructure systems play an important role in the ecological, economic and physical planning of cities. The type of infrastructure that is important for social sustainability and development is called green infrastructure (Kamer Aksoy & Arslan, 2022; Fang & Ma, 2023). It is stated that climate change due to global warming is irreversible and can only be slowed down to a certain extent by taking precautions. Various scenarios are developed to determine the changes that may occur in this process, and possible changes are determined in advance and measures that can be taken are tried to be determined (Koç, 2021). Ecological solutions implemented in green infrastructures can play an important role in minimizing and eliminating environmental damage caused by changes in the climate. In order to create cities that are more resilient to global climate change, it is of great importance to implement studies and plans that consider ecological balance in order to maintain the balance of the city and ensure its sustainability. It is possible to reduce the negative effects of sudden and unexpected climatic events caused by global climate change in the areas we live in and to make cities more resistant to these effects with Ecological Solutions (Coşkun Hepcan, 2019; Chakraborty et al. 2022; Fang & Ma, 2023).

6. Ecological Solutions

The application of solutions based on sustainable and ecological parameters in urban areas in order to reduce the damages of climate change, which is considered the biggest environmental problem of this time, and to prevent further warming of the world, is called ecological solutions (Kamer Aksoy & Arslan, 2022). It aims to minimize the effects of climate change and increase welfare without harming nature, covering environmentally friendly practices such as ecological solutions, protection of natural resources, sustainable green areas, and green energy production (Coşkun Hepcan, 2019; Fang & Ma, 2023).

Considering this, ecological solutions that support green infrastructures as a solution that will increase the function and quantity of ecosystem solutions can be considered as an urban planning tool to reduce the impact of climate change. The damage to natural areas caused by uncontrolled urban expansion negatively affects the urban area and quality of life. Although the development of ecological solutions began primarily as a conservation approach, it has also been applied in different disciplines. Urban landscape planning helps us combat climate change by enabling the production of various ecosystem services. Innovative urban planning and design tools are needed to reduce the negative effects of climate change on urban environments and quality of life (Kamer Aksoy & Arslan, 2022). Some ecosystem services are local (provision of pollinators), others are regional (flood control or water purification), and still others are global (climate regulation). Ecosystem services affect human well-being and all its components, including basic material needs such as food and shelter, individual health, safety, good social relations, and freedom of choice and action (MEA, 2005). Regulatory ecosystem services of ecosystems (Figure 2) have an important place in reducing the effects of climate change and increasing resilience in cities.

The green infrastructure approach is a tool used to create sustainable urban environments. Open and green areas in the city improve urban health and quality of life by reducing the effects of microclimate, noise, dust and heat. Ecological solutions form the basis of sustainable urban planning with nature-based solutions, and these solutions are an important part of the green infrastructure approach (Yörüklü, 2021).

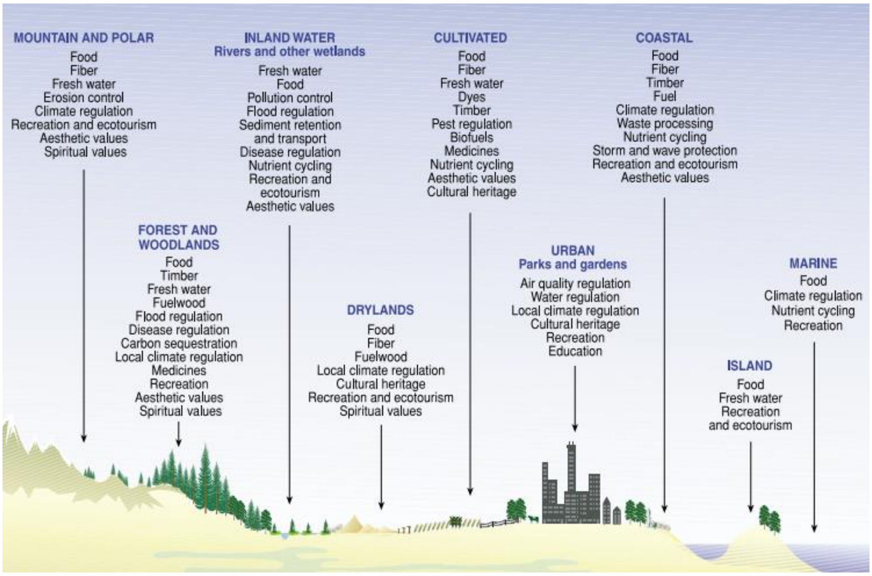

Figure 2. Ecosystem Cross Section (MEA, 2005).

Shading, evapotranspiration, wind speed control, protection from extreme weather events, reducing surface runoff, improving air quality are some of the ways that green infrastructure will help urban climate adaptation (Ortaçeşme & Zeğerek Altunbey, 2022). Examples of ecological solutions that should be implemented to reduce the negative effects of climate change in cities (Yörüklü, 2021) are listed below;

Use of Renewable Energy: The use of renewable energy sources instead of fossil fuels can reduce the effects of climate change.

Preservation of Natural Resources: Preventing deforestation and afforestation efforts can be effective in combating climate change by increasing the absorption of greenhouse gases.

Creation of Eco-Cities: The effects of climate change can be reduced in cities by creating sustainable green infrastructures, green areas, walking and transportation networks.

Waste Management: Ecological balance can be maintained and greenhouse gas emissions can be reduced through recycling, waste separation and reduction efforts.

The idea of EBA for urban sustainability has been developing for nearly 50 years. Different concepts have emerged such as Urban Forestry (UF), Ecosystem Based Adaptation (EBA), Urban Ecosystem Services (UES), Green Infrastructure (GI) and more recently Nature Based Solutions (NBS) (Escobedo et al., 2019). Some concepts, such as "urban forests," primarily enrich academic discussions, while others are intended for the field of policy development (Hanson et al., 2020; Haase, 2021).

It is necessary to expand existing urban green infrastructure such as walls, roofs (or other elevated areas) and open spaces to improve urban green infrastructure and develop a strategic tool to mitigate the negative consequences of urban development and climate change (Ortaçeşme & Zeğerek Altunbey, 2022). Although the total amounts of carbon storage provided by soil and water in urban spaces are small compared to rural areas, urban environments also contain a range of vertical and horizontal artificial surfaces where nature-based solutions can provide additional carbon storage capacity. Nature-based solutions can play an important role in maximizing carbon storage potential under conditions of rapid urbanization (Naturvation, 2020).

Nature-based ecological solutions developed for various problems arising from climate change in urban areas (Naturvation, 2020);

- Green buildings (Green roofs, Green walls/facades, Green balconies etc.),
- Gray infrastructure facilities containing green (Street and alley afforestation, Railway afforestation, Stream corridors, Home gardens, Green parking lots, Green playgrounds and school gardens, Corporate green areas etc.),
- Parks and urban forests (Large urban parks/forests, Neighborhood parks/pocket parks, Botanical gardens, Green corridors etc.),
- Community gardens (Hobby gardens, Community gardens, Urban orchards),
- Blue infrastructure (Lakes/ponds, Streams/canals/etc., Deltas, Coastlines, Wetlands/swamps/, Salt marshes),
- Sustainable rainwater facilities (Rain gardens, Rain ditches and filter strips, Sustainable urban drainage systems, etc.),
- Indoor green areas (Green walls and ceilings, Atriums),
- Classified under the headings of natural landscapes (Urban Nature Atlas, 2021).

7. Conclusion

Climate change specific to cities occurs due to the destruction and reduction of green areas. In order to avoid this climate change and reduce its negative effects, the search for solutions that can be applied in cities has increased. Some of these solutions include protecting natural areas in urban areas and strengthening green infrastructure.

Studies have shown that changing urban climates, especially by lowering temperatures, has extraordinary benefits of green infrastructure for both human well-being and the flora and fauna with which we share cities.

Green spaces and aquatic ecosystems have been shown to be highly effective in cooling and regulating urban climates, increasing the capacity to adapt to climate change. Although the role of green infrastructure in protecting and preserving both flora and fauna in cities is not yet widely understood, it offers opportunities to protect biodiversity and ensure ecosystem health and improvement. Natural and semi-natural areas that make up urban green infrastructure play a crucial role in mitigating the impact of a changing climate on human environments. Considered as the biggest environmental problem of today, green infrastructure systems, which are based on sustainable and ecological elements and increase the quality of ecosystem services, can be considered as an urban planning tool in order to reduce the effects of climate change or prevent the increase of change. In this regard, it is important to protect, maintain and improve existing components of urban green infrastructure, to develop new alternative forms of urban green space such as urban agricultural activities and rain gardens or other green forms of urban stormwater management, or to use non-traditional or abandoned areas. In order to minimize the effects of the climate crisis and plan more livable cities, ecological solutions need to be used more and integrated into urban and regional plans with different contents.

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The article complies with national and international research and publication ethics.

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

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The Importance of Ecosystem Services in Urban Planning for Sustainable Cities

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1. Introduction

Humans have always been intertwined with nature since their existence and have tried to make the best use of nature. This has not been easily achieved in every period. Especially today, rapidly developing concepts such as urbanization and industrialization have begun to destroy green areas (Kart, 2002). The unplanned and/or planned urbanisation efforts and practices together with the increase in population in the cities, as a result of the rapid proliferation of unplanned and wrong horizontal/vertical constructions, adversely affect the urban ecosystem and accordingly the existing urban quality of life (Gezer & Gül, 2009; Gül et al., 2020). While the ecosystem is negatively affected by urbanization activities, urban parks, which have important functions within the urban ecosystem, are known as one of the most important components that can reduce these negative effects (Akkurt & Akten, 2021).

The ecosystem approach encourages the protection and sustainable use of nature, and accepts that natural resources and people with cultural diversity are an integral part of ecosystems. Therefore, it is important to understand the functioning of ecosystems and their services. Ecosystem services are the contributions or benefits that people receive from ecosystems. Studies to evaluate these services have been increasing since the 1970s. The ecosystem services approach provides ecological, social and economic assessments regarding the inclusion of ecological values in the process of nature protection, natural resource management and spatial planning. Today, it is seen that an absolute balance cannot be achieved between the concepts of "environment" and "development" included in spatial plans, nature protection and natural resource management strategies (Bostan & Gül, 2017). It is possible to include ecological processes in spatial plans with the ecosystem services approach. The protection and development of landscapes can be ensured by determining, mapping and including these services in plan decisions.

Ecosystems are a whole in which each component in its content is dependent on and interacts with each other. They are both open systems with their own boundaries. According to Evrendilek (2004), in analyzing this structure; 1) temporal dimension, 2) spatial dimension, 3) structure of the ecosystem, 4) function of the ecosystem, 5) pressures should be evaluated in 5 components [3]. The whole of the situations and events consisting of the movement, transportation and decomposition of energy and matter occurring in the living and non-living areas of the ecosystem into and out of the system constitutes the ecosystem process (Naeem et al 1999).

The physical and chemical processes that emerge from the vital activities (feeding, growth) of plant, animal and microorganism communities are also ecosystem functions. The resources that emerge as a result of this function and process of the ecosystem consist of ecosystem products (food etc.) and services (waste disposal etc.). These resources, which express the benefits obtained directly or indirectly from ecosystem functions, are called "ecosystem services" (Costanza et al 1997; Albayrak, 2012).

Addressing these services in spatial and temporal dimensions, determining the pressures experienced in service receipt are important in terms of service quality. Spatial definition of agricultural areas providing food services and determining the effects / pressures such as urbanization, proximity to water / industry, rainfall status can provide contributions such as access to clean food on a local scale or reducing hunger rates on a global scale (Kaya & Uzun, 2019).

In order to define ecosystem services, the spatial planning system should be integrated with the institutional and legal structure. According to Albayrak (2012), this integration process should primarily be evaluated together with national and sectoral policies and legal regulations. Studies should be conducted to inform planners and decision-makers about ecosystem services and to include them in existing administrative and decision-making structures in line with the information needs and requirements of planners and decision-makers. Planning studies should be conducted at the landscape scale, which is perceived as the most useful and appropriate for land use decisions, especially regarding the quality, diversity, flow rates and distribution of these services (Termorshuizen & Opdam, 2009; Van et al, 2012).

Ecosystem services are defined as the benefits that people obtain from ecosystem functions (de Groot et al, 2002; MA, 2005) or the direct and indirect contributions of ecosystems to human well-being (TEEB, 2010).

The scope of the study is limited to ‘urban ecosystem services’, defined here as those provided by urban ecosystems and their components. Urban ecosystems are ecosystems where built infrastructure covers a large part of the land surface or where people live in high densities (Picket et al., 2001).

They include all ‘green and blue spaces’ in urban areas, including parks, cemeteries, gardens and courtyards, urban allotments, urban forests, wetlands, rivers, lakes and ponds. Definitions of urban areas and their boundaries vary between countries and regions, depending on the type of land use, total population, population density, distance between dwellings and percentage of non-primary sector employment. Given that many ecological flows and interactions extend well beyond urban boundaries defined for political or biophysical reasons, urban ecosystems are defined here in a broader sense, encompassing hinterland, urban catchments, peri-urban forests and croplands that are directly governed or affected by energy and material flows from the city centre and suburban landscapes (Baggethun & Barton, 2013).

The emphasis of this study is to examine the management policies that need to be addressed for sustainable cities in terms of the discipline of landscape architecture. In this context, the conceptual understanding of ecosystem services and their classes is presented within the framework of national / international literature and the spatial planning process, the relationship between landscape planning and ecosystem services, spatial plans and the integration of landscape plans with ecosystem services are emphasized.

1.1. The concept of sustainability and sustainable cities

According to Karaman (1996), the concept of sustainability is based on continuity. While continuation is the spontaneous continuation of an event, sustainment means that the continuation is done by someone else. Anything sustainable means continuous. The resources of sustainable structures should be evaluated and these resources should be protected. The concept of sustainability is defined as the ability of a society, an ecosystem or any structure with continuity to continue its work without interruption, without deterioration and without destroying the main resources (Kaypak, 2012). Van Geenhusian & Nijkamp (1994) define sustainable cities as cities that find solutions and adapt to environmental problems by taking socio-economic interests into account (Altuntaş, 2012). There is no clear, agreed upon definition of the terms sustainable city and sustainable human settlements. Various sources say that it is a part of environmental, economic, social, political, demographic, institutional and cultural goals (Satterthwaite, 1997). According to (UNESCO-MOST, 1996), sustainability is the long-term continuity of socially shaped relationships between society and nature (Çahantimur & Yıldız, 2008). Sustainability is a socio-cultural concept that foresees development and has a vision of the future, rather than just an ecological or environmental concept. It includes many issues from the balanced establishment of all kinds of living environments to communication and participation (Ciravoğlu, 2006). Sustainable cities are well-planned, environmentally sensitive environments that provide equal opportunities and facilities for everyone, offer a high quality of life, and meet people's needs. The characteristics that communities in these environments should have are given in Table 1.

Table 1. Characteristics of sustainable communities

Activity, Inclusion, Security	Good Governance
Good Transportation	Good Service
Environmental Awareness	Good Development
Good Design and Construction	Equality for All

Sustainable cities should consider economic, social and environmental factors in relation to each other, and urban development policies should provide cooperation between larger urban and rural areas in the context of healthy cities, ecological cities and bioregions.

The reason why the sustainability perspective focuses on cities is that especially large cities consume natural resources and cause pollution and waste to increase (Yazar, 2006).

According to Ertürk (1996), sustainable urbanization is cities that address human needs in today's conditions and provide development in a way that will meet the needs of future generations, while according to Geenhuisan & Nijkamp (1998), it is a city where socio-economic development is compatible with the environment and energy in order to ensure change in continuity (Tosun, 2009). As can be seen in Table 2, the main principles of sustainable cities are the continuity of development in the draft of the principles of strong economy, clean environment, social equality and participation (Bayram, 2001).

Table 2. Development Principles of Sustainable Cities

PRINCIPLES	LESS SUSTAINABLE LIVING	MORE SUSTAINABLE LIVING
STRONG ECONOMY	Competition, tax regulations, public investments, employment of large industries, continuity of certain business areas, change of penalties and regulations	Strategy collaboration, development of workforce skills, knowledge base, creation of attractive environments
CLEAN ENVIRONMENT	Use of "too many" resources, maximum and best use, separation of uses, spatial dispersion	Conservation of resources and prevention of pollution, mixed use; creation of parks and conservation areas compatible with the transportation system, high density
SOCIAL EQUALITY	Increasing disparity between income groups and races, specialized services, individual customers	Strategic investments in the workforce, creation of opportunities for public and private engagement, and integrated services for families and communities
PARTICIPATION	Minimal community participation, centralized management	Encouraging community participation, local autonomy, cooperation between different jurisdictions

According to another approach, sustainable urban development is evaluated in three classifications. These are;

1. Environmental principles; Instead of eliminating the negative effects on environmental elements resulting from urban activities, priority should be given to protection. It is necessary to minimize waste, increase recycling, reduce unnecessary use of resources, and the use of renewable and recyclable resources and the protection of biodiversity are also important.

2. Social and economic principles; Technologies aimed at protecting environmental elements should be used in the projects developed. Public participation in environmental policies should be ensured in terms of social acceptability.

3. Management principles; Being flexible in the formation of environmental policies, harmonizing different theories related to the environment and creating strategies that will be effective in the long term can be counted among these principles (Bayram, 2001).

In line with the above information, we can list the planning and design principles of sustainable cities as follows (Sınmaz, 2013):

- Ensuring long-term economic and social security
- Protection and restoration of biodiversity and natural ecosystems
- Determining the cultural identity of cities
- Empowering people in the sustainable development process
- Establishing cooperation towards a sustainable future
- Developing sustainable production and consumption in line with the use of environmentally friendly technologies and efficient demand management.
- Transparent management

1.1. Ecosystem Services

The scientific history of the concept of ecosystem services dates back to the 1970s; however, the use of the concept in the literature gained momentum in the 1990s (De Groot et al., 2010). The concept of "Ecosystem Services" was first defined by Daily (1997) as "the conditions and processes that natural ecosystems and species perform for the sustainability of human life". Costanza et al. (1997) stated that the benefits provided by ecological functions; De Groot et al. (2010) stated that the benefits provided by both processes and functions; and Boyd & Banzhaf (2007) stated that ecosystem services are only directly utilized products. The concept became more widespread with the United Nations Millennium Ecosystem Assessment (MEA) report published in 2005. While ecosystem services were described as natural capital in the report, it was emphasized that the capacity of natural capital to support future generations with human activities was decreasing. The second most important international study following the MEA report is the research titled “The Economics of Ecosystem and Biodiversity (TEEB)”, which emerged with the initiative of the UN Environment Program. One of the aims of the research, which emphasized biodiversity, economics and interdisciplinary studies, was to “emphasize the increasing costs of biodiversity loss with ecosystem degradation” (Demiroğlu & Karadağ, 2015).

Within the framework of the previously stated definitions, ecosystem services can be defined as the benefits provided to people from ecosystem functions or the direct and indirect contributions of ecosystems to human well-being (Çoban & Yücel, 2018). In the MEA report, ecosystem services were evaluated by classifying them in 4 main ecological function groups and 30 categories, namely resource-providing services, regulating services, cultural services and supporting services. In the TEEB report, ecosystem services classification was evaluated by classifying them in 4 main ecological function groups and 22 categories, namely resource-providing services, regulating services, culture and comfort services and habitat services (Table 3).

Table 3. Ecosystem Service Classification: MEA and TEEB classification (MEA, 2015; TEEB, 2015)

	RESOURCING SERVICES (MEA)		**RESOURCING SERVICES (TEEB)**
1	Food	1	Food
2	Biological raw material	2	Raw Materials
3	Decorative resources	3	Ornamental resources
4	Genetic resources	4	Genetic resources
5	Fresh water	5	Water
6	Biochemicals and medical products	6	Medical resources
REGULATING SERVICES		**REGULATORY SERVICES**	
7	Air quality regulation	7	Air purification
8	Climate regulation	8	Climate regulation (including C-sequestration)
9	Water flow control	9	Regulation of water flow
10	Erosion control	10	Erosion prevention
11	Water treatment and waste control	11	Waste treatment (especially water treatment)
12	Epidemic disease control	12	Biological control
13	Pest control	13	Preventing or mitigating disruptions
14	Pollination	14	Pollination
15	Natural risk reduction	15	Continuity of soil fertility
CULTURAL SERVICES		**CULTURE AND COMFORT SERVICES**	
16	Recreation and ecotourism	16	Recreation and tourism
17	Spiritual and ethical values	17	Spiritual Experience
18	Social Relations	18	Information for cognitive processing
19	Information system		
20	Educational value		
21	Sense of place and space	19	Aesthetic information
22	Aesthetic values	20	Inspiration for culture, art and design
23	Inspiration		
24	Cultural heritage value		
25	Cultural diversity		
SUPPORTING SERVICES		**HABITAT SERVICES**	
26	Nutrient cycling	21	Continuity of the life cycle
27	The water cycle	22	Gene pool protection
28	Photosynthesis		
29	Soil formation		
30	Primary production		

When Table 1 is examined, the ecological function group that MEA specified as “Cultural Services” is named as “Culture and Comfort Services” in the TEEB classification. The “Spiritual and ethical values” and “Social relations” categories in the MEA classification correspond to the “Spiritual experience” category in the TEEB classification. While there are two different categories under the names of “Information system” and “Educational value” in the MEA classification; these categories are classified as “Information for cognitive processing” in the TEEB classification. While there are three different categories under the names of “Inspiration”, “Cultural heritage value” and “Cultural diversity” in the MEA classification, TEEB presented a single category for these categories under the name of “Inspiration for culture, art and design”.

The ecological function group that MEA specified as “Supporting Services” is named as “Habitat Services” in the TEEB classification. In addition, the categories of “Nutrient cycle”, “Water cycle”, “Photosynthesis”, “Soil formation” and “Primary production” in the MEA-Supporting Services ecological function group are given as the category of “Continuity of life cycle” in the TEEB-Habitat Services ecological function group. In addition, the category of “Gene pool protection” is also included in the TEEB classification.

2. The Role of Ecosystem Services in Urban Planning

Ecosystem services are related to the studies that aim to increase the quality of life between people and ecosystems. People consume the resources that ecosystems provide, and the decrease in these resources threatens economic development. Giving importance to the ecosystem also means giving importance to soil, animals, people, nature and other living things. While ensuring the balanced use and protection of ecosystem resources and meeting basic needs efficiently, it aims to provide these needs from nature correctly, to establish a relationship between nature and people and to prevent nature from being harmed in this process. A balance must be achieved while meeting the needs. If this balance is not achieved, problems such as pollution, energy waste, extinction of species and disruption of the natural balance will be encountered (Kaya, 2019).

For this reason, natural sciences and social sciences have begun to be on the same side with the principles of sustainable development. Ecosystem services are, in short, products that provide direct and indirect benefits to people while ensuring the sustainability of natural and cultural ecosystems and protecting natural resources (Kaya, 2019).

Today, more than 50% of the world's population lives in cities, and it is estimated that this rate will reach 70% by 2050 (Anna et al, 2016). Urbanization negatively affects natural resources because it changes people's land use, transportation, industrial and agricultural production, consumption and social activity patterns. The scattered development of today's cities and their spread over large areas have negatively affected natural habitats. For example; Thailand has lost 96% of its wetlands, Australia 95%, and the USA 53%. Reducing the environmental impacts of urban development is only possible with an ecological planning approach (Mansuroğlu et al., 2012).

According to Seto et al. (2011), five important trends affecting biodiversity and ecosystem services in the global urbanization process can be summarized as follows:

1. *The rate of increase in urban construction areas is higher than the rate of increase in urban population.*

   In the global context, urban construction areas are growing twice as fast as the population (Seto et al., 2011). This means that the growth rate of areas covered with impermeable gray infrastructure is faster than the population growth rate. In the context of urban morphology, the urban periphery, where agricultural, forest and pasture lands are concentrated, is the area where the ecosystem services of the city are intensively provided. The main source of income of those living in the urban periphery and rural areas is agriculture and animal husbandry. The physical expansion of cities also threatens the production in these areas. Therefore, the lifestyle, cultural and production activities of those living in these areas are negatively affected.

2. *Urban areas change local and regional climate.*

   Land use changes in the city and its surroundings have a significant effect on temperature and precipitation (Seto & Stephard, 2009). Transformation of natural surface into a hard surface, heat storage in walls, anthropogenic heat, air pollution and three-dimensional urban geometry cause an increase in the urban heat island effect. Intensive urban activities such as heating, transportation and industry (anthropogenic activities) cause an increase in temperature in urban areas. Intensive human activities in urban areas are paralleled by high aerosol production, pollution and carbon dioxide concentration. Aerosols have a cooling and heating effect depending on their type. Urbanization also affects precipitation variability, which is called the "urban precipitation effect".

3. *Urbanization increases the demand for the use of natural resources.*

   The expansion of urban construction areas will lead to an increase in the consumption of resources such as water, energy, and timber. At the same time, habitat, biodiversity, and ecosystem services will be directly and indirectly affected, especially agricultural lands, with a knock-on effect.

4. *Urban expansion threatens areas important for biodiversity.*

   As cities expand rapidly, they also threaten areas important for biodiversity. It is predicted that urban areas will destroy 1.8% of hotspots important for biodiversity by 2030. This destruction is expected to occur in developing countries, especially China.

5. *Urbanization affects the (green) economy*.

   In the future, urbanization is expected to occur mostly in developing economies; these countries give less importance to the improvement and protection of biodiversity and ecosystem services. In these areas, international capital, especially multinational corporations, international real estate companies and private real estate actors shape local development.

In terms of the healthy progress of the ecological process, the ecological, economic and social contributions of open green areas should be evaluated and studies should be carried out in this direction to ensure continuity. According to Bulut et al. (2014), the impact of urban open green areas is quite significant in the formation of sustainable cities provided by ecosystem services in terms of minimizing the destruction of the natural environment.

Many policies have been developed within the scope of sustainable urbanization. According to Bongardt et al. (2002), disproportionate use of natural resources will inevitably lead to problems such as infrastructure problems, health problems and economic inequalities (Kaya, 2019).

While the pressures experienced in urban areas cause the concept of urban society to be separated from ecosystems; demands for natural capital and ecosystem services are increasing in our urbanized planet. Urban ecosystems are structural infrastructures and/or areas where people live densely, covering a large proportion of the area. Urban ecosystems consist of inner regions that are directly affected or managed by the energy and material flow in the city center and suburban areas (Baggethun & Barton, 2013). In this context, the concept of urban ecosystem services was first used by Bolund and Hunhammar (1999). The concept was defined as “the values and benefits provided to the city dwellers by the inner ecosystems located within a city” (Demiroğlu & Karadağ, 2015). Baggethun & Barton (2013) examined and classified the important ecosystem services in urban areas and the ecosystem functions and components that form the basis of these services in 11 groups (Table 4).

Table 4. Classification of important ecosystem services in urban areas and their underlying ecosystem functions and components (Baggethun & Barton, 2013).

	Ecosystem services	Functions and components	Examples	Examples of components
1	Food supply	Energy conversion in edible plants via photosynthesis	Vegetables produced in urban plots and peri-urban areas	Food production (tons/year)
2	Regulating water flow and mitigating surface runoff	Filtration of water and regulation of river discharge and surface runoff	Soil and vegetation infiltrate water during heavy and/or prolonged rainfall	Soil infiltration capacity; % impermeability depending on permeable surface
3	Regulating city temperature	Photosynthesis, shading and evapotranspiration	Trees and other urban vegetation provide shade and block moisture and wind.	Leaf Area Index; Tree cover m2 of the area covered with trees. (C)
4	Noise reduction	Absorption of sound waves by vegetation and water	Absorption of sound waves by vegetation barriers - especially thick vegetation	Leaf area (m2) and distance to road (m); Noise reduction dB (A) / plant unit (m)
5	Purifying the air	Filtering and binding detection of gases and particulate matter	Binding and removing pollutants through the stems, roots and leaves of urban vegetation.	Removal-destruction of O3, SO2, NO2, CO, and PM10 (ton year-1) is multiplied by the tree cover area (m2)
6	Healing environmental extremes	Absorption of kinetic energy and physical barrier	Storm, flood, and wave buffering with vegetation barriers; Heat absorption during severe heat waves	Cover density of vegetation barriers in areas built separately from the sea
7	Waste treatment	Deterioration or removal of Xenic nutrients	Waste filtering and nutrient binding by urban wetlands	Mg, kg-1 P, K, Mg and Ca according to given soil/water quality standards

8	Climate regulation	Carbon sequestration and binding in photosynthesis	Carbon capture and storage by biomass of urban shrubs and trees	Carbon sequestration by trees (….)
9	Pollination and seed dispersal	Movement of flower gametes by biota	Urban ecosystems provide habitat for birds, insects, and pollinators.	Species diversity and abundance of birds and bumblebees
10	Recreational and mental development	Ecosystems and recreational and educational values	Urban parks provide multiple opportunities for recreation, meditation, and pedagogy.	Surface area of public green areas (ha) / urban dweller
11	Animal Watching	Providing habitat for animal species	Urban green spaces provide habitat for birds and other animals that people enjoy watching.	Abundance c birds, butterflie and other animal valued for the aesthetic qualities

In urban areas; green and blue areas including parks, cemeteries, gardens, urban parcels, urban forests, wetlands, rivers, lakes and ponds provide ecosystem services. The ecosystem services, functions and components in urban areas given in Table 2 are a summary of the ecological evaluation of ecosystem services. Urban ecosystem services are important from an ecological perspective as well as from an economic, social and cultural perspective. The loss of ecosystem services in urban areas also brings economic costs. For example; the loss of urban vegetation increases the energy costs in cooling in summer months (Baggethun & Barton, 2013).

3. Conclusion and Suggestions

The ecological problems that occur today are numerous, and they bring with them major problems such as population growth, urbanization, agricultural activities, food demand, energy and environmental pollution. McHarg, a landscape architect and planner, stated that cities that are shaped and developed in line with economic-focused decisions are kept away from natural sciences (Mcharg, 1969; Çetinkaya & Uzun, 2014). Odum, on the other hand, stated that ecologically based decisions are fundamental in eliminating the conflict between humanity and nature (Evrendilek, 2004). The concepts of landscape and ecosystem, which are in the working stages of ecology, can be addressed in the planning process in solving these problems. Both concepts have a dynamic structure that changes according to time and space.

Social change is inevitable for all societies in the world. Differences between countries, their competition and struggles, religious and ethnic characteristics can be counted among the important factors of this change. As a result of people, especially Western societies dominated by Calvinist thought within a liberal economic order, turning the world into a large industrial complex for the sake of prosperity and development; it has led to practices that have led to fundamental problems that constitute the cause of ecological deterioration in many parts of the world today (Gökdayı, 1996). Nowadays, local governments and academic studies have started to give importance to sustainable and smart cities. It is important to understand sustainable and smart cities in order to ensure the sustainability of ecosystem services.

Sustainable use of natural resources depends on the healthy progress of ecosystem processes, and in this context, certain planning studies should be carried out, legal regulations should be included, the value of nature should be understood and its protection should be ensured from the lowest scale to the highest scale (Kaya, 2019). In cities; climate components including changes in air temperature, wind and humidity differ from rural areas. Urban parks are also of great importance in preventing the situation defined as urban heat island, which increases the temperature values in the city center with long-term heat storage of large non-reflective surfaces. The urban heat island effect can be prevented with appropriate planting solutions designed in urban parks. At the same time, urban green space systems with strong connections provide habitat for many flora and fauna that would normally disappear in the city (Atanur & Ersöz, 2020). For urban open-green spaces to effectively serve the city ecosystem and its residents, the goal should be to achieve an equitable spatial distribution throughout the entire city. The organization of green spaces should be perceived as a public investment for equal social life and should align with a long-term vision for a green city.

This is crucial for the city to provide a sustainable, equitable, and accessible environment. Those involved in urban planning, including managers, policymakers, decision-makers, planners, and designers, should work towards developing the urban open-green space system in a way that benefits society, especially as they prepare for a resilient future in the face of challenges such as climate change, natural disasters, and pandemics (Gül, Dinç & Aydemir, 2024).

Some results and suggestions regarding the relationship between the ecosystem services approach and the planning process in solving the negativities experienced as a result of pressures on ecosystems (human activities, natural disasters, climate change, etc.) and ensuring the sustainability of natural resources are given below (Kaya & Uzun, 2019):

- It is important to make joint decisions among some institutions at a sub-scale in landscape plans and to include these decisions in investment programs. A tool should be created to facilitate the development of suggestions based on ecosystem services methodology for municipalities and other institutions and the inclusion of these suggestions in spatial planning processes. In this process, cooperation between planning experts and public institutions is required.
- The ecosystem services approach should be included in the spatial strategy plans, environmental order and zoning plans stages along with landscape planning.
- Determination, evaluation and use of ecosystem services is a new tool for spatial planning. It offers the opportunity to evaluate the landscape by dividing it into units at sub-scales. It can be used to collect information about the planning area and its values, and facilitates decision-making about the benefits and disadvantages of planning scenarios.
- Ecosystem services are part of natural resource management that must be managed at appropriate levels.
- Biophysical assessment of ecosystem services is fundamental information in nature conservation or land use planning processes. It

allows the assessment of ecological components, especially in urban planning.

- Evaluation of ecosystem services provides the opportunity to evaluate the advantages and disadvantages of the intended development direction from both environmental and social and economic perspectives. Therefore, evaluations that will be made together with landscape planning that allows evaluations that include natural and cultural processes will ensure sustainability in natural resource management, protection of biodiversity and increase the level of human welfare.
- Ecosystem services and economic activity are closely linked and changes in one affect the other. Planning studies based on these services will enable sectoral assessments and contribute to development processes.
- Spatial determination of ecosystem services and service providing areas is important for the sustainability of ecological connections (spot-corridor-matrix) and ecosystem health. In this context, studies and trainings on ecosystem services should be focused on the sustainable use of natural resources in public institutions (Landscape Protection Branch, Plant Health Services, Fisheries and Aquaculture, Basin Management, etc.) and academia (Landscape Architecture, Urban and Regional Planning, Agricultural Engineering, Environmental Engineering, etc.).

It is possible to evaluate the services of ecosystem services such as development of green infrastructure (spot-corridor-matrix), increase of carbon storage capacities (spot-corridor-matrix), efficient use of rainwater (spot-corridor-matrix) at a higher scale with landscape function analyses. Studies can be carried out at a lower scale in order to increase and support the quality of these services, in determining the areas to be afforested, plant species to be used, and landscape repair decisions against disasters such as erosion, floods, etc. For example, in a city with low air quality, strengthening the green infrastructure and making decisions regarding landscape sensitivity in land use decisions can guide the improvement of air quality at a higher scale. Afforestation decisions can be made in areas determined at a higher scale with natural plant species that support air quality regulation specific to that city. As a result, sustainable cities have an important understanding in creating ecologically livable spaces that guarantee the well-being of human life. In this context, it is thought that spatial plans will make significant contributions to the planning and implementation processes by addressing the problems encountered in the sustainability of ecosystems, the protection of biodiversity, the increase of human welfare and economic development in the protection-use balance with the ecosystem services approach, the importance of which is understood at the international level, and by adding ecological processes to the planning approach.

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There is no conflict of interest.

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