NEW TRENDS IN LANDSCAPE RESEARCH-2025

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GREEN ROOF / ROOF GARDEN, LIVING WALLS / VERTICAL GARDENS , NATURE-BASED SOLUTIONS, BIOPHILIC DESIGN,

ACTIVE MOBILITY , POLLINATOR-FRIENDLY CORRIDORS, BIOMATERIALS, SPONGE CITY CONCEPT, LOW-CARBON MOBILITY

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PREFACE

Dear readers,

The strong connection between landscape, environment, and quality of life is at the center of scientific research today. With the goals of sustainable cities, healthy living spaces, and ecological integrity, landscape architecture intersects with many disciplines, including agriculture, environmental sciences, urban planning, health, biology, and ecology. In recent years, these multidimensional relationships have enabled an increase in interdisciplinary approaches and new directions in landscape research.

In this context, the discipline of landscape architecture is increasingly taking on a strategic role in producing solutions to environmental problems. Work in areas such as nature-based solutions, ecological planning, climate adaptation, green infrastructure systems, and sustainable land use has gained significant momentum both in academia and in practice. These developments bring with them a new scientific orientation that focuses not only on design aesthetics but also on environmental responsibility and social benefit.

Landscape architecture is not merely an aesthetic design discipline but a comprehensive scientific field that aims to protect natural and cultural resources, improve quality of life, and enhance environmental awareness. The compilation and research articles in this book bring together disciplines such as Horticulture, Agricultural Economics, Field Crops, Soil Science, Aquaculture, Biotechnology, Ecology, and Urban and Regional Planning, among others, that contribute to this field, with the aim of evaluating the nature-culture-human interaction within a holistic framework.

Our greatest hope is that this book, titled **"New Trends in Landscape Research – 2025**" will contribute to academic knowledge, serve as a source of inspiration for new research, and shed light on approaches related to sustainable landscape planning in particular. We sincerely thank all the academics and research students who contributed to our book with their valuable work, as well as Liberty Publishing House for their support at every stage of the process.

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Environmental Management Project Examples with Sustainable Solutions Approach in Protecting Natural Resources

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1. INTRODUCTION

Our world is experiencing a period in which natural resources are limited and human activities are increasingly putting pressure on the environment. Resources such as water, soil, air, sunlight and minerals are the basic elements that support the economic and social development of humanity. However, excessive consumption of these resources also brings with it problems such as climate change, biodiversity loss and environmental degradation (Yilmaz et al., 2021a; Jie et al., 2023). Therefore, the protection and sustainable management of natural resources has become one of the most important issues of our time. The concept of sustainability is related not only to environmental problems but also to economic and social justice. Effective management of natural resources provides a basis for meeting the needs of future generations and contributes to improving the quality of human life. In this context, the management of natural resources plays a critical role for the well-being of societies (Başol et al., 2005; Güven et al., 2019).

The aim of this study is to analyze the classification of natural resources, the importance of their protection and their role in the context of sustainable development. The management of natural resources was examined in terms of economic, social and environmental dimensions, and how it could contribute to achieving sustainable development goals was examined. In this context, the classification of natural resources as organic and inorganic, the differences between renewable and non-renewable resources, and the strategies required for the protection and management of these resources were emphasized. Within the scope of the study, environmental management projects were evaluated with a sustainable solutions approach in the protection of natural resources. In this context, the applicability of systems in Türkiye and in the world and the policies required for the dissemination of these systems were examined.

1. NATURAL RESOURCES

Natural resources are classified as living natural resources, which are defined as biodiversity and consist of plants, animals and microorganisms; living environments consisting of air, water and soil, which biodiversity depends on, and inanimate natural resources, which also include minerals and fossil fuels (Çelik, 2020; Sun, 2022).

Natural resources are vital for human life and economic activities, are found in nature and can be used in various ways (Güven and Demirci, 2019).

2.1. Classification of Natural Resources

Natural resources are examined under two headings, organic and inorganic, according to their origin;

Organic natural resources:

Carbon-based, generally formed by biological processes, obtained from the remains of living or once-living organisms, and their production. Biodiversity, vegetation, animal and plant products are organic natural resources.

Inorganic natural resources:

A natural resource form consisting of metals and minerals that are frequently used in industries and industrial areas that are not carbon-based and are formed spontaneously. Water, soil, minerals, sun, wind are the main inorganic natural resources.

Natural resources are examined under two subheadings as renewable and non-renewable resources in terms of continuity;

Renewable natural resources:

A type of resource that does not take long to form or renew itself, repeats itself thanks to natural cycles in nature, and can be used in the long term with correct and effective management. Examples include sun, wind, water cycle, biomass and forests.

Non-renewable natural resources:

A type of natural resource that is formed as a result of long periods and is very difficult or impossible to repeat, and must be managed correctly for effective use. The usage limit is important for both environmental health and the sustainability of the resource. Fossil fuels, minerals, nuclear energy can be given as examples (Başol et al., 2005; Güven et al., 2019).

1.2.The Importance of Protecting Natural Resources

With the increasing pressure on the environment, the healthy continuation of the ecosystem has been threatened; rapidly increasing production and consumption have accelerated the pollution of air, water and soil, natural resources have begun to deteriorate and deplete, many plant and animal species have become extinct, the self-renewal feature of nature and the power of the environment have been damaged (Karaca, 2019; Yilmaz et al., 2021).

Economic and social development can only be achieved without compromising the quality of life of human beings with a sustainable environmental policy. Sustainable development that will protect the natural environment should, first of all, protect resources and enable the use of future generations. Today, it is known that production and consumption that harm the environment trigger a deviation from this balance. What needs to be done is to carry out production and consumption with fewer resources and to cause less damage to the environment (Karaca, 2019).

Natural resources are limited in the world. They have no alternative and their quantities cannot be increased by any means. Except for a few minerals, current science and technology have not discovered alternative substances to be used instead of natural resources (Başol et al., 2005). The system that provides order and balance between humans and all other living worlds and nature is called an ecosystem. Every change in the ecosystem directly affects living things (Pirli et al, 2023). For this reason, the basis of the ecosystem is natural resources. Economic and social sustainability lies at the basis of natural and balanced growth. Industrialization, rapid population growth and excessive consumption cause natural depletion and accumulation of ecosystems. The system that provides order and balance between humans and all other living worlds and nature is called an ecosystem. Every change in the ecosystem directly affects living things. For this reason, the basis of the ecosystem is natural resources. In this process, uncontrolled use of climate leads to the concentration of ecosystems, climate conditions, biological expansion and many other climate problems (Uçar, 2021). Natural resources remain only the basis of economic production, but also contain basic elements such as energy, water, soil and air that are necessary for people to live. At the same time, their protection is not only the right of today but also the right of the future. The concept of "sustainable development" is based on this perspective; In other words, while meeting our current needs, we must ensure that generations can meet their own needs. Therefore, preserving this growth is not only a necessity, but also a social responsibility.

The depletion or pollution of natural resources can lead to serious economic crises in the future. Therefore, strategies such as the effective use of natural resources, reducing waste and starting more products with replaceable energy consumption are of great importance for economic growth and development. These are only possible with the right management and development plans (Başol et al., 2005; Yeni, 2014; Holden et al., 2016; Semtrio, 2024).

2. SUSTAINABILITY AND SUSTAINABLE DEVELOPMENT

The issue of sustainability is at the very center of the triangle of energy, economy and environment, and therefore is discussed in a wide range of areas, from governments and intergovernmental organizations to social scientists, natural scientists, politicians and local and international environmental organizations. Due to the multidimensional structure of the concept of sustainability, different branches of science working on this subject have developed different approaches and different definitions (Yeni, 2014). The term sustainable development was first defined in the Brundtland Report. Accordingly, sustainable development is: "Development that meets the needs of today without compromising the ability of future generations to meet their needs (Semtrio, 2024). The Brundtland Report evaluated sustainable development in terms of its economic, environmental and social dimensions. Thus, it demonstrated with a holistic approach that economic values alone are not sufficient for development.

Sustainable development is a normative value system on the same level as human rights, democracy and freedom, and is closely linked to all these systems (Yazici & Gülgün, 2019). Therefore, sustainable development is essentially a strong moral declaration about what should be done. We call such a declaration a moral imperative (Holden et al., 2016). Sustainable development means acting in a way that secures the development of today and the future. This is only possible without depleting natural resources and without harming the ability of future generations to meet their needs. Sustainable development is evaluated within the scope of the connection between economic development and social and environmental values. In other words, it can be argued that economic development is incomplete and unsustainable when social and environmental development is not achieved. (Basol et al., 2005; Holden et al., 2016).

It is claimed that the concept of sustainable development is based on three moral imperatives: meeting basic human needs, ensuring social equality and respecting environmental limits. The constraints define the 'sustainable development area' (Holden et al., 2016). It is also argued that these three moral imperatives impose constraints on human behavior. Therefore, there is agreement with Rawls (1999) that the priority of following moral imperatives is to determine the constraints that individuals must comply with before deliberating their own preferences. As a result, sustainable development determines the constraints that individuals must comply with. Sustainability refers to continuity or minimum reduction in economic, social and environmental terms in order to meet the needs of people in the present while at the same time not depriving them of this right in future generations. The concept of sustainability is classified under three headings:

3.1. Economic Sustainability

An economically sustainable system should be able to produce goods and services continuously, maintain manageable levels of government and external debt, and avoid excessive sectoral imbalances that harm agricultural or industrial production.

3.2 Social Sustainability

A socially sustainable system should provide adequate social services, including distributional equity, health and education, gender equality, and political accountability and participation.

3.3 Environmental Sustainability

An environmentally sustainable system should maintain a stable resource base by avoiding overexploitation of renewable resource systems and consuming non-renewable resources only to the extent that investment is sufficient substitutes. This includes preserving biodiversity, atmospheric stability, and other ecosystem functions not normally classified as economic resources. (Holden et al., 2016; Yeni, 2014; Semtrio, 2024) resources have been utilized.

4. SUSTAINABILITY PROJECT EXAMPLES IN THE WORLD

4.1 Cornwall Eden Project

The Eden Project is an initiative that was initiated by transforming a former clay pit in Cornwall, England, and aims to redefine the distance between nature and humans. The project includes huge biomes that simulate tropical and Mediterranean climates, and thousands of plant species are brought together in these biomes. It offers visitors the opportunity to observe and experience different vegetation within a managed ecosystem. The Eden Project offers education that focuses on the themes of sustainability, ecological balance and living in harmony with natural resources, and provides people with environmental awareness (Belousova, et al., 2021). The biomes in the Eden Project are produced with specially designed ETFE (Tetrafluoroethylene copolymer) material (Figure 1) and one of these biomes hosts one of the largest closed rainforests in the world. The Rainforest Biome offers different plant species together in the humid air of the tropical climate, allowing the managed to observe the diversity of tropical forests (Sanchez-Alvarez, 2022). On the other hand, the Mediterranean Biome offers a cooler environment and provides an enriched experience with plant species, spice scents and natural beauty specific to the region. The outdoor areas of the Eden Project stand out with extensive gardens enriched with plant species from different climate zones. These areas, equipped with plants from regions such as Australia, South Africa and California, offer opportunities for both mental and social development to visitors through activities such as outdoor activities, workshops and nature-themed storytelling that increase environmental awareness (Figure 1). In addition, projects such as the "Pollinator Path Builder" contribute to the preservation of ecosystems by supporting bees and other pollinators (Baczyńska and Lorenc, 2012).

Figure 1. The Eden Project in Cornwall (Baczyńska and Lorenc, 2012)

The Eden Project, founded by Tim Smit, has become a platform that promotes a lifestyle in harmony with nature, beyond being a botanical garden. The income generated is reinvested in the project to strengthen environmental awareness and support sustainable agricultural practices. Eden, which hosts close to one million visitors each year, continues to strengthen the bond between nature and humans, inspiring similar projects worldwide. The Eden project also provides an environment for undergraduate and graduate programs to conduct workshops and experimental studies (Baczyńska and Lorenc, 2012).

4.2. Andasol Spain Project

The Andasol Solar Power Plant, located in the Andalusia region of southern Spain, is one of Europe's pioneering large-scale solar thermal power plants using parabolic trough technology (Figure 2). The project is divided into three plants, each with a capacity of 50 MW and contributing a total of 150 MW of clean energy: Andasol 1, Andasol 2 and Andasol 3. These plants cover an area of 1.53 million square meters and are equipped with 210,000 mirrors that focus sunlight onto absorption pipes (Millennium, 2008).

Figure 2. Reference Andasol-1 in Granada, Spain (Millennium, 2008)

The project significantly reduces carbon emissions, with an expected reduction of 450,000 tons per year compared to coal-fired power plants. It is designed to power around 500,000 people in Spain, and contributes to Spain's efforts to combat climate change. One of the key features of the Andasol plants is their advanced thermal energy storage system. This allows them to produce electricity even when sunlight is insufficient by storing energy in mirrors that absorb light during the day, which can then be used to generate power at night (Millennium, 2008). Andasol 1 was installed in 2008, Andasol 2009, and Andasol 3 was completed in 2011. This project not only helps to meet Spain's peak electricity demand, but also contributes to significantly reducing electricity consumption (Millennium, 2008).

4.3. An Rance Tidal Power Station Project- France

Located at the mouth of the Rance River in the Brittany region of France, the Rance Tidal Power Station is the world's first operational tidal power station, completed in 1966 (Figure 3). The station consists of 24 turbines, each producing 10 MW, and can meet the annual energy needs of approximately 130,000 homes. The station operates within a tidal range of 8.2 meters, which can reach up to 13.5 meters in extreme conditions (Shetty and Priyam, 2022). This allows the creation of a significant tidal reserve. Figure 3 describes the tidal energy production technique.

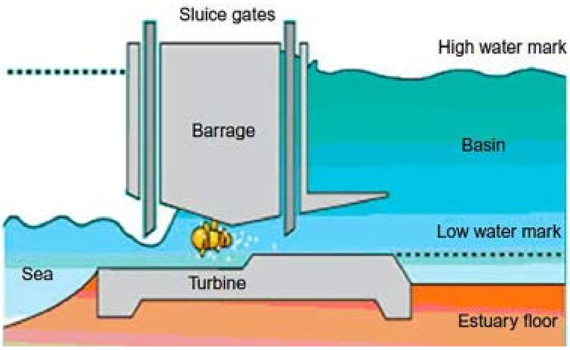

Figure 3. Diagram of the Tidal Barrage (Shetty and Priyam, 2022).

The construction of the station took several years, starting in January 1961 and culminating in the full commissioning of 24 turbines in September 1967. The infrastructure of the plant also includes a 750-

meter-long dam and a 332.5-meter-long power generation section. The plant has been in operation for over fifty years. The Rance Tidal Power Plant continues to be an exemplary project in renewable energy, demonstrating the feasibility of utilizing tidal movements for electricity generation (Özaltın and Binark, 2021; Shetty and Priyam, 2022).

5. Sustainability Project Examples in Türkiye

5.1. Ecovillages

Ecovillages have been developing with increasing interest in recent years as sections where sustainable living and environmentally friendly practices are at the forefront. These villages aim to protect natural resources, provide energy efficiency, do organic farming, revitalize the local economy and adopt environmentally compatible lifestyles. However, ecovillages in Türkiye are limited in number due to the difficulties in the initial stages, and they face difficulties such as economic infrastructure, number of volunteers and accommodation on the land. Such projects can generally be more successful with the cooperative model. Some ecovillages; Belentepe Permaculture Farm; produces its own electricity and food. Gağgı Farm, which was established in 2010 on a 50-acre land at an altitude of 850 meters on the west side of Karlık Mountain in Sarıyurt village in Bayındır district of İzmir, is building a life where people do not differentiate according to country, language and race (Figure 4), (Kılıç and İşcan, 2019).

Figure 4. Gağgı farm (Kılıç and İşcan, 2019)

5.2. GES (Solar Power Plant) Projects:

Türkiye is a country that is rapidly concentrating its solar energy potential and making significant investments in this area. Solar power plants operate with two different systems: photovoltaic and thermal systems (Figure 5). While photovoltaic systems operate panels that convert sunlight directly into electrical energy, in thermal systems, sunlight is concentrated by means of special mirrors and these light heats liquids, creating vapor pressure; it uses this pressure to convert mechanical heat into kinetic energy (Kınalı, 2019).

Figure 5. Karaman Municipality 1000 kW Solar Power Plant Outlook (Kınalı, 2019)

Türkiye's solar energy capacity has experienced a rapid increase in recent years; the installed capacity, which was only 40 MW in 2014, increased by approximately 10,000 MW in 9 years. Solar energy capacity is expected to increase by approximately 500% by 2035, which means that Türkiye's installed solar power will reach 52.9 GW. In 2022, Türkiye produced a total of 50.14 terawatt-hours of electricity from wind and solar energy sources, which constituted 15.4% of total electricity production (Kınalı, 2019). It is seen that solar energy is increasing, Türkiye's energy production will play an important role, and the country's energy independence and sustainability are critical when it comes to sustainability. Solar energy will be the energy source with the largest share in Türkiye's electricity production in the future, and as investments in this area continue, the country's energy needs will be met largely from sustainable energy (Kınalı, 2019). 5.3. Soma RES Project: Soma Wind Power Plant stands out as one of Türkiye's largest and Europe's leading onshore wind power plants. Soma RES started production with 20 turbines in 2009 and continues to be maintained with a major investment in 2014 (Figure 6). Today, the energy efficiency of the plant has been maximized by using high-tech turbines produced by Enercon. These turbines, which automatically rotate according to the direction of the wind, provide efficient production by making the best use of Soma's annual average wind potential of 7-8 m/s (Özer, 2022).

Figure 6. Soma RES Project (Özer, 2022)

The construction of the power plant started in 2013 and became operational in 2014. This process is an important step taken to meet Türkiye's rapidly increasing energy demand, leading to an increase in wind energy capacity. In addition to providing environmentally friendly energy production, Soma RES has created regional employment and made significant contributions to the local economy (Öztürk, 2023). This power plant, which helps strengthen Türkiye's energy independence, proves that wind energy can be an alternative to fossil fuels as a clean and extractable resource and diversifies the country's energy portfolio.

6. FLOATING PANEL SYSTEMS

Floating solar energy systems can be taken as a model that produces energy with solar panels installed on water surfaces such as large ponds, dams and water connections. The origins of these systems, referred to as "Floating Solar", date back to the early 2000s, but the first commercial examples began in 2006 in the United States and Japan. The main goal of this initial work was to save land and generate energy in large water bodies such as irrigation canals.

6.1. Floating Solar Energy Systems from the World

A wide variety of large floating solar energy projects have been developed around the world, such as the United States, France, and India. Floating solar energy systems will become even more widespread in the future with the energy policies and energy incentives of countries (Djalab et al., 2024). Floating solar energy systems have many advantages such as efficiency in land use, easy installation thanks to their lightweight structures, increased energy efficiency, reduced evaporation, improved water quality, environmentally friendly energy provision, and rapid installation with their modular structures (Figure 7).

Figure 7. Floating photovoltaic (FPV) systems in Hyogo, Japan (Galdino and de Almeida Olivieri, 2017)

However, they also have disadvantages such as high initial costs, resistance to weather conditions, microplastic formation, obstacles in fishing and transportation, and long-term sustainability issues. Therefore, the applicability of floating panels depends on careful consideration of the advantages and disadvantages (Nguyen 2017).

6.2. Floating Solar Energy Systems in Türkiye

The first example in Türkiye was implemented in 2017 with a 240 KW system on Lake Büyükçekmece in Istanbul. While the intensive use of fossil fuels brings environmental problems, the idea that Türkiye is rich in water resources may be misleading. There are 861 dams and 714 hydroelectric power plants (HES) in Türkiye, and these structures produce approximately 107,801.82 GWh of energy annually. However, the protection and efficient use of existing water resources is critical for future energy needs (Unsur, 2021; Candar, 2022).

Floating solar energy systems have the potential to increase the functionality of HESs as structures that can be installed on dam lakes and adapt to the water level. These systems can reduce evaporation by 50% by keeping the dam water cool, thus contributing to the protection of water resources. The installation of floating solar energy systems on facilities such as Atatürk, Keban, Karakaya, Ilısu and Hirfanlı, which are the largest dams in Türkiye, can provide significant amounts of renewable energy production. When integrated with existing reservoir hydroelectric power plants and offshore wind power plants, these systems both increase energy production capacity and reduce costs (Özaltın, Binark, 2021; Şenli, 2023). Figure 8 shows the Floating Solar Power Plant implemented in 2017 on Büyükçekmece Lake, one of the sources that provides clean water to Istanbul.

Figure 8: Floating solar power plant implemented for the first time in Türkiye (Acar and Durdu, 2024)

Test projects are being carried out in Türkiye and studies are continuing in this field. The widespread use of these systems can also provide economic gains by reducing fossil fuel dependency. Türkiye's potential in the field of solar energy offers a great opportunity for sustainable energy solutions in the future (Ghannadi, 2024).

7. CONCLUSION

Natural resources constitute the cornerstones of human life and play a critical role in economic and social development. However, excessive consumption and mismanagement of these resources lead to serious problems such as climate change, biodiversity loss and environmental degradation. Therefore, sustainable management of natural resources has become one of the most urgent needs of our day.

Sustainable development encourages the effective and balanced use of resources by addressing environmental, economic and social dimensions together. In this context, strategies developed on the classification, protection and management of natural resources contribute to both the reduction of environmental problems and the preservation of the health of ecosystems. Understanding the differences between renewable and non-renewable resources provides important guidance on how these resources can be used more efficiently.

The study aims to shed light on the determination of effective strategies for the protection of natural resources by evaluating environmental management projects implemented in Türkiye and around the world. The success of these projects is directly related not only to technical solutions but also to social awareness and participation. The awareness of societies and their active role in the protection of natural resources is a decisive factor in achieving sustainable development goals. As a result, the protection of natural resources is a vital responsibility to ensure the quality of life not only for current generations but also for future generations. In this context, the cooperation of policy makers, civil society organizations and individuals plays a critical role in developing sustainable solutions. In order to create a solid foundation for the future, more effective policies and strategies need to be developed in the management and protection of natural resources. This will be an important step in both ensuring environmental sustainability and supporting economic development.

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The Semiotic Analysis of Plants as Exhibition Objects in Art

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1. INTRODUCTION

The coexistence sustained within various ecosystems across the world has witnessed humanity's encounters with plant species that exist within different life cycles. Humans have observed plant species with diverse life cycles and experienced spatial interactions with them. Throughout history, plants have been used by humans to meet their nutritional needs, as well as for medicinal purposes. Moreover, as will be emphasized in this study, plants have also been preferred in various fields such as art, architecture, and landscape design due to their aesthetic qualities. However, our relationships with plants have become increasingly fragile in the face of global ecological crises (Kaçmaz Akkurt & Şemsiyeci, 2024). Human-induced destruction has led to significant losses in the plant world (Çakar et al., 2019). Activities such as mining, the expansion of agricultural lands, and deforestation have caused a decline in plant populations (Ankaya & Pirli, 2020).

To draw attention to the human-driven destruction of nature, the concept of the Anthropocene—originally proposed by Paul Crutzen and Eugene F. Stoermer and later adopted by many natural scientists—has been introduced into the academic literature (Yazici, 2017; Çakıroğlu, 2022; Yazici & Temizel, 2020). The pressure exerted on ecosystems by population growth, industrial development, and urbanization has led to the extinction of animal species and plant types (Kaçmaz Akkurt & Şemsiyeci 2022). The healthy functioning of urban ecosystems requires consideration of not only the technical infrastructure but also social and cultural sensitivity and artistic aspects (Pirli et al., 2023; Yazici & Gülgün, 2019). Paradoxically, however, the Anthropocene—defined through the human (anthropos) axis—has been described as perhaps the historical period most distant from humanity, the furthest removed from human existence (Ertürk, 2017–18; Sezen et. al., 2024; Aşur et al.2022).

Increasing environmental damage and advancing technological developments have made it necessary to integrate the fields of environment and communication in order to deal with these problems (Nükte, 2025). Exhibition spaces are regarded as recreational environments that offer the potential for interaction with nature; in this respect, they align with sustainable tourism policies and support visitors' development of environmental awareness (Pirli & Yazici, 2022a; Aşur & Akpınar Külekçi, 2020). Recreation areas planned within the scope of sustainable landscape design enable both the conservation of environmental values and the generation of socio-economic benefits through tourism (Ankaya & Pirli, 2024). As ecotourism emphasizes low-impact engagement with natural and cultural heritage, exhibition areas designed with ecological awareness can serve as complementary spaces that foster environmental education and promote sustainable tourism practices (Ünal Ankaya et al., 2018; Gülgün et. al., 2015) In this context, exhibition spaces can also become part of sustainable tourism by offering visitors recreational and educational experiences that make the nature–culture interaction visible. The symbolic meanings attributed to plants in Persian garden culture—such as immortality, purity, or wisdom—can inspire the spatial and narrative design of contemporary exhibition areas, where plant elements are used not only aesthetically but also as carriers of cultural memory (Aşur et. al., 2020; Yazici et al., 2018; Yazici & Gülgün, 2016).

The use of alternative cultivation techniques in urban environments emphasizes the need for resilient plant species that can adapt to limited space and changing climatic conditions (Kaçmaz, 2021; Pirli & Yazici, 2022b). It offers new possibilities for integrating such plants into artistic exhibition spaces in cities. In sustainable urban development, public spaces designed with ecological and cultural sensitivity—such as exhibition areas—play a key role in enhancing environmental awareness and supporting the integration of green infrastructure into everyday urban life (Atıl et al., 2005) Revitalised post-industrial landscapes, where former factory buildings are transformed into exhibition and cultural venues, reflect both the aesthetic reinterpretation of space and its reintegration into public life (Yazici, 2022).

Aesthetic and functional landscape designs that integrate natural and built elements are found to increase user engagement and enhance spatial quality in public areas (Pirli et al., 2022). 'Earth Dreams: The Anatolia' exhibition is one of the most appropriate examples of how digital art installations can transform public spaces into immersive cultural experiences and establish a bridge between the past and the future of technology (Ulaşzade & Güneş Gölbey, 2024)

According to the report titled "The State of the World's Plants", published by researchers at the Royal Botanic Gardens, Kew in the United Kingdom—which serves as the first global assessment of the world's flora—scientists estimate that there are approximately 390,900 plant species known to science. The study also revealed that 2,034 new plant species were discovered in 2015. According to the report, there are currently around 391,000 known vascular plant species, and approximately 369,000 of these (or 94%) are flowering plants (URL 1).

The report, which highlights the richness of biodiversity within the world's flora, also draws attention to a dramatic process underway, warning that 21% of plant species are threatened with extinction due to threats such as climate change, habitat loss, disease, and invasive species. The report states that around 2,000 new plant species are discovered or identified each year, but most of these are already on the brink of extinction. Based on the best available estimates, scientists indicate that 21% of all plant species—or one in every five—are likely to be at risk of extinction (URL 2).

The ongoing anthropogenic dominance has necessitated a shift in our perspective toward non-human living beings. Artists who envision a method of dismantling interspecies hierarchies through ecological collaboration have realized works that demonstrate how art can serve as a means of raising awareness. Although this study focuses on exhibitions that draw attention to interconnected issues such as biodiversity loss and the climate crisis through plants, it is limited to works that use plants as the primary material and express their subtext through them.

2. READING THE SUBTEXT OF AN ARTWORK THROUGH SEMIOTICS

In the contemporary era, characterised by the dominance of aesthetics, design, and digital intelligence, everyday life is undergoing significant socio-cultural transformation. Rapidly evolving technologies not only reshape user behaviours but also generate new spatial practices, habits, and layers of meaning (Pirli, 2020). Within this context, exhibition spaces in urban environments have emerged as dynamic platforms where technological innovation intersects with artistic expression, offering multisensory and interactive experiences that redefine the boundaries between audience, space, and content. Viewing nature as an object to be domesticated or eliminated is, in many ways, the other side of seeing nature as a source of insight and a promise of innocence (Wallace, 2017–18). Art possesses the tools necessary to convey the changing value of plants to the viewer. In the face of ecological crises, art can be used as a means of raising awareness by offering an indirect way to carry plants—those that resist extinction—into the future. In this study, where we will examine such examples, plants are positioned within fictional compositions constructed in an effort to create a narrative. The primary criteria for selecting the exhibitions evaluated in this study are: observing biological diversity, demonstrating an attitude contrary to anthropocentric perspectives, and conveying ecological crises through the elements of the ecosystem.

The main material of the exhibitions, plants, are presented either individually or in compositions with other plants based on their unique characteristics, without being subjected to human intervention. Rather than manipulated plants, what stands out here are designs that highlight the intrinsic values of the plants themselves. These exhibitions include messages that raise awareness and are open to interpretation. They offer the possibility of using fictional spaces to step back in the face of human-induced ecological crises and to understand the living beings with whom we share a connection. When art is regarded as the designer of “what is meant to be shown,” plants can be considered within the perspective constructed by the artist, detached from purely aesthetic concerns. In this way, interpreting the deliberately embedded messages within the exhibitions also becomes possible through the plants that serve as the primary material of these displays.

The attempt by artists to construct meaning through plant compositions can also lead to the objectification of the plant. In this context, the viewer, who is expected to interpret and make sense of the object, moves away from the conventional knowledge used to define the now-objectified plant. Positioned before the viewer in a context different from its natural purpose in the ecosystem, the plant becomes an object presented to be interpreted. Meaning-making involves both assigning linguistic labels to a non-linguistic world and interpreting the relationship between those labels and the meanings of signs that do not necessarily have a fixed connection to that world (Kıran, 2010). Semiotics has developed the frameworks and tools for interpreting objects that function as carriers of meaning.

3. METHOD

This section outlines the research model, the study population and sample, and finally the purpose of the study.

3.1. Research Model

In this study, two different methods were employed to enhance both the theoretical and practical aspects of the research. Within the scope of the study, which evaluates artworks in which plants are the main material, a literature review was conducted. Exhibitions addressing audiences through the key concepts of ecology, nature, and environment were explored. The literature was narrowed in line with the purpose by focusing on these key concepts, and the findings were evaluated. In determining the sample, the criterion was that plants were used as the main material in the artworks. Another method used in this study was semiotic analysis, a qualitative research method grounded in the study of signs and meanings. The artworks examined within the scope of the study were analyzed through the lens of semiotic theory, which originated with Ferdinand de Saussure and was further developed by Roland Barthes. Saussure's model introduces the triadic relationship between the "signifier" (the form or sound/image of the sign), the "signified" (the concept or meaning associated with the signifier), and the "sign" (the whole that emerges from this association). This structuralist framework emphasizes the arbitrary and relational nature of signs within a language system.

Roland Barthes expanded on Saussure's ideas by applying semiotics to cultural texts and everyday phenomena, particularly in the field of art and media. Barthes introduced the concepts of denotation and connotation, highlighting how a sign can carry multiple layers of meaning: the literal, explicit meaning (denotation), and the cultural, ideological, or symbolic meanings (connotation). This perspective allows for a deeper interpretation of artworks by uncovering both the manifest and latent messages embedded within them. By employing these three fundamental semiotic components—sign, signifier, and signified—this study analyzed the subtexts embedded by the artists in their works. This approach facilitated a more nuanced understanding of how plants as materials convey complex ecological and cultural narratives beyond their immediate aesthetic presence.

3.2. Scope and Selected Works

This study focuses on artworks featured in exhibitions that are thematically aligned with the key concepts of ecology, environment, and nature. Within this thematic framework, works in which plants are utilized as the primary material were purposefully selected for in-depth analysis. While the selection of exhibitions was guided by the aforementioned concepts, it is acknowledged that it was not feasible to include all relevant exhibitions within the scope of this research. Accordingly, the analyzed works were selected in line with the study's purpose and methodological boundaries. The semiotic analysis of two such works, where the plant functions as the central artistic material, is presented through detailed sign analysis tables.

3.3. Aim of the Study

The aim of this study is to explore the potential of semiotic analysis as a methodological tool for interpreting the underlying meanings embedded within artworks. It seeks to evaluate how semiotics can function as a guiding framework that facilitates the audience's ability to decode signs and access subtextual narratives while engaging with artistic works. The study further questions how such analyses might enhance the aesthetic experience, foster awareness of what is seen, and enable a deeper internalization of the artistic narratives through the discovery of embedded meanings.

4. FINDINGS AND INTERPRETATION

4.1. Diana Scherer, *Nurture Studies*

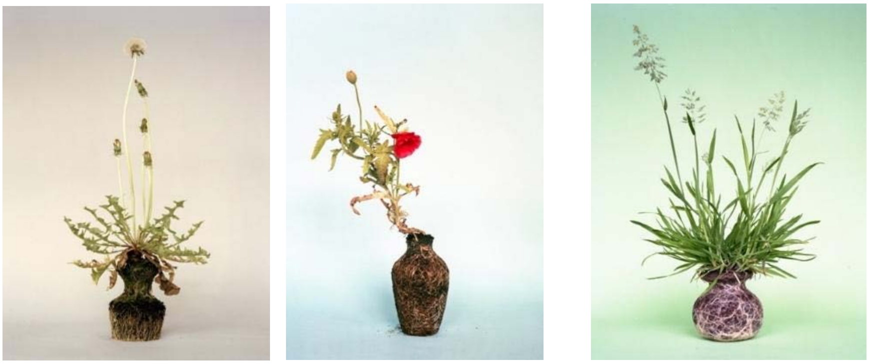

Figure 1. Plant growth in the work titled “Nurture Studies” (URL 3)

The collection titled Nurture Studies, consisting of thirty-two individual works, explores human practices aimed at manipulating nature. The preparation process involves the artist collecting vases, filling them with soil, planting a seed, and then waiting for the seeds to reach their optimal stage of development. Each piece takes approximately five months to produce. The work, which centers on observing the life cycle of plants, draws attention to human intervention in their growth processes shaped by aesthetic concerns. The artist, who sources wild weeds and seeds from her own garden, makes visible the aesthetic impositions of humans on other living beings by breaking the vases after the plants have completed their development.

Table 1. Display Table of the Artwork Shown in Figure 1

Sign	Signifier	Signified
Object	Wild Plants	The domestication of wild plants by humans
Object	Soil shaped within a vase	The use of soil as an aesthetic object through human intervention

4.1. Sonia Rentsch, Harm Less

Figure 2. An example from the work titled "Harm Less"

The Harm Less series depicts a collection of weapons crafted from sticks, leaves, seeds, sharp twigs, and flowers. Notable for the simplicity of its compositions, the work stands out with its striking visual details. Although these creations—essentially made from botanical debris—are ephemeral, their connotations are richly layered. Presenting a botanical protest against war and violent conflict, the series draws attention to the social, ecological, and cultural destruction that war engenders. The nature of the materials used underscores a preference for what is less destructive or inherently peaceful.

Table 2. Semiotic Analysis Table of the Artwork Depicted in Image 2

Sign	Signifier	Signified
Object	Seeds, twigs, and plant fragments	The destructive impact of weapons on nature as instruments of violence

4. CONCLUSIONS AND RECOMMENDATIONS

This study explored how plants are positioned as the primary narrative material in artworks that contain subtexts intended to capture the attention of audiences concerned with ecological issues. In an age marked by intensified ecological, cultural, and political crises, artists increasingly question the nature of the human–nature relationship and present plants as both the object and subject of this inquiry. Exhibitions in which plants are used as the central material invite a re-evaluation of pressing themes such as biodiversity loss, militarism, the domestication of nature, and the imposition of anthropocentric aesthetic judgments. Within this framework, plants are not merely natural entities in our environment but are presented to the viewer as meaningful living beings with whom we share existence.

The artworks analyzed in this study demonstrate that art serves not only as a medium of representation but also as a space for transformation. Plants, as mediators of this representation, are not only part of visual aesthetic production but also carriers of political, ethical, and ecological discourse. This highlights the potential of art to render visible—and to reconstruct—the increasingly fragile relationship between humans and the natural world.

Through art, the meanings attributed to plants guide viewers to perceive them not merely as aesthetic objects, but as co-inhabitants of the Earth. In this sense, art offers a means to move beyond anthropocentric approaches and encourages the recognition of the intrinsic value of the non-human other (i.e., the plant).

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Night View of Bicycle Paths in Çanakkale City Center

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1. INTRODUCTION

Today, more than half of the world's population lives in cities. The differences in the lives of urban residents have led to many changes (Temiz, 2016). The continuous changes and developments in cities significantly affect their physical, social, and economic structures. Another important phenomenon that is simultaneously affected by these structures is urban users. Urban users constitute the components that reflect the city's identity, based on the interaction of physical, social, and economic structures. The most suitable approach to identifying urban identity components is the references urban users make to the city (Sağlık, 2019). In growing cities, the rate of motor vehicle use is increasing in parallel with the spread of cities over large areas. As the areas of cities expand, the share of environmentally friendly transportation methods such as bicycle transportation based on human power is gradually decreasing (Karasahin and Uz, 2004).

When transportation planning is carried out, it is necessary to create methods that meet the needs of the city and its inhabitants, allowing for the rapid, comfortable, economical, safe, environmentally friendly, quiet, and low-cost transportation of people, vehicles, and goods without external dependency (Aydoğan, 2018). Bicycling, which is healthy, economical, fast, enjoyable, and environmentally friendly, serves as an effective and sustainable transportation solution to these issues (Lorasokkay, 2011). The bicycle is a type of transportation, and it can also be used effectively as a healthy transportation vehicle when its potential to replace private vehicles in medium and short distance journeys is embraced and included in correct planning and transportation projects (Elbeyli, 2012)

Çanakkale, located in the northwest of Turkey, is recognized for its historical and cultural richness, drawing attention with both its past and current dynamic structure. However, beyond being a historical city, the importance of bicycle paths is increasingly emphasized with the adoption of modern transportation solutions and sustainable lifestyles. Especially in recent years, environmentally friendly transportation alternatives have been reducing traffic congestion within the city and enabling individuals to adopt healthier lifestyles. In large cities where environmental pollution is increasingly rising, bicycle use is seen as one of the alternative solutions to this problem (Akay, 2006).

The use of bicycle paths at night offers a safe transportation alternative in the dark and helps users feel secure. Lighting systems enhance the safety of these paths by ensuring the visibility of cyclists and pedestrians. Good lighting reduces the risk of getting lost in the dark and helps prevent potential accidents. Moreover, illuminated bicycle paths enrich the aesthetic appearance of the city, making its historical and natural beauties more visible. Colorful lighting and eye-catching designs make the bicycle paths attractive while positively impacting the overall image of the city. This situation creates an appealing atmosphere for both locals and tourists, enhancing the enjoyment of cycling at night. Bicycle trips are the lowest cost trips among vehicle trips. It can be said that the total cost of bicycles is even lower than the cost of public transportation, due to the relatively low initial investment costs and operating and maintenance costs. In this way, bicycles can be used as private cars for low-income groups (Oregon Bikeway/ Pedestrian Office, 1992).

The nighttime appearance of bicycle paths in Çanakkale provides significant insights into the social and environmental dynamics of the city, further highlighting the role of these paths in urban life. Cycling at night is gaining importance not only as a mode of transportation but also as an activity that supports individuals' healthy lifestyles. In this context, the bicycle paths in Çanakkale have become symbols of sustainable transportation and social interaction.

In conclusion, the nighttime appearance of bicycle paths in Çanakkale offers both aesthetic value and contributes to the social life of the city.

2. THE PLACE AND IMPORTANCE OF BICYCLES IN SUSTAINABLE TRANSPORTATION

Among urban transportation modes, cycling is the least harmful to the environment and the most energy-efficient form of transport. Consequently, interest in bicycles is steadily increasing, as cycling offers numerous ecological, economic, physical, and psychological benefits compared to other modes of transportation (Dağ, 2022). In recent years, the growing awareness of climate change and environmental issues, such as air pollution and noise pollution resulting from motor vehicle use, has brought sustainable transportation strategies to the forefront.

Transportation methods other than motor vehicles are viewed as healthier, more efficient, and cheaper forms of transport for short distances within cities. The increasing understanding of the environmental, social, and economic benefits of cycling, along with its ability to provide faster access compared to other modes of transport under certain conditions, has led to a rise in the use of bicycles as one of the most suitable transportation options (Lundberg & Weber, 2014).

In summary, the role of bicycles in sustainable transportation is vital, contributing positively to environmental health and urban mobility while promoting a more active lifestyle among individuals.

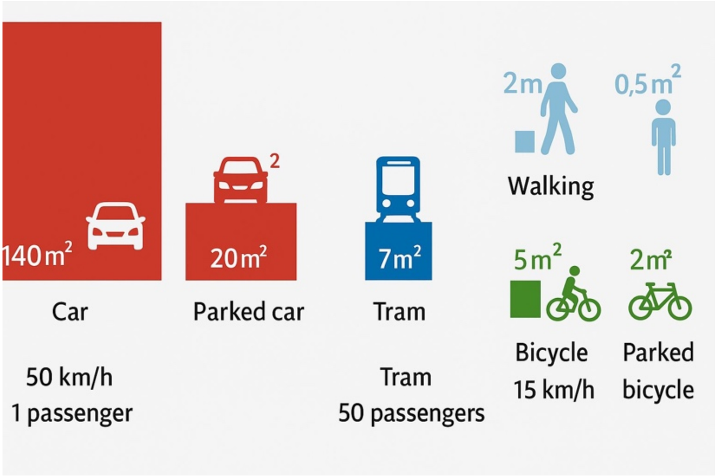

Figure 1. Area Occupied by Transportation Systems (Harms & Kansen,2024)

2.1 Night Lighting Systems

2.1.1 Types of Lighting

The lighting systems used on the bicycle paths in Çanakkale are equipped with energy-efficient solutions, such as LED lamps. These lamps save energy and have a long lifespan. The types of lighting systems include:

Pole Lighting: Poles located on both sides of the roads.

Recessed Lighting: Special recessed lamps located on the road.

Colored Lighting: Colored lights used for aesthetic purposes.

2.1.2 Importance of Lighting

Lighting on bicycle paths at night is critical for ensuring user safety, increasing visibility, and enhancing the overall cycling experience. Well-lit paths allow drivers and pedestrians to be seen better, reducing the risk of collisions and making night cycling more comfortable. Lighting helps users feel safe, encourages social interaction, and strengthens community ties. Additionally, these aesthetically enriched paths attract both locals and tourists, adding vibrancy to the city's nightlife. In conclusion, lighting on night bicycle paths combines safety and aesthetic elements, making it an indispensable part of a sustainable transportation alternative.

2.2 Safety

The width of the bicycle path foreseen for one-way bicycle paths is 1.5 m. A minimum safety distance of 1.5 m should be left between the bicycle path and the adjacent motor vehicle lane (Cengiz and Kahvecioğlu, 2015)

2.2.1 User Safety

The risks associated with cycling at night are directly related to lighting and the condition of the roads. Measures that can be taken to enhance safety on the bicycle paths in Çanakkale include:

• **Adequacy of Lighting:** Sufficient lighting increases user visibility.

• **Emergency Buttons:** Installation of buttons for emergencies along the road.

• **Security Cameras:** Presence of security cameras along the paths helps users feel more secure.

2.3 Social Security

Social security on bicycle paths at night is also important. To ensure that people do not hesitate to walk or cycle alone:

• **Support Personnel:** Security personnel patrolling at night.

• **Community Events:** Organizing events such as night bike tours.

2.4 Aesthetics and City View

2.4.1 Visual Aesthetics

Well-lit bicycle paths enhance the city's aesthetics at night. Colored lighting and eye-catching designs make the bicycle paths attractive and enrich the overall appearance of the city.

2.4.2 City View

Çanakkale's historical structures and natural beauties can be observed from a different perspective while cycling at night. Especially the paths by the sea enchant users with their night views.

2.5 Social Interaction

2.5.1 Community Interaction

The use of bicycle paths at night increases social interaction. People find opportunities to exercise and spend time with friends while using these paths. This situation contributes to strengthening community ties.

2.5.2 Events and Organizations

Night events and organizations held on bicycle paths in Çanakkale enhance social interaction among participants. Night bike tours, concerts, and festivals ensure that bicycle paths play an important role in social life.

2.6 Environmental Impacts

2.6.1 Sustainable Transportation

The use of bicycle paths reduces vehicle traffic in the city and prevents environmental pollution. Cycling at night is beneficial for both individual health and environmental health.

2.6.2 Interaction with Green Spaces

When bicycle paths are designed to be intertwined with green spaces, they offer an experience connected to nature at night. This situation strengthens users' bonds with nature and increases environmental awareness.

3. PROBLEMS ENCOUNTERED

• **Damaged Roads:** Although cycling is considered a safe mode of transportation, riding on damaged or under-construction roads does not always provide a safe riding experience.

• **Bicycle Paths Starting at Café and Restaurant Seating Areas:** This situation, commonly seen in the city center of Çanakkale, often leads to minor accidents due to sudden people coming in front of cyclists.

• **Worn Bicycle Path Paints:** Poorly maintained bicycle paths are difficult to distinguish during the day and nearly eliminate visibility at night. This situation minimizes safe cycling.

Insufficient Lighting: Insufficient lighting leads to the inability to see roads, which can cause minor accidents.

Human Factor: The human factor can be considered the biggest problem encountered. Most people do not differentiate between bike lanes and often use bike paths. This situation can be quite challenging for people riding bikes on narrow roads.

Insufficient Bike Lanes: Bike routes that lack cohesion. Starting in a specific area and ending in the middle of the road. The fact that the distance of transportation by bicycle is short, transportation plans do not match with land use decisions, accessibility is low due to inadequate infrastructure, the person is unprotected in traffic and is affected by climatic conditions, the quality of walking and bicycle paths is low, and the terrain is sloping, can be seen as a deterrent factor in our cities for pedestrian and bicycle transportation (Aysan 1996; Ulvi 2002).

4. WHAT A BIKE LANE SHOULD BE LIKE

The increasing use of motor vehicles in recent years has led to a rise in fossil fuel consumption, triggering environmental pollution and climate change. One of the primary approaches to mitigate the effects of this situation is to promote the use of bicycles as a means of transportation (Şükran, 2024). A bike lane should possess various features to provide a safe, comfortable, and sustainable transportation experience.

Firstly, the width of the bike lane should be designed to comfortably accommodate two-way bike traffic, with a minimum width of 1.5 meters. The surface material should be smooth and durable, with slip-resistance and shock-absorbing properties, ensuring users have a safe riding experience. The lighting system should be adequate for nighttime use and equipped with energy-efficient solutions such as LED lights. Additionally, the visibility of the bike lane should be enhanced, with clear markings and warning signs along the roadside.

Bike lanes should be designed separately from pedestrian and motor vehicle traffic, utilizing physical barriers or delineators for safety. A route integrated with green spaces, offering natural scenery, allows cyclists to experience nature closely. To enhance social interaction, rest areas, water sources, and spaces for social events should be created along bike lanes. Finally, regular maintenance and cleaning of bike lanes should be ensured to guarantee a healthy and enjoyable experience for users. The combination of these elements will facilitate the functional and aesthetic design of bike lanes, contributing to the development of a sustainable transportation alternative.

4.1 What Colors Should Bicycle Paths Be?

According to the "Regulation on the Design and Construction of Bicycle Paths, Bicycle Stations, and Bicycle Parking Areas in Urban Roads" published in the Official Gazette, bicycle paths should be blue and must not be at the same level as or above the sidewalks.

4.2 How Should Night Bicycle Paths Be?

Night bicycle paths should be specifically designed to ensure the safety of drivers and cyclists while providing a comfortable riding experience.

The advantages of bicycle use can be listed as creating economic value, protecting the environment, not causing traffic congestion or parking problems, facilitating transportation, and enabling healthy living, outdoor sports, and socializing (Çeyiz and Koçak, 2015).

4.2.1 Lighting

Adequate and balanced lighting is one of the most important elements. There should be lights that cover the entire road, do not cause glare, but illuminate the ground clearly.

• LED lighting should be preferred: energy-efficient and long-lasting.

• Lighting should be intensified, especially at curves, intersections, and hazardous areas.

4.2.2 Reflective Elements and Markings

• Road lines should be made with fluorescent paint or reflective material.

• Barriers, poles, and other obstacles should be equipped with reflectors.

• Direction, speed limit, and warning signs on the roads should also be suitable for nighttime visibility.

4.2.3 Surface Quality

The surface must be smooth, without cracks or potholes, which is very important for night riding.

• Slip-resistant surface coatings should be used.

4.2.4 Separated Lanes

On roads shared with cars, the bicycle path should be clearly separated by a physical barrier or high visibility.

• To increase nighttime visibility, colored asphalt or special surface patterns can be preferred.

4.2.5 Security and Monitoring

Camera systems can be placed at strategic points; this enhances the feeling of security and allows for intervention in possible incidents.

• Emergency buttons or help points should also be considered.

4.2.6 Rest and Emergency Areas

There should be rest points at regular intervals along the road. These areas can have lighting, seating, and perhaps a pump or small maintenance station.

• In some cities, innovative solutions such as illuminated surface coverings or solar-powered reflective stones are also being implemented.

Innovative Approaches (Example Applications)

• **Netherlands – Van Gogh-Roosegaarde Road:** A bicycle path covered with phosphorescent stones that glows at night using solar energy.

• **Copenhagen:** Sensor-activated LED lights that increase light intensity by detecting bicycle passage.

4.3 Examination of the Bicycle Path on Troya Street in Çanakkale City Center

Troya Street in the center of Çanakkale stands out as an important route for bicycle transportation. It is one of the main places where people can come and easily ride bicycles. This study will also present observations about Troya Street.

4.3.1 Length and Material

The bicycle path on Troya Street is 3.5 km long, starting in front of Troypark Shopping Mall and continuing to Sarıca. The entire bicycle path uses lockable paving stones, with an average width of 2 meters along the road, increasing to 4 meters in entrance areas. The side curbs average 20 cm.

Figure 3. (Troya street)

4.3.2 Shape and Color

• The bicycle paths on Troya Street frequently feature bicycle shapes.

• The directions of travel are indicated as shown in Figure 3.

• While the color of the road alignment is blue, the shapes and texts are marked in white.

4.3.3 Vegetative Buffer Zone

The bicycle paths around Troya Street in Çanakkale play an important role both aesthetically and ecologically. Greening efforts throughout the city enhance the surroundings of these paths, providing both visual appeal and environmental benefits.

Troya Street features a considerable variety of plant species. However, the vegetation along the edges of the bicycle paths is localized. While some areas have dense plant coverage, others are limited to grass only. This situation highlights a lack of sufficient vegetative buffer zones along the bicycle paths. The existing plants in the area are predominantly trees, with the acacia tree being the most commonly used species.

Figure 4. (Troya street)

4.4.3.1 Vegetation Obstructing Bicycle Path

Cyclists using the bicycle path occasionally encounter vegetation obstructing their passage. This issue becomes more pronounced during early spring when plants bloom, further exacerbating the obstruction and negatively impacting the cyclist's experience.

Figure 5. (Troya street)

4.4.4 Table

One of the critical elements for cyclists is signage. Warning signs should not be so small that they are noticed only at the last moment; instead, they should be clearly visible and properly positioned throughout the area.

On Troya Street, a sufficient number of signs are available to indicate the bicycle path and provide route guidance. Along the route, signage is present in sections where the bicycle lane shares space with pedestrian paths, in areas dedicated solely to bicycles, and at the starting and ending points of the path. Rather than being placed at fixed intervals, signs are installed in locations where they are deemed necessary.

• **Current average spacing between signs:** 300–400 meters

• **Recommended spacing:** Directional and warning signs every 100–150 meters

• **Improvement suggestion:** All signs should be covered with reflective material to enhance visibility, especially at night.

4.4.4.1 Assessment of Bicycle Infrastructure on Troya Street, Çanakkale

Based on the current data, it can be concluded that the bicycle signs on Troya Street:

• Are partially sufficient,

• However, in some areas, they are missing or inadequately placed,

• And especially in terms of nighttime visibility, there is significant room for improvement.

Figure 6. (Troya street)

4.4.5 Lighting

In nighttime cycling, the most critical safety issue is undoubtedly lighting.

4.4.5.1 Bicycle Path Lighting Standards

In Turkey, the lighting of bicycle paths is regulated according to specific standards defined in sources such as the Bicycle Paths Regulation and the Lighting Portal:

• **Illumination Level:** A general lighting level of 5 lux is considered sufficient for most bicycle paths. However, in specific cases such as training or racing, illumination levels of 300 lux or even 600 lux may be recommended.

• **Lighting Types:** Various lighting types can be used for bicycle paths, including LED street luminaires, floodlights, and bollard fixtures.

• **Lighting Height:** In cases where solar panels are used, the bottom surface of the panels must be at least 3 meters above the ground level of the road.

• **Lighting Distance:** According to Turkish standards, the spacing between poles should generally be between 20–30 meters (Lighting Portal, 2021). However, on Troya Street in Çanakkale, this distance exceeds 40 meters in some sections, leading to the formation of dark zones.

Lighting Conditions on Troya Street Bicycle Paths: On the bicycle paths along Troya Street in Çanakkale:

Street lighting typically covers an area of about 20 meters—extending approximately 8–10 meters to the left and right from directly beneath the lamp. The average illuminance (lux) under the streetlights is about 16.1 lux, but it drops to as low as 0.3 lux at the farthest point the light reaches.

There is no dedicated lighting for the bicycle paths themselves; instead, general street and roadway lighting is relied upon. In some locations, streetlights are placed 8–10 meters away from the bicycle path, while in others, they only illuminate the path from the end of the bicycle lane toward the road, rather than directly above or along it.

Figure 7. (Troya street, lighting)

4.4.6 Damaged Roads

Damaged roads pose a significant risk for nighttime cycling. In dark environments where visibility is limited, surface defects such as potholes, cracks, or uneven pavement may go unnoticed by cyclists, potentially leading to falls, injuries, or accidents. This danger is especially heightened on poorly lit bicycle paths, where riders may not have enough time to react or maneuver. Furthermore, damaged roads can harm bicycle components such as tires, rims, and suspension systems, shortening the equipment's lifespan and negatively impacting riding comfort. Therefore, regular maintenance of bicycle paths and the preservation of smooth and safe surfaces are crucial for ensuring rider and supporting the sustainability of urban cycling, especially at night safety support.

Figure 8. (Troya Street , bicycle path)

5. CONCLUSION AND EVALUATION

In addition to its historical and cultural richness, Çanakkale serves as a significant example in terms of adopting sustainable lifestyles through modern transportation solutions. The expansion of bicycle paths and their use during nighttime are reshaping the city's transportation dynamics and enabling individuals to adopt healthier lifestyles The illumination of bike paths at night holds great importance not only for safety but also for aesthetics and social interaction. A well-designed lighting system enhances users' visibility, offering a safe transportation alternative in the dark and preventing potential accidents. Moreover, aesthetically enriched bike paths create an attractive atmosphere for both locals and tourists, adding vibrancy to the city's nightlife.

From an environmental perspective, the use of bicycle paths reduces vehicle traffic in the city and helps prevent environmental pollution. Cycling at night offers a beneficial alternative in terms of both individual health and environmental well-being, strengthens users' connection with nature, and increases environmental awareness. However, existing issues should not be overlooked. Damaged roads, inadequate lighting, and the placement of café and restaurant seating areas at the entrances of bicycle paths may pose safety risks for cyclists. In addition, human factors—such as pedestrians who do not recognize the boundaries of bike paths—can lead to accidents.

In conclusion, while Çanakkale's bicycle paths have become a symbol of sustainable transportation and social interaction, it is of great importance to take necessary steps to improve the safety and quality of these routes. In the future, better planning of bike paths, regular maintenance, and raising public awareness will support Çanakkale's goal of becoming a more bicycle-friendly cit

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Design of Water Surface Environments in Green Areas Water Gardens and Plants That Can Be Used

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1. INTRODUCTION

Water has a very special quality as an element in landscape design. Over many centuries and in many countries it has in turn been acknowledged and exploited, and it has inspired. It has been a great provider not only in physical terms, but also in the many ways it has contributed to both natural and man-made environments through its aesthetic qualities (Whalley, 1988).

Water, which has countless features such as tranquility, movement, sound, optics, joy, cooling, recreation, color and light, is a versatile design element in landscape architecture studies. It is an indispensable need that creates healthy environments for people in terms of biology, physics and psychology in interior and exterior spaces and is found in spaces of different forms and sizes.

Recently, the art of landscape gardening sharpened in using natural components like soil, water and air. Among them, water plays a major role as most important element that can be included in landscape design. A waterscape is an art and science of incorporating water features into a of landscape in which the expanse of water is a dominant feature where planting of aquatic and semi-aquatic plants in and around the pool, ponds, streams and other water features (Nagajyothi ve Pratheeksha, 2023).

Water gardens, which are created by planning the water in the landscape design with in-water and coastal plants in accordance with the design principles, have many aesthetic, functional and ecological contributions to the environment. Aquatic plants not only provide nutrients and oxygen to the water environment but also serve as shelter and breeding grounds for aquatic organisms. Many of them have aesthetic functions with their leaves or flowers and visually appealing images (Söğüt 1996). However aquatic plants have not been included in the subjects of Landscape Architecture. These plants, which both help the natural life functionally and appeal to the eye aesthetically, need to explain the qualifications they possess, to make the researches that these plants contain and to make them deserved the place and importance of the landscape architecture studies (Külekçi, 2000).

In this study, the design principles of water gardens in landscape architecture are explained and it is aimed to introduce coastal and in-water plants that have visual, aesthetic and functional value in the design used with the water item. In this context, information such as morphological characteristics, ecological requirements, flowering periods, planting times, life spans of plants were compiled from various sources, and various usage suggestions were presented in terms of plant design.

2. WATER GARDENS DESIGN PRINCIPLES

“Water gardens” is the name given to the water unit that forms a complete ecological balance with its flora, fauna and microorganisms, which emerges by designing the water with aquatic plants in an aesthetic form suitable for the surrounding landscape, according to the planning principles and application technique (Swindells, 1999).

The principles of water garden design can be explained as follows: (Kavaklı, 1994; Koç et al, 2000; Muratoğlu, 2010).

- One of the most important issues to be given importance is the location of water in the garden. Since the water surface is the most attractive part of the green area, care should be taken to ensure that it is well perceived and that it forms a focal point from suitable places when determining its location.

- Most aquatic plants require sunlight, and the sun creates the necessary heat for aquatic plants. When determining the location of the water surface, a sunny location should be chosen. Ideally, a location that receives at least eight hours of sunlight should be chosen.

- The type of land use and circulation in the area also affect the use of water plants. The proximity of the water surface to the road, its shape and size affect the selection and use of plants. Water is also an organizing element in the area within the general regulation principles. If water creates an area only for plant use, it should be arranged in accordance with the regulation principles such as emphasis, harmony and contrast within the general principles and should form a whole only within itself.

- Aquatic plants can be arranged either formally or informally. Formal arrangement is generally preferred for small areas of water, while informal arrangement can lead to chaos. In small water surfaces, formal arrangement with few plant species increases efficiency. In large areas, formal or informal arrangements can be made according to the type of arrangement; however, formal arrangement requires more labor and time.

- Locations should be chosen that are sheltered from cold north and east winds. Water plants are damaged by these winds as they cause cold and strong turbulence.- In the water garden, resting and viewing areas and walking paths should be planned in accordance with the size of the area.

- The water edge slope around the water surface should be no more than 50%.

- When determining the location of water gardens where the base level is desired to be created, places with good drainage should be preferred in order to prevent intermittent soil and tank drifting into the ground with rainfall. In life with drainage problems, drained or raised pools should be preferred before establishing an earthen water garden.

- Reinforced concrete flooring or bituminous flooring systems should be used against soil permeability.

- Water revenue-expenditure and overflow systems should be established in water structures.

- Plant crates should be made of sustainable materials, not metal.

- Precautions should be taken for ventilation and water movement should be created. For this purpose, oxygen tanks connected to an electric cable can also be used.

- Measures should be taken against the danger of falling into the water and drowning, especially of domestic animals on the shores of water structures, and flat step-type natural stones should also be used for this purpose.

- In order to monitor aquatic plants and fauna at night, in-water lighting should be installed and spaces for monitoring should be created in large structures.

- If the water garden includes light and pump systems, it should be planned in a location where electricity can be easily supplied. This is economically and safely feasible.

- In waterfront plant design, trees such as horse chestnut (*Aesculus hippocastanum*), whose fruits have a toxic effect in water, should not be used on the waterfront. In the selection of waterfront plants, care should be taken to plant deciduous trees as far away from the water surface and in the opposite direction of the wind direction as possible, as their leaves decompose in the water and emit methane gas and damage the plants. Tree roots around the water surface can also damage the pool structure over time, so this situation should be carefully considered when determining the location.

3. PLANT USE IN WATER GARDENS

Aquatic plants: colors, textures, forms, scents are the most attractive and eye-catching elements of water gardens. However, by using water and aquatic plants together in an environmental arrangement, the reflective feature of the water is emphasized, creating a colorful and sparkling atmosphere and improving the landscape quality (Külekçi, 2000). The use of aquatic plants in water gardens is limited by environmental factors such as the water condition, topographic structure, plant and water characteristics, especially the climate.

3.1. Environmental Factors

One of the most important factors affecting the use of a plant in any area is its climatic characteristics. Climatic features in the area affect the way the water and the plant are used, as well as whether the plant will be used in the field or not (Söğüt, 1998; Swindells,1999; Robinson, 2003).

- The most important factor affecting the conditions of use in plant selection is temperature. Aquatic plants of tropical origin are not very resistant to low temperatures. In cases where the conditions are not suitable, sensitive aquatic plants should be used in pots or transferred to pools in closed places.

- A sudden increase in water temperature is a limiting factor in herb utilization. In cool-cold climatic zones, an electric water heating system is applied.

- The state of light or illumination in the environment affects the use of aquatic plants. All aquatic plants require a lot or little light for photosynthesis. Some aquatic plants need sunny environments, while others need shady environments. In the designs made, arrangements should be made by taking into account the shade-light needs of the plants.

3.2. Plant-related Features

Plant-related characteristics limit the use of plants in water gardens. The characteristics related to the plant are listed below (Ataturay, 1993; Söğüt, 1998; Swindells,1999; Robinson, 2003):

- The form of the plant affects the use in the arrangement and the number of plants used. The form of the plant in the water can provide a transition or harmony in this way, as well as create a complete accent or contrast. For example, in the aquatic environment associated with the grass area, *Nymphaea sp.* instead, the use of *Acorus gramineus* 'Variegatus', which is upright in shape and grows in groups, can achieve this goal.

- The size, color and effect of plant flowers contribute to the creation of aesthetic principles. Effects such as harmony or contrast can also be created with flowers of different colors used in water.

- The leaf size, shape, color and brightness of the plant also determine its use.

- By taking advantage of the texture characteristics of plants, different effects can be created both among themselves and within the environment and general arrangement. While some aquatic plants are quite finely textured (*Hottonia* sp., *Myriophyllum* sp.) some of them are also quite coarse (*Pontederia cordata*) textured.

- The size of the aquatic plant is also an important factor limiting its use. Especially in an arrangement made in constantly moist soils, fast-growing and large-built coastal plants can be used. These plants provide a good connection Decoupling between a water surface and other plants.

- The growth rate of aquatic plants is important in terms of determining the size of the final area that it will cover.

- The size, shapes and textures of plants that exist around the water surface may make it necessary to prefer similar properties in water.

- Plants that develop very strongly and spread over large areas in a short time should be planted in separate sections or crates to be kept under control.

3.3. Features related to water surface and depth

In addition to the characteristics of the plant related to its own structure, its functional effect on the aquatic environment also affects its choice in use. The characteristics related to the water environment are listed below (Ataturay, 1993; Söğüt, 1998; Swindells,1999; Robinson, 2003):

- Aquatic plants need water at certain depths depending on their habitat. If the depth of water is not sufficient for the aquatic plants used in an arrangement, plant growth and development will show disruptions depending on sensitivity. Plants suitable for water depth should be selected. According to the water depth of the plant, sets of different depths can be created in pools or artificial lakes. Or the plant may need to be hung in a container on the edge of the water structure.

- The size of the water surface is effective in plant selection. It is suitable to make arrangements with large groups of plants in large areas and small groups in small areas. It is not recommended to cover the entire water surface with plants. No more than 1/3 of the water surfaces should be covered with plants, the remaining area should be left open. However, in shallow waters for special purposes, the water surface can be completely covered with plants.

- The slope of the area where water is used also affects the use of plants. Appropriate plant selection should be made according to the state of stagnant or mobile water. However, plants should be arranged in such a way that the perception of water is not prevented. The plants to be selected in the arrangement can have the effect of emphasizing or reducing the slope.

4. AQUATIC PLANTS USED IN WATER GARDENS

Aquatic plants are plants that have different uses on the water shore, on the surface and inside. The plants discussed in this section are aquatic plants that can be used for different purposes in landscaping from the point of view of landscape architecture. The plants were studied under the titles of coastal plants, aquatic plants and floating plants (Söğüt, 1998).

Coastal plants: These plants are usually plants that grow in soils (mud) that are constantly wet along the water banks, or in waters that are several centimeters deep. Some of these plants can also spend certain periods in normal soil conditions.

In Table 1, where coastal plants are included, the design characteristics of plants are numbered with consecutive numbers. The descriptions of these features are presented at the bottom of the table.

Table 1. Coastal plants that can be used in water gardens (Söğüt, 1998; Topaldemir and Taş, 2024; Anonymous, 2025a; Anonymous, 2025b; Anonymous, 2025c; Anonymous, 2025d).

Abbreviations: L: Leaf - F: Flower - D.F.: Design Feature						
COASTAL PLANTS						
Plant Form/ Height (cm)	**Leaf / Flower Feature**	**Flower Form / Flowering Period**	**Leaf Form**	**Life Span / Planting Time**	**Ecological Requirements**	**D.F.**
***ACORUS* / Acoraceae**						
***Acorus calamus* L. (Sweet Flag) (Topaldemir and Taş, 2024)**						
Cluster Form/ 15-90	L: Scented Leaf F: Yellowish green	Spadix, cylindrica/ May-June	Long spear	Perennial-Herbaceous/ March-June	Still-shallow waters, full sun	1
***Acorus calamus* 'Variegatus' (Variegated Sweet Flag)**						
Cluster Form – Upright/ 60-90	L: Green, cream and pink F: It rarely blooms	Spadix, cylindrical/ Summer	Long spear	Perennial-Herbaceous/ March-June	Shallow waters	2
***Acorus gramineus* Sol. (Japanese Sweet Flag)**						
Cluster Form – Upright/ 15-50	L: Scented Leaf F: Yellow whitish	Spadix, cylindrical/ March-June	Long spear	Perennial-Herbaceous/ March-June	Shallow waters	3
***Acorus gramineus* 'Variegatus' (Variegated Japanese Sweet Flag)**						
Cluster Form – Upright/ 15-30	L: Dark green, cream F: Green	Spadix, cylindrical/ Early and midsummer	Long spear	Perennial-Herbaceous/ March-June	Shallow waters, penumbra	4
***ALISMA* / Alismataceae**						
***Alisma plantago-aquatica* L.**						
Upright Structur/ 15-30	L: Bright green F: Rose pink, red	Pyramidal cluster/ Early autumn	Spear	Perennial-Herbaceous/ Spring	Sandy loam soil, Shallow water, Full sun	5
***Alisma parviflora* Engelm. (Small-flowered Water-plantain)**						
Upright Structur/ 30-75	L: Bright green F: White, pink	Pyramidal cluster/ Summer	Oval	Perennial-Herbaceous/ Spring	Sandy loam soil, Shallow water, Full sun	6

Table 1. Coastal plants that can be used in water gardens (cont.).

Plant Form/ Height (cm)	Leaf / Flower Feature	Flower Form / Flowering Period	Leaf Form	Life Span / Planting Time	Ecological Requirements	D.F.
Abbreviations: L: Leaf - F: Flower - D.F.: Design Feature						
***Alisma ranunculoides* (L.) Parl. (Small Water-plantain)**						
Upright Structur/ 15-30	L: Bright green F: Rose pink, red	Pyramidal cluster/ Autumn sowing	Spear shaped	Perennial-Herbaceous/ Spring	Sandy loam soil - Shallow waters	7
***Alisma lanceolatum* (Lanceleaf Water-plantain)**						
Upright Structur/ 15-130	L: Bright green F: Pink, purple or white	Pyramidal/ April-September	Long Oval	Perennial-Herbaceous/ Spring	Still water, marsh, full sun	8
***Alisma gramineum* Lej. (Narrowleaf Water-plantain)**						
Upright Structur/ 20-90	L: Bright green F: Pink, white	Cluster/ Late summer	Oval	Perennial-Herbaceous/ Spring	Stagnant water, swamp	9
***BUTOMUS* / Butomacea**						
***Butomus umbellatus* L. (Flowering Rush)**						
Upright Structur/ 50-150	L: Bronze, purple or green F: Pink, red	Umbrella/ June-August	Sword shaped triangular	Perennial-Herbaceous/ Spring	Shallow waters, constantly moist areas	10
***CALLA* / Araceae**						
***Calla palustris* L.**						
Upright Structur/ 15-30	L: Bright green F: White	Spadix, cylindrical/ May-June	Heart shaped	Perennial-Herbaceous/ Spring	Shallow water and moist areas	11
***Calla aethiopica* L. (Calla Lily)**						
Upright Structur/ 60-75	L: Green F: White	Spadix, cylindrical/ May-June	Broad spear shape	Perennial-Herbaceous/ Spring	Sunny areas rich in organic matter	12
***CALTHA* / Ranunculaceae**						
***Caltha palustris* L. (Marsh Marigold)**						
Upright Structur/ 15-60	L: Dark green F: Bright yellow	Simple single flower / July-August	Round	Perennial-Herbaceous/ Spring-Autumn	Moist soils rich in nutrients	13

Table 1. Coastal plants that can be used in water gardens (cont.).

Abbreviations: L: Leaf - F: Flower - D.F.: Design Feature						
Plant Form/ Height (cm)	**Leaf / Flower Feature**	**Flower Form / Flowering Period**	**Leaf Form**	**Life Span / Planting Time**	**Ecological Requirements**	**D.F.**
***Caltha palustris* 'Alba' (Kral Çiçeği)**						
Upright Structur/ 30-40	L: Dark green F: White	Simple single flower / March-July	Round	Perennial-Herbaceous/ Early Spring	Shallow waters and moist soils	14
***Caltha palustris* 'Flere Pleno' (Double-flowered Marsh Marigold)**						
Horizontal-vertical/ 15-30	L: Dark green F: Golden yellow	Layered/ Spring-Early summer	Round	Perennial-Herbaceous/ Early Spring	Shallow waters and moist soils	15
***Caltha leptocephalus* (Alpine Marsh Marigold)**						
Horizontalvertical / 15-45	L: Dark green F: Silvery White	Bowl/ Late Spring	Round, heart	Perennial-Herbaceous/ Early Spring	Full sun and continuous	16
***Caltha polypetala* Hochst. (Marsh Marigold)**						
Round form/ 30-100	L: Bright green F: Golden yellow	Bowl/ Late spring-summer	Round, heart	Perennial-Herbaceous/ Early Spring	Full sun and constantly moist areas	17
***CAREX* / Cyperaceae**						
***Carex nigra* L. (Black Sedge)**						
Clustered vertical/ 7-70	L: Dark green F: Purple	Cylindrical spike/ May-July	Thin long strip	Perennial-Herbaceous/ Spring-early summer	Constantly moist soil and shallow water	18
***Carex pendula* 'Hudson' (Hudson's Pendulous Sedge)**						
Round top/ 90-120	L: Dull Green F:Brownish green	Cylindrical spike/ May-July	Thin long strip	Perennial-Herbaceous/ End of March	Constantly moist soil and shallow water	19
***Carex riparia* 'Aurea' (Golden Greater Pond Sedge)**						
Round top/ 30-75	L: Golden yellow F: Brown	Cylindrical spike / May-August	Thin long strip	Perennial-Herbaceous/ May-August	Moist soils	20
***CYPERUS* / Cyperaceae**						
***Cyperus longus* L. (Sweet Cyperus)**						
Vertical form/ 90-120	L: Bright green F: Red brown	Flat spikelet/ Late summer	Drooping umbrella	Perennial-Herbaceous/ Early Spring	Clay loam Soil - Permanently moist area	21

Table 1. Coastal plants that can be used in water gardens (cont.).

Abbreviations: L: Leaf - F: Flower - D.F.: Design Feature						
Plant Form/ Height (cm)	**Leaf / Flower Feature**	**Flower Form / Flowering Period**	**Leaf Form**	**Life Span / Planting Time**	**Ecological Requirements**	**D.F.**
***Cyperus vegetus* Willd. (Stout Sedge)**						
Vertical form/ 30-60	L: Bright green F: Reddish black	Flat spikelet/ Late summer	Drooping umbrella	Perennial-Herbaceous/ Early Spring	Clay loam Soil - Permanently moist area	21
***Cyperus alternifolius* L. (Umbrella Papyrus)**						
Vertical form/ 90-120	L: Bright green F: Brown, Green	Cluster/ Late summer	Umbrella	Perennial-Herbaceous/ Early Spring	Clay loam Soil - Permanently moist area	21
***IRIS* / Iridaceae**						
***Iris laevigata* Fisch. (Rabbit-ear Iris)**						
Clustered form/ 60-90	L: Green F: Blue	Drooping petal/ Early summer	Straight Sword	Perennial-Herbaceous plant/ Early summer	Sunny areas, moist waterfronts	22
***Iris laevigata* 'Alba'**						
Clustered form/ 60-90	L: Green F: White	Drooping petal/ Early summer	Straight Sword	Perennial-Herbaceous plant/ Early Spring	Sunny areas, moist waterfronts	22
***Iris laevigata* 'Colchester'**						
Clustered form/ 60-90	L: Green P: Purple, blue, white	Drooping petal/ Early summer	Straight Sword	Perennial-Herbaceous plant/ Late autumn	Sunny areas, moist waterfronts	22
***Iris laevigata* 'Murakumo'**						
Clustered form/ 60-80	L: Green F: Blue	Drooping petal/ Early summer	Straight Sword	Perennial-Herbaceous plant/ Early Spring	Sunny areas, moist shallow water edges	22
***Iris laevigata* 'Regal'**						
Clustered form/ 60-75	L: Green F: Purplish red	Drooping petal/ Early summer	Straight Sword	Perennial-Herbaceous plant/ Late autumn	Sunny, constantly moist shallow waters	22

Table 1. Coastal plants that can be used in water gardens (cont.).

Abbreviations: L: Leaf - F: Flower - D.F.: Design Feature

Plant Form/ Height (cm)	**Leaf / Flower Feature**	**Flower Form / Flowering Period**	**Leaf Form**	**Life Span / Planting Time**	**Ecological Requirements**	**D.F.**
***Iris laevigata* 'Eosa Queen'**						
Clustered form/ 60-75	L: Bright green F: Pink	Drooping petal/ Early summer	Straight Sword	Perennial/ Early Spring	Sunny areas, moist	22
***JUNCUS* / Junaceae**						
***Juncus effusus* L. (Soft Rush)**						
Clustered form/ 30-150	L: Green F: Yellowish	Wisteria/ Late Spring	Long strip	Perennial-Herbaceous plant/ Spring	Permanently moist areas, waterfronts	23
***Juncus effusus* 'Spiralis' (Spiral Soft Rush)**						
Clustered form/ 30-45	L: Dark green F: Reddish	Cluster/ June-August	Spiral	Perennial-Herbaceous plant/Spring	Permanently moist areas, waterfronts	23
***Juncus effusus* 'Vittatus' (Variegated Soft Rush)**						
Clustered form/ 30-45	L: Golden yellow and green F: Cream White	Sparse cluster/ June-August	Long strip	Perennial-Herbaceous plant/Spring	Permanently moist areas, waterfronts	23
***Juncus acutus* L. (Spiny Rush)**						
Clustered form/ 25-150	L: Green F: Reddish brown	Group-spherical/ June-October	Long strip	Perennial-Herbaceous plant/Spring	Marshes and saltwater edges	23
***MENTHA* / Labiatae**						
***Mentha aquatica* L. (Water Mint)**						
Upright structure/ 15-90	L: Dark green F: Purple	Group-sphere-shaped/ Summer	Long, oval	Perennial-Herbaceous plant/ Spring-autumn	Constantly moist soils	24
***MENYANTHES* / Menyanthaceae**						
***Menyanthes trifoliata* L. (Bogbean)**						
Upright structure/ 12-30	L: Pink, white F: White	Star shaped/ Late Spring	Oval	Perennial-Herbaceous plant/ Spring, early summer	Moist soils, marshes, lakeside	25

Table 1. Coastal plants that can be used in water gardens (cont.).

Plant Form/ Height (cm)	Leaf / Flower Feature	Flower Form / Flowering Period	Leaf Form	Life Span / Planting Time	Ecological Requirements	D.F.
Abbreviations: L: Leaf - F: Flower - D.F.: Design Feature						
***PHRAGMITES* (Kamış) / Graminaceae**						
***Phragmites australis* Cav. (Reed)**						
Upright structure/ 120-150	L: Green F: Silvery white, purplish	Compound cluster/ Late summer	Long strip	Perennial-Herbaceous plant/Spring	Humid areas with full sun	26
***Phragmites australis* 'Variegatus' (Variegated Common Reed)**						
Upright structure/ 90-120	L:Variegated cream, green	-	Long strip	Perennial-Herbaceous plant/Spring	Humid areas with full sun	27
***POLYGONUM* / Polygonaceae**						
***Polygonum amphibium* L. (Water Smartweed)**						
Upright structure/ 30-90	L: Green F: Pink	Cylindrical/ June-September	Long, oval	Annual-Herbaceous/ Spring	Fully sunny areas	28
***Polygonum lapathifolium* L. (Pale Persicaria)**						
Upright structure/ 30-100	L: Green F: Pink	Long cylindrical/ August-September	Flat, ellipse, lanceolate	Annual-Herbaceous/ Spring	Fully sunny areas	29
***Polygonum persicaria* L. (Lady's Thumb)**						
Upright structure/ 30-100	L: Green F: Bright pink	Cylindrical/ Early summer - autumn	Flat, ellipse, lanceolate	Annual-Herbaceous/ Spring	Fully sunny areas	30
***Polygonum hydropiper* L. (Waterpepper)**						
Upright structure/ 20-80	L: Green F: Pink or greenish	Spike/ July-September	Spear-oval	Annual-Herbaceous/ Spring	Full sun, constantly wet areas	30
***Polygonum bistorta* L. (Bistort)**						
Upright structure/ 30-60	L: Light green F: Pink	Cylindrical spike / Late Spring	Oval	Annual-Herbaceous/ Spring	Shady, slightly moist soil and rocky areas	31
***PONTEDERIA* / Pontederiaceae**						
***Pontederia cordata* L.**						
Upright structure/ 45-90	L: Bright green F: Blue	Cylindrical spike/ Autumn	Oval-spear	Perennial-Herbaceous/ Spring	Clay loam soil, sunny areas	32

Table 1. Coastal plants that can be used in water gardens (cont.).

Abbreviations: L: Leaf - F: Flower - D.F.: Design Feature

Plant Form/ Height (cm)	Leaf / Flower Feature	Flower Form / Flowering Period	Leaf Form	Life Span / Planting Time	Ecological Requirements	D.F.
***SAGITTARIA* / Alismataceae**						
***Sagittaria sagittifolia* L. (Arrowhead)**						
Upright structure/ 30-90	L: Green F: White	Globe/ July-August	Oval	Perennial-Herbaceous/ Spring	Sunny areas, shallow waters	33
***Sagittaria latifolia* Willd. (Broadleaf Arrowhead)**						
Upright structure/ 30-90	L: Dark green F: Cream white	Globe/ Summer and autumn	Narrow lanceolate	Perennial-Herbaceous/ Spring	Constantly moist areas	33
***Sagittaria japonica* Miq. (Japanese Arrowhead)**						
Upright structure/ 45-60	L: Green F: Cream white	Folded globe/ Summer	Spear	Perennial/Spring-autumn	Constantly moist areas, shallow pools	33
***JUNCUS* (Hasırotu) / Junaceae**						
***Juncus effusus* L. (Soft Rush)**						
Clustere/ 30-150	L: Green F: Yellowish	Cluster/ June-August	Pointed stripy	Perennial/Spring-autumn	Permanently moist areas, waterfronts	34
***Juncus acutus* L. (Spiny Rush)**						
Clustered pointed/ 25-150	L: Green F: Red Brown	Group sphere/June-October	Pointed strip	Perennial/Spring-autumn	Marshes, saltwater edges	34
***MENYANTHES* (Bataklık tırfılı) - Menyanthaceae**						
***Menyanthes trifoliata* L. (Buckbean)**						
Upright structur/ 12-30	L: Pink, white F: White	Sparse spike/ Late Spring	Long, oval	Perennial-herbaceous/	Moist soils, marshes, lakeside	35
***POLYGONUM* L. / Polygonaceae**						
***Polygonum lapathifolium* L. (Pale Persicaria)**						
Belt form/ 30-100	L: Green F: Pink	Drooping cylinder/ August-September	Flat, ellipse, lanceolate	Annual-Herbaceous/ Spring	Partially shaded areas, nutrient soil	36
***Polygonum persicaria* L. (Spotted knapweed)**						
Arch shaped/ 30-100	L: Green F: Bright pink	Drooping cylinder/ August-September	Flat, ellipse, lanceolate	Annual-Herbaceous/ Spring	Partially shaded areas, nutrient soil	36

Table 1. Coastal plants that can be used in water gardens (cont.).

Plant Form/ Height (cm)	Leaf / Flower Feature	Flower Form / Flowering Period	Leaf Form	Life Span / Planting Time	Ecological Requirements	D.F.
Abbreviations: L: Leaf - F: Flower - D.F.: Design Feature						
***SCRIPTUS* L. / Cyperaceae**						
***Scirpus lacustris* L. (Lake Club-rush)**						
Upright structur/ 100-300	L: Green F:Reddish brown	Umbrella/ July-August	Sagging strip	Perennial-herbaceous/ Spring	Shallow, stagnant waters, swampy areas	37
***Scirpus littoralis* Schrad. (Shore Bulrush)**						
Upright structur/ 100-150	L: Green F: Brown	Cylindrical/ August-February	Drooping stripy	Perennial-herbaceous/ Spring, autumn	Shallow, stagnant waters, swampy areas	38
***SPARGANIUM* L. / Sparganiaceae**						
***Sparganium ramosum* 'Hudson' (Branched Bur-reed)**						
Belt shaped/ 25-200	L: Green F: Green, brown	Globe/ Summer	Sword form	Perennial-herbaceous/ Spring, autumn	Permanently moist areas and waterfronts	38
***Sparganium emersum* 'Rehman' (Narrowleaf bur-reed)**						
Sagging belt/ 20-90	L: Green F: White	Cylindrical/ July-August	Wide and flat	Perennial-herbaceous/ Spring	Constantly moist areas	38
***TYPHA* L. (Kedi Kuyruğu) / Typhaceae**						
***Typha Minima* 'Hoppe' (Mini Cattail)**						
Upright structur/ 30-60	L: Green F: Reddish brown	Cylindrical/ July-August	Wide and flat	Perennial-herbaceous/ Spring	Loamy humus soils	39
***Typha angustifolia* (Narrow-leaved Bullrush)**						
Upright structur/ 120	L: Green F: Reddish brown	Cylindrical/ May-July	Narrow and flat	Perennial-herbaceous/ March-May	Permanently moist areas and waterfronts	40
***Typha latifolia* L. (Broadleaf Cattail)**						
Upright structur/ 180-250	L: Light yellow green F: Brown	Cylindrical/ June-July	Wide and flat	Perennial-herbaceous/ March-May	Permanently moist areas and waterfronts	41

1: It can be used for various compositions to create a Natural Look, create a background and contrast effect. **2:** Its attractive, fragrant spear-like leaves remain dark green with distinctive white stripes throughout the season. They create a backdrop effect. **3:** It can be used for various compositions to create a background and contrast with the colors and sizes of its flowers and leaves. **4:** It is usually used in rock gardens as a solitary or group plant to create a background effect. **5:** It is effective with its leaves. Its flowers open in the afternoon and close in the evening, its leaves are decorative. It can be used in large pools. **6:** It blooms on spikes. It is suitable for use on riverbanks. It attracts wild animals. **7:** It can be used in areas where emphasis is desired with the leaf form. **8:** Its leaves are above water. Its flowers open in the afternoon. It creates a green surface by covering the water surface with its leaves. **9:** Its leaves are above or below water. Its flowers are showy and eye-catching because they are above water. **10:** Effective with its leaves that change color according to the season. Bronze colored leaves in autumn. Showy compositions with showy flowers and leaves. Creates a contrast with *Pontederia cordota*. **11:** It can be used to emphasize the rough texture of its leaves and flowers, and the color of its fruits. **12:** It can be used as a transition plant between different forms. **13:** Its leaves and flowers are quite bright and showy. It opens its flowers high from the neck. It blooms in early spring. It is suitable for design for color and flower effect. It creates an accent effect in terms of color and texture. **14:** It can be used to draw attention and highlight the design with the showiness of its flowers. **15:** It adds variety to the design in terms of form with its flowers resembling a pompom shape. **16:** With its aesthetic form, it can be used to transition between designs and create emphasis. **17:** It is quite decorative and eye-catching with its large pool and flower colors on the edges of the moving water. **18:** It can be used to create a backdrop for plants used with purple flowers. **19:** It can be used to create emphasis in designs with its drooping form. **20:** It is suitable for use on pool edges. The yellow color of its leaves can create a contrasting effect with green-leaved species. **21:** It can be used decoratively in shallow waters with its leaves forming drooping umbrellas. **22:** It is used to create green masses with cluster forms. It can be used to create different compositions with its striking flowers. It creates a background with other plants with its flowers blooming on its leaves. It can be used to create contrast with other plants with its natural appearance. **23:** It adds movement to the design with its long, thin leaves and forms a backdrop for other short plants. **24:** It is generally used for medicinal and spice purposes. It is used decoratively with its abundant leaves and flowers. It is used in areas that need to be covered immediately due to its rapid growth. **25:** It creates an aesthetic appearance with its decorative leaves and white flowers blooming on a stem. **26:** Due to its tall stature and rapid growth, it can be used with a flower effect in plant arrangements in large areas. **27:** It is more effective to plant densely because it is a slow growing species. It can be used to create a contrasting effect in designs because its leaves are striped and cream colored. **28:** Since they grow quickly, they can be used decoratively in large areas with flower and leaf effects. They can be used solitary with distinct flower colors to create an accent effect. **29:** Since they grow and spread extremely fast, they should be planted in a controlled manner in design. **30:** An accent effect can be created thanks to the solitaire with distinct flower colors. **31:** Flower spikes are very showy and grow superficially in water. Available as solitary in design. **32:** It is used decoratively with its blue flowers blooming on the spike. Can be used in groups in ponds and lakes. **33:** With its white flowers, it provides a softening effect in the transition between compositions. **34:** It can be planted at the edges of ponds or pools of water to create a natural transition area. It can be planted near the water surface or submerged in shallow water, adding depth and height to the aquascape. **35:** It creates an aesthetic appearance with its decorative leaves and white flowers blooming on a stem. **36:** Since they grow quickly, they can be used decoratively in large areas with flower and petal effects in design. **37:** The use of the principle of repetition can be achieved by using it in many different areas. **38:** It can be used for decorative purposes with its spherical flower clusters emerging from the trunk nodes. Having wide leaves, it can be used together with other narrow-leaved plants to create contrast in designs. **39:** Because they grow very quickly, they can be used in limited areas. **40:** The flowers are quite striking on the spikes. They can be used to create emphasis. **41:** It is suitable for pool edges. It creates a contrast with itself with the leaf tips curved downwards.

In-water plants: The reason why aquatic plants provide oxygen balance in water is because they constantly enrich the water with oxygen. Aquatic plants provide shelter and protection for fish and other small aquatic organisms, and some of them are used as food by these organisms. Microorganisms living on aquatic plants are also effective in increasing the rate of photosynthesis in water.

In addition to the presence of unpretentious plants such as *Chara aspera*, *Elodea canadensis*, which can be qualified as "water grasses" in aquatic plants, there are also plants such as *Hottonia palustrus*, *Potamogeton crispus* and *Ranunculus aquatilis*, which give aesthetics and mobility to water. The roots, trunk and leaves of the plant are in water. The flowers usually open above the water level.

In addition to ensuring aesthetics in the arrangements to be made with water, maintaining the balance in the water may also be important. In a water landscape arrangement, maintaining the arrangements in the constantly moist soils on the shore and shallow water areas can also be used to create visual emphasis in the space.

In Table 2, where the plants living in water are included, the design properties of the plants are numbered with consecutive numbers. Descriptions of these features are presented at the bottom of the table.

Table 2. Plants that live in water that can be used in water gardens (Söğüt, 1998).

IN-WATER PLANTS						
Abbreviations: L: Leaf - F: Flower - D.F.: Design Feature						
Plant Form/ Height (cm)	**Leaf / Flower Feature**	**Flower Form / Flowering Period**	**Leaf Form**	**Life Span / Planting Time**	**Ecological Requirements**	**D.F.**
***APIUM* / Apiaceae**						
***Apium inundatum* L. Rchb.fil. (Lesser Marshwort)**						
Upright structur/ 30-100	L: Green F: White	Sphere/ Spring, autumn	Oval spear	Perennial/ Spring, autumn	Sunny area, rich soil	1
***CALLITRICHE* / Plantaginaceae**						
***Callitriche stagnalis* Scop. (Water Starwort)**						
Emanative/ 15-50	L: Green F: White	Lanceolate/ Summer	Round	Herbaceous perennial/ March, may	Permanently moist or wet soils	2
***ELODEA* / Hydrocharitaceae**						
***Elodea canadensis* Michx. (Canadian Waterweed)**						
Upright structur/ 25-140	L: Pinkish green F: White	Petal/ June-September	Long stripy	Herbaceous perennial/ March-may	Slow flowing waters	3
***HOTTONIA* / Primulaceae**						
***Hottonia palustris* L. (Water Violet)**						
Upright structur/ 10-30	L: Green F: White	Simple five leaves/ May-July	Narrow strip	Herbaceous perennial/ Spring	Still, slow-flowing fresh water	4
***LOBELIA* / Campanulaceae**						
***Lobelia dortmanna* L. (Water Lobelia)**						
Upright structur/ 20-60	L: Light green F: Blue purple	Umbrella form/ Summer	Long strip	Herbaceous perennial/ Spring	Sunny semi-shady areas stagnant water	5
***LUDWIGIA* / Onagraceae**						
***Ludwigia natans* (Marsh marigold)**						
Ivy/ 15-30	L: Dark green, purplish F: Greenish yellow	Petal / June-September	Oval spear	Perennial Herbaceous / March	Clayey, loamy soil	6

Table 2. Plants that live in water that can be used in water gardens (cont.).

Abbreviations: L: Leaf - F: Flower - D.F.: Design Feature						
Plant Form/ Height (cm)	**Leaf / Flower Feature**	**Flower Form / Flowering Period**	**Leaf Form**	**Life Span / Planting Time**	**Ecological Requirements**	**D.F.**
***Ludwigia stolonifera* (Guill. And Perr.) (Creeping buttercup)**						
Ivy/ 30-60	L: Dark green F: Yellow	Petal / Summer	Lanceolate ellipse	Perennial / spring-summer	Current waters like lakes and rivers	6
***Ludwigia palustris* (Marsh marigold)**						
Ivy/ 10-40	L: Brown Red F: Reddish brown	Star / July-September	Round elliptical	Perennial / spring-summer	Sunny areas and flowing waters	6
***MYRIOPHYLLUM* / Haloragidaceae**						
***Myriophyllum spicatum* L. (Spiked watermilfoil)**						
Lying/ 50-250	L: Brown Green F: Pinkish red	Cluster / June-July	Compound	Perennial / spring-summer	They live both in water and on land	**7**
***RANUNCULUS* (Düğün Çiçeği) / Ranunculaceae**						
***Ranunculus aquatilis* L. (Water buttercup)**						
Emanative/ 30-90	L: Dark green F: White with yellow in the middle	Petal / May-July	Simple three-leaf	Perennial / Spring and fall	Calm and slowly flowing oxygenated waters	8
***Ranunculus bullatus* L. (Bulbous buttercup)**						
Emanative/ 20-25	L: Green F: Orange, yellow	Layered / Autumn-Winter	Oval	Perennia-Herbaceous /Spring	Still and slow-flowing waters	9
***Ranunculus fluitans* Lam. (River buttercup)**						
Emanative/ 15-60	L: Green F: White	Petal / June-July	Strip	Perennia-Herbaceous /Spring	Still and slow-flowing waters	10

1: Its green leaves and white flowers add an aesthetic appeal to wetlands. This increases the visual appeal in parks and gardens. **2:** Its thin leaves and spreading on the water surface provide an aesthetic appearance as well as a great background view. **3:** It is used for emphasis with its white flowers emerging to the surface of the water. It also provides a clean water appearance with its water cleaning feature. **4:** Red leaves can be used to establish separability between species. **5:** With its large, showy flowers, it is suitable for use as a transition plant, creating a backdrop for other plants. **6:** It can be used for the purpose of camouflaging the in-water images that need to be closed with a remarkable leaf and flower color and a hugging climber form. It can also be used to create a contrast with other green-colored plants in the design. **7:** Their stems acquire a reddish color during maturity and provide a decorative appearance with the aesthetic arrangement of their leaves. **8:** With its bright and colorful flowers, it can be used to attract attention in designs. **9:** Because its flowers are fragrant, it is suitable for use in waters near seating areas. **10:** With its white colored flowers, it can provide transition funds to other plants in the design.

Floating plants: Floating plants develop in two types. Some of them cling to the soil at the bottom of the water with their roots, their leaves float on the water, and their flowers open on the water. Some of the floating plants, on the other hand, float freely on the water without clinging to any place. These plants are plants that drift freely on the water surface with wind and wave movements and have no relationship with the soil. They usually develop in colonies (Söğüt, 1998).

In Table 3, where there are plants floating in water, the design properties of plants are numbered with consecutive numbers. The descriptions of these features are presented at the back of the table.

Table 3. Floating plants that can be used in water gardens (Söğüt, 1998).

Abbreviations: L: Leaf - F: Flower - D.F.: Design Feature						
FLOATING PLANTS						
Plant Form/ Height (cm)	**Leaf / Flower Feature**	**Flower Form / Flowering Period**	**Leaf Form**	**Life Span / Planting Time**	**Ecological Requirements**	**D.F.**
***AZOLLA* / Salviniaceae**						
***Azolla caroliniana* Lam. (Water Fern)**						
Clustered/ 1-2,5	L: Green, Red	-	-	Perennial-Herbaceous / Spring-summer	Shady areas, still fresh waters	1
***HYDROCHARIS* / Hydrocharitaceae**						
***Hydrocharis morsus ranae* L. (European Frogbit)**						
Badge form/ spread 5-15	L: Green F: White	Simple three leaves/ Summer	Round	Perennial-Herbaceous / Late spring to early summer	Sunny areas, slow-flowing waters	2
***LEMNA* / Araceae**						
***Lemna trisulca* L. (Star Duckweed)**						
Permeative	L: Green	-	Long thin strip	Perennial-Herbaceous/ early spring	Half-shaded, still waters	3
***NELUMBO* / Nelumbonaceae**						
***Nelumbo nucifera* (Sacred Lotus)**						
Upright structure/ 90-120	L:Shiny metallic green F: Rose Pink	Oval Petal/ Summer	Round	Perennial-Herbaceous / Spring-summer	Sunny areas, slow-flowing waters	4
***NUPHAR* / Nymphaceae**						
***Nuphar lutea* Sm. (Yellow lotus)**						
Upright structure/ 10-30	L: Green F: Yellow	Globe / Summer - autumn	Heart	Perennial-Herbaceous / Spring	Temperate and cold areas	5
***Nuphar odorata* Aiton (Fragrant Water Lily)**						
Upright structure/ 150	L:Green F:White	Multi-layered globe / June-September	Round	Perennial-Herbaceous / Spring	Temperate and cold areas	6

Table 3. Floating plants that can be used in water gardens (cont.).

Abbreviations: L: Leaf - F: Flower - D.F.: Design Feature						
Plant Form/ Height (cm)	**Leaf / Flower Feature**	**Flower Form / Flowering Period**	**Leaf Form**	**Life Span / Planting Time**	**Ecological Requirements**	**D.F.**
***PISTIA* / Araceae**						
***Pistia stratiotes* (Water Cabbage)**						
Permeative, cluster/ 15-60	L: Light green	Petal	Oval	Perennial - Evergreen/ Spring	Slow flowing waters	7
***STRATIOTES* / Hydrocharitaceae**						
***Stratiotes aloides* L. (Water Sword)**						
Permeative, cluster/ 20-40	L:Green F: White	Petal/ June-July	Sword	Perennial- Evergreen/ Spring	Shade areas	8
***TRAPA* / Trapaceae**						
***Trapa natans* L. (Water Chestnut)**						
Permeative	L: Dark green F: White	Star/ June-July	Triangle	Annual/Spring	Slow flowing waters	9
***UTRICULARIA* / Lentibulariaceae**						
***Utricularia minor* L. (Lesser bladderwort)**						
Permeative/ 5-30	L: Dark green F: Light yellow	Flat oval/ June-July	Long sword	Perennial carnivorous/ May-June	Fresh, still water	10

1: The invasive leaves cover the stems and form a flat leaf surface on the water. The leaves, which are green in summer, turn red at the end of summer. With this effect, it can be used for color effects during seasonal transitions. **2:** Thanks to its large leaves, it covers the water surface and can be used to hide images on the ground. **3:** It provides a natural green carpet appearance in water gardens, ponds or ornamental pools with its thin and elegant leaves floating just below the water surface. **4:** It can be grown outdoors in large containers during the summer. It can be used for leaf and flower colors. **5:** Its flowers have an unpleasant odor. Part of its root and stem is in the soil, and its leaves grow over water. Its fruits are decorative. It can be used with various flower colors of other species for accent and color effect. **6:** Since its flowers are fragrant, using them as a group will spread a pleasant scent around. **7:** Its leaves turn white when dry. It can be used in designs to create emphasis and achieve a mass effect with its coarse textured leaves. Its leaves are open during the day and half-closed at night. **8:** Since it is very spreading, it is quite suitable for water surfaces that are desired to be covered. They can be used to attract attention with the unusual nature of their leaves. **9:** It can be used to create a contrast in shape with upright and clustered plants living in shallow waters on the coast. **10:** It can be used to create emphasis and background between other plants with its yellow flowers.

5. CONCLUSION

Landscape design combines aesthetics and functionality, making living spaces more attractive and convenient. Water surfaces and plant designs in landscape design support this situation from an aesthetic and ecological point of view. Therefore, it is of great importance to take into account water gardens in the design processes. Water gardens make significant contributions to the environment by offering aesthetic, ecological and social benefits in landscape architecture. These areas provide a relaxing and peaceful environment by increasing the aesthetics of the landscape with the visual appeal of the water element. In addition, water gardens support biodiversity and contribute to ecosystem balance by hosting a variety of aquatic plants and living creatures.

This study was conducted with the aim of emphasizing the importance of using water elements and aquatic plants in landscape architecture and introducing coastal and aquatic plants that have visual aesthetic value in design. Morphological properties of plants are visually important in plant design. The height of the plants, leaf and flower characteristics and flowering periods guide the design. In addition, their ecological wishes are a decisive factor for plant selection. In this context, all these features have been collected in a single table, making it easier to access. In addition, design proposals for the use of aquatic plants have been developed.

As a result, water gardens play a significant role in landscape design as aesthetic, visual, and functional elements. A successful design within the scope of landscape architecture can be achieved by creating spaces that offer functional diversity and respond to user needs, taking into account principles of herbal design, the dendrological characteristics of plants, environmental conditions, and user preferences. With this study, it is aimed at contributing to the plant design studies to be carried out in water gardens.

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From Classical Landscape Design to Xeriscape: Proposals for Planting and Application

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1. INTRODUCTION

Today, global climate change, urbanization pressures, and the gradual depletion of water resources have necessitated the re-evaluation of classical (traditional) landscape practices. Classical landscape designs often feature large turf areas, exotic plants with high water requirements, and maintenance-intensive systems (Akat Saraçoğlu, 2023). However, such practices conflict with the principles of sustainability and place pressure on environmental resources (Meek & Larson, 2019). The global climate crisis stands out as one of the most serious ecological problems threatening both living organisms and natural ecosystems (Çetinkale Demirkan & Akat, 2024; Gülgün et al., 2015). Climate change and decreasing water resources have made sustainable and water-efficient approaches essential in landscape design (Akgedik et al., 2025). As a large portion of the world's available water is used in agriculture, it is vital to meet the water needs of plants in the most accurate and economical way possible (Akat, 2020). Xeriscape has emerged as a design approach that responds to these needs (Ertop, 2009; İlhan et al., 2024a; Yazici et al., 2017). Xeriscaping is seen as an effective approach for efficient water use and environmental sustainability (Akat Saraçoğlu & Çakar, 2023a).

This study, which provides the necessary information for the conversion of classical landscape areas into xeriscapes, examines the classical landscape approach and the issue of sustainability. Within the scope of the study, the concept of xeriscaping is defined, its fundamental principles are outlined, the characteristics of planting design in xeriscape applications are discussed, and suggestions are provided for plant species that can be used in such applications. Furthermore, the advantages of the xeriscape approach are highlighted, the necessary steps to convert conventional landscape areas into xeriscapes are identified, implemented examples are presented, and relevant evaluations and recommendations are offered accordingly.

2. CLASSICAL LANDSCAPE APPROACH AND SUSTAINABILITY ISSUES

In classical landscape design, the aim is often to enhance environmental aesthetics by creating turf areas. These vegetative areas soften hard surfaces and structural elements, creating more functional spaces (Ayanoğlu, 2023). Classical landscape practices mainly focus on aesthetics and are based on large turf areas, trees and shrubs that require frequent watering, and high-input systems needing intensive maintenance and fertilization (İlhan et al., 2024a; 2024b). This approach causes serious environmental and economic issues, especially in regions with limited water resources (Trowbridge & Bassuk, 2004). Furthermore, it leads to reduced biodiversity, deterioration of soil structure, and increased carbon footprint. From environmental, social, and economic perspectives, the classical landscape approach is not aligned with sustainability goals (Cameron et al., 2012). In a study by Ayanoğlu and Demirel (2023), the classical landscape and xeriscape approaches were compared in terms of cost, consumption, and design in a residential garden. The results showed that designs based on xeriscaping saved 54% in water consumption, 36% in electricity use, 64% in maintenance costs, and 5% in application costs compared to those based on classical landscaping.

3. DEFINITION AND IMPORTANCE OF XERISCAPE

In the context of efficient water use, the xeriscape approach stands out. Compared to classical landscapes, xeriscaping reduces water consumption while creating aesthetically pleasing and sustainable comfort zones. It also significantly reduces maintenance costs (Ayanoğlu, 2023). Xeriscaping is a landscape design approach that aims to conserve water resources and protect the environment by minimizing water use (Akat Saraçoğlu & Çakar, 2023a). This method is especially implemented in arid and semi-arid climates and in areas with limited water resources (Ertop, 2009). Xeriscape applications enable the creation of aesthetic, functional, and sustainable landscapes even in regions with water scarcity. In these applications, the use of climate-adapted plants, water-efficient irrigation systems, and soil improvement techniques is of great importance (Ellefson & Winger, 2004; İlhan et al., 2024b).

Beyond conserving water, xeriscaping reduces maintenance costs, preserves the natural character of landscapes, and enhances biodiversity. With these attributes, xeriscape has become a key component of sustainable urban design (EEA, 2012).

4. PRINCIPLES OF XERISCAPE

The foundational principles of xeriscape design encompass a series of practices that support sustainability. These principles are summarized below:

Proper Planning and Design: The design must consider site topography, sun and shade balance, soil characteristics, wind direction, climatic data, and user needs (Ellefson & Winger, 2004; Bayramoğlu, 2016). A site analysis should be conducted and planned to ensure water conservation (Çakar et al., 2018; Akat Saraçoğlu & Çakar, 2023a; TOB, 2024).

Soil Preparation: Enhancing the soil structure with organic matter improves both plant growth and the soil's water retention capacity. It is crucial to use well-drained soils with high organic content (Bayramoğlu, 2016). Measures should be taken to increase soil moisture retention and prevent erosion (TOB, 2024).

Plant Selection: Drought-tolerant native and indigenous species should be prioritized (Ertop, 2009; İlhan et al., 2024b). Selected plants should be capable of surviving on minimal irrigation or natural rainfall (Çorbacı et al., 2011).

Designing Low-Maintenance Lawns: Low-water-consuming, easy-to-maintain turf species should be used. The placement and size of turf areas significantly affect water consumption, so they should be minimized (Akat Saraçoğlu & Çakar, 2023a; Ertop, 2009). Turf zones should be designed as continuous, connected sections rather than isolated patches to facilitate efficient irrigation (Bayramoğlu, 2016). The goal is to reduce labor and input costs by requiring minimal maintenance, thereby increasing long-term sustainability (Dunnett & Kingsbury, 2004).

Efficient Irrigation: In xeriscape designs, plants are grouped into three zones based on water needs. This zoning—from central to outer areas—enables the creation of aesthetic, functional, and sustainable areas using water efficiently (Çorbacı et al., 2011). The main principle is to use supplemental irrigation as little as possible. Therefore, drip irrigation is preferred to minimize water loss (TOB, 2024; Akat Saraçoğlu et al., 2022). Sprinklers should be used in the morning, while drip irrigation can operate at any time of day. The key objective is to irrigate according to plant water needs (Akat Saraçoğlu, 2024).

Use of Mulch: Mulch helps retain soil moisture by preventing excessive evaporation and suppressing weed growth (Ertop, 2009). Both organic and inorganic mulches can be used in xeriscapes.

Appropriate Maintenance: Regular pruning, fertilization, and weed control are necessary for plant health and water management (Akat et al., 2017).

5. PLANT DESIGN IN XERISCAPE APPLICATIONS

5.1. Characteristics of Plants Used in Xeriscape

Plants used in xeriscape applications should be selected based on their low water requirements, compatibility with local climate conditions, and high aesthetic value. These plants should also be evaluated for their maintenance needs, soil stabilization capacity, and support for biodiversity (Ertop, 2009). Primarily, native and endemic species should be prioritized for ecological sustainability. Using endemic species—plants that thrive only in specific regions and are fully adapted to local conditions—is especially important for conserving biodiversity (Akat Saraçoğlu, 2023).

5.2. Plant Groups and Their Functions in Xeriscape Applications

In xeriscape applications, plants can be grouped based on their functional, aesthetic, and ecological characteristics. This classification simplifies the design process and enhances the efficiency of maintenance and irrigation planning. These plant groups provide both visual richness and ecological benefits, making them ideal for functional landscape design (Gülgün et al., 2014). Moreover, combining different plant groups allows for year-round vibrancy and more balanced water use in landscape areas (İlhan et al., 2024b).

Trees: Drought-tolerant tree species offer essential functions such as shading, windbreaking, and microclimate regulation. Commonly used species in the Mediterranean climate include *Pinus brutia*, *Cupressus* *sempervirens*, and *Quercus coccifera* (Ertop, 2009). These species are also known for their low maintenance requirements.

Shrubs: Shrubs play a crucial role in sustainable green space design due to their low water needs, resilient morphology, and multifunctionality. They help prevent soil erosion, act as windbreaks, regulate microclimate, reduce noise pollution, and support biodiversity while offering aesthetic value (Kjelgren et al., 2000). Frequently used Mediterranean species include *Pistacia lentiscus*, *Nerium oleander*, and *Spartium junceum*, which are favored for their drought resistance and visual appeal (Le Houérou, 2000).

Groundcover plants: These plants reduce evaporation by covering the soil surface in landscape areas, prevent surface erosion, and suppress weed growth with their dense structures. Examples of this group include *Thymus serpyllum*, *Dymondia margaretae*, *Gazania rigens*, and *Vinca minor*. These plants contribute both aesthetically and functionally to landscape areas by creating visual diversity with their wide spreading capacity, low height, and colorful foliage and flower forms. They are especially used in xeriscape applications for economically and aesthetically covering large areas. Their low maintenance requirements, limited water needs, and year-round visual appeal make them preferred choices (Ertop, 2009). The proper combination of groundcover plants and shrubs ensures that landscape areas are long-lasting, sustainable, and cost-effective

Succulents and Cacti: This group includes the lowest water-consuming plants, which can store water in their thick leaves. Species like *Sedum spp.*, *Agave americana*, *Aloe vera*, and *Opuntia spp*. are used in both horizontal and vertical landscaping (TOB, 2024).

Perennial Herbaceous Plants: Perennial herbaceous plants adapted to arid climate conditions enable the maintenance of green cover in landscape areas throughout the year. Species such as *Salvia officinalis, Achillea millefolium*, and *Echinacea purpurea* also possess medicinal and aromatic properties. These plants are additionally notable for their resilience to environmental stress factors (Ertop, 2009).

Bulbous and Tuberous Plants: This group includes plants that possess modified underground organs such as true bulbs, bulb-like stems, corms, tubers, tuberous roots, or rhizomes. These plants enliven landscape areas by creating strong visual impact, particularly during spring and summer seasons (Akat, 2021). In xeriscape applications, species that are adapted to arid environments—such as *Iris germanica, Allium giganteum,* and *Narcissus poeticus*—are commonly preferred. These plants require low maintenance outside their growth periods (Ertop, 2009).

Aromatic and Medicinal Plants: Local aromatic species are particularly important for the sustainability of xeriscaping.

In addition to their therapeutic effects on human health, they contribute to the visual quality of the landscape with their color and fragrance. Moreover, they support urban agriculture and beekeeping activities (Akat et al., 2020; Çetinkale Demirkan & Akat, 2018). Representative species in this group include *Melissa officinalis, Salvia officinalis, Thymus vulgaris, Rosmarinus officinalis*, and *Mentha piperita* (Ertop, 2009; Akat Saraçoğlu et al., 2020).

5.3. Recommended Plant Species for Xeriscape Applications in Türkiye

Below is a list of some plant species that can be used in xeriscape applications in various regions of Türkiye (Table 1).

Table 1. Some plant species that can be used in xeriscape applications in various regions of Türkiye (Çorbacı et al., 2017).

TREES	
DECIDUOUS (GYMNOSPERMAE)	
Ginkgo biloba L.	*Larix decidua L.*
DECIDUOUS (ANGIOSPERMAE)	
Acer campestre L.	*Hippophae rhamnoides L.*
Acer negundo L.	*Koelreuteria paniculata Laxm.*
Acer palmatum Thunb.	*Liriodendron tulipifera L.*
Acer platanoides L.	*Liquidambar styraciflua L.*
Acer pseudoplatanus L.	*Liquidambar orientalis Mill.*
Acer tataricum L.	*Magnolia grandiflora L.*
Aesculus hippocastanum L.	*Malus floribunda Siebold.*
Ailanthus altissima (Mill.)	*Maclura pomifera (Raf.) Schneid.*
Betula alba L.	*Platanus x acerifolia (Ait.) Willd.*
Betula nigra L.	*Platanus orientalis L.*
Carpinus betulus L.	*Prunus armenica L.*
Catalpa bignonoides Walter.	*Prunus avium L.*
Celtis australis L.	*Prunus ceracifera "Pissardii"*
Cercis siliquastrum L.	*Quercus robur L.*
Elaeagnus angustifolia Wahl.	*Quercus rubra L.*
Elaeagnus orientalis L.	*Rhus typhina L.*
Fraxinus americana L.	*Robinia pseudoacacia L.*
Fraxinus angustifolia	*Sophora japonica L.*
Fraxinus excelsior L.	*Ulmus campestris L.*
Gleditsia triacanthos L.	*Ulmus glabra Huds.*
EVERGREEN (GYMNOSPERMAE)	
Cedrus atlantica (Endl.) Carr.	*Picea pungens Engelm.*
Cedrus deodora (Roxburg) G. Don.	*Picea pungens "Glauca"*
Cedrus libani A. Rich.	*Pinus brutia Ten.*
Chamaecyparis lawsoniana (A.Murr.) Parl.	*Pinus halepensis Mill.*
Chamaecyparis nootkatensis (Lamb.)Sudw.	*Pinus mugo Tura*
Cupressus arizonica Greene	*Pinus nigra L.*
Cupressus sempervirens L.	*Pinus pinaster Ait.*
Cupressocyparis leylandii	*Pinus pinea L.*
Juniperus chinensis L.	*Pinus silvestris L.*

Table 1 (continued)

Juniperus sabina L.	*Pseudotsuga menziesii (Mirb.) Franco var. glauca*
Juniperus oxycedrus L.	*Taxus baccata L.*
Juniperus virginiana L.	*Thuja occidentalis L.*
Picea abies (L.) Karst.	*Thuja orientalis L.*
SHRUBS	
EVERGREEN (GYMNOSPERMAE)	
Juniperus chinensis L. "Aurea"	*Juniperus squamata "Blue Carpet"*
Juniperus communis L. "Hibernica"	*Juniperus virginiana "Sky Roket"*
Juniperus horizontalis Moench	*Picea glauca (Moench)Voss var. conica*
Juniperus × media Melle	*Thuja orientalis "Aurea"*
Juniperus sabina "Aurea"	*Thuja orientalis "Pyramidalis Aurea"*
DECIDUOUS (ANGİOSPERMAE)	
Berberis thunbergii "Atropurpurea"	*Ligustrum vulgare L.*
Buddleia davidii Franch.	*Lycium barbatum L.*
Chaenomeles japonica (Thunb.) Lindl.	*Philadelphus coronarius L.*
Caragana arborescens Lam.	*Potentilla fruticosa L.*
Colutea arborescens L.	*Ribes aureum Pursh.*
Cornus alba L.	*Rosa canina L.*
Cotoneaster horizontalis L.	*Spirea vanhouttei Zabel.*
Deutzia gracilis Sieb.	*Symphoricarpus albus L. Blake*
Euonymus alatus (Thunb.) Sieb.	*Symphoricarpus orbiculatus L.*
Forsythia intermedia Zabel.	*Syringa chinensis Schmidt ex. Wilderow*
Jasminum nudiflorum Lindl.	*Syringa vulgaris Mill.*
Hydrangea arborescens L.	*Viburnum fragrans Bunge*
Hydrangea macrophylla (Thunb.) Ser.	*Viburnum lantana L.*
Ligustrum ovalifolium Hassk.	*Viburnum opulus L.*
EVERGREEN (ANGIOSPERMAE)	
Abelia x grandiflora (Andre) Rehd.	*Ilex colchica Pojark*
Aucuba japonica Thunb.	*Kerria japonica (L.) DC*
Berberis julianae Schneid	*Ligustrum jonandrum*
Buxus microphylla Sieb. et Zucc.	*Mahonia aquifolium (Pursh) Nutt.*
Camellia japonica L.	*Osmanthus fragrans Lour.*
Cotoneaster bullatus Boiss.	*Pittosporum tobira (Thunb.) Ait "Nana"*
Cotoneaster salicifolius Franch.	*Pyracantha coccinea M. J. Roemer*

Table 1 (continued)

Eleagnus pungens Thunb."Maculata Aurea"	*Rosmarinus officinalis L.*
Euonymus japonica Thunb.	*Viburnum rhytidophyllum Hemsl.*
Gardenia jasminoides Ellis	*Viburnum tinus L.*
Ilex aquifolium L.	*Yucca flamentosa L.*
SMALL TREES	
DECIDUOUS (ANGIOSPERMAE)	
Calycanthus floridus L.	*Lonicera tatarica L.*
Cotinus coggygria (Scop.)	*Magnolia x soulangeana Soul.-Bod.*
Crataegus crus-galli L .	*Sambucus nigra L.*
Crataegus monogyna Jacq.	*Sambucus nigra "Aurea"*
Crataegus oxycantha L.	*Syringa x chinensis Schmidt ex Willd*
Hibiscus syriacus L.	*Syringa vulgaris L.*
Lagerstroemia indica L.	*Vitex agnus-castus L.*
EVERGREEN (ANGIOSPERMAE)	
Buxus sempervirens L.	*Laurocerasus officinalis Roem.*
Eriobotrya japonica Lindl.	*Ligustrum japonica Thunb.*
Euonymus europea L.	*Pittosporum tobira (Thunb.) Ait*
PALMS	
Acrocomia aculeata Jack.Lodd ex.Mart	*Howea forsteriana (T. Moore & F. Muell.) Becc.*
Areca lutescens Bory.	*Jubaea chilensis (Molina) Baill.*
Beaucarnea recurvata Lem.	*Livistona chinensis (Jacq.) R. Br.ex Mart.*
Brahea armata S.Watson	*Livistona decipiens Beccari.*
Butia capitata (Mart.) Becc.	*Nannorrhops ritchieana(Griff) Aitch.*
Chamaerops humilis L.	*Phoenix canariensis Hort.ex.Chabaud*
Chrysalidocarpus lutescens (Bory) H. Wendl.	*Phoenix dactylifera L.*
Cocos nucifera L.	*Phoenix reclinata Jack.*
Copernicia baileyana Leon	*Phoenix rupicola T.Anderson*
Copernicia hospita Mart.	*Sabal mexicana Mart.*
Copernicia macroglossa H.Wendl. EX. Becc	*Sabal domingensis Becc.*
Cycas circinalis L.	*Serenoa repens W.Bartram*
Dioon edule Lindl.	*Trachycarpus fortunei (Hook)H.Wendl*
Dizygotheca elegantissima (Veitch) Vig.& Guill.	*Washingtonia filifera H.Wendl*

Table 1 (continued)

VINES	
DECIDUOUS (ANGIOSPERMAE)	
Bougainvillea spectabilis Willd.	*Parthenocissus quinquefolia Planch.*
Campsis radicans (L.) Seem. ex. Bureau	*Wisteria sinensis (Sims) DC.*
EVERGREEN (ANGIOSPERMAE)	
Euonymus fortune "Aurea Variegata"	*Lonicera caprifolium L. Kugel*
Hedera helix L.	*Vinca major L.*
Jasminum officinale L.	*Vinca minor L.*
PERENNIAL HERBACEOUS PLANTS	
Achillea filipendulina Lam.	*Gypsophila paniculata L.*
Achillea ptarmica L.	*Helleborus orientalis Lam.*
Achillea tomentosa (Boiss.)	*Helianthemum nummularium (L.) Mill.*
Ajuga reptans L.	*Hemerocallis hybrida L.*
Alcea rosea L.	*Iberis sempervirens L.*
Alchemilla mollis (Boser) Rothm	*Iris germanica L.*
Alyssum saxatile L.	*Kniphofia uvaria L.*
Amaranthus caudatus L.	*Lamium maculatum L.*
Anemone coronaria L.	*Lavandula angustilfolia Mill.*
Anemone sylvestris L.	*Liatris spicata (L.) Willd*
Aquilegia hybrida Rose & White	*Linum perene L.*
Artemisia schmidtiana J.Jakupovic	*Lunaria annua L.*
Aster alpinus L.	*Mesembryanthemum nodiflorum L.*
Astilbe japonica L.	*Monarda didyma L.*
Bergenia cordifolia (Haw.)Sternb.	*Nepeta x faassenii H.*
Calendula officinale L.	*Papaver orientale L.*
Campanula carpatica Jacq.	*Papaver rhoeas L.*
Campanula rotundifolia L.	*Paeonia lactiflora Pall.*
Centaurea dealbata Willd.Susanna et al.	*Phlox subulata L.*
Centaurea cineraria L.(Lacaita) Pign.	*Rudbeckia x hirta hybrida*
Centranthus rubber L.	*Salvia argentea L.*
Cerastium tomentosum L.	*Salvia farinacea L.*
Chrysanthemum maximum DC.	*Santolina chamaecyphrissus L.*
Coreopsis grandiflora Nutt.	*Saponaria ocymoides L.*
Dianthus barbatus L.	*Sedum acre L.*
Dianthus caryophyllus L.	*Sedum album L.*
Dianthus plumarius L.	*Sedum spectabile Bor.*
Echinacea purpurea L.	*Sempervivum hybrids L.*
Eschscholzia californica Cham.	*Stachys lanata K.Koch*

Table 1 (continued)

Euphorbia polychrome Jacq.	*Teucrium chamaedrys L.*
Felicia amelloides (L.) Voss.	*Thymus serpyllum L.*
Felicia fruticosa (L.) Nicholson	*Verbascum nigrum L.*
Gaillardia aristata Pursh	*Verbena officinalis L.*
Gerbera jamesonii L.	*Veronica spicata L.*
Gazania linearis Thunb.	*Veronica prostrata L.*
ANNUAL HERBACEOUS PLANTS	
Ageratum houstonianum Mill.	*Leonotis nepetifolia (L.) R. Br.*
Anthirrhinum majus L.	*Limonium sinuatum L.*
Begonia x semperflorens Hook.	*Pelargonium x hortorum Bailey*
Brassica oleracea L.	*Petunia x hybrida*
Calendula officinalis L.	*Portulaca grandiflora Hook.*
Catharanthus roseus (L.) G. Don	*Salvia splendens L.*
Cosmos sulphureus Cav.	*Senecio cineraria DC.*
Digitalis purpurea L.	*Tagetes erecta L.*
Gaillardia pulchella Foug.	*Tagetes patula L.*
Gomphrena globosa L.	*Viola tricolor L.*
Impatiens walleriana Hook.	*Zinnia elegans L.*
TURFGRASSES	
Agropyron cristatum (L)Gaertn	*Festuca arundinacea (Schreb)*
Agropyron cristatum "Ephraim"	*Festuca arundinacea (Schreb) "Jaguar"*
Agropyron smithii (Rydb)A.Löve.	*Festuca arundinacea (Schreb) "Arit"*
Bouteloua gracilis &Willd.ex Lag.Ex Griffiths	*Festuca glauca "Boulder Blue"*
Bermuda grass (L.)	*Festuca trachyphylla "Durar"*
Buchloe dactyloides (Nutt)Columbus	*Festuca ovina L.*
Cynodon dactylon (L.) Pers.	*Lolium perenne L. "TOPGAN"*
Dactylis glomerata L.	*Poa ampla Merr.*
Elymus canadensis L.	*Poa compressa Reubens*
Elymus lanceolatus (Scribn.&J.G.Sm.) Gould	*Poa pratensis L.*
Elymus trachycaulus subsp. Trachycaulus	*Poa pratensis L. "4 SEASON"*
Elytrigia intermedia (Host) Nevski	*Panicum virgatum L.*
Eremochloa ophiuroides [Munro] Hack.	*Zoysia japonica Steud.*
SUCCULENTS AND CACTI	
Aloe vera Linn.	*Opuntia humifusa (Raf.) Raf.*
Euphorbia tirucalli L. (ET)	*Stapelia variegata Linn.*
Kalanchoe fedtschenkoi Hamet & Perrier	*Tradescantia pallida (Rose) Hunt.*

6. ECOLOGICAL, ECONOMIC AND AESTHETIC EVALUATIONS

Xeriscape applications offer not only aesthetic benefits but also significant ecological and economic advantages in terms of sustainability.

Landscape areas designed with the xeriscape approach can achieve rich diversity in color, texture, and form. Additionally, the pleasant fragrances provided by aromatic plants add a unique appeal to the designs. One of the most important aspects of xeriscape applications is their ecological superiority without causing any aesthetic compromise. The use of native plant species can reduce water consumption by up to 50%, thereby enabling substantial water savings (Ellefson and Winger, 2004; Akat Saraçoğlu, 2023). Vegetation established according to xeriscape principles helps prevent soil erosion and preserves soil structure. Moreover, the inclusion of pollinator-friendly plant species supports the habitats of bees, butterflies, and similar organisms, contributing to biodiversity (Cameron et al., 2012). In addition to ecological benefits, xeriscape applications provide considerable economic advantages. Water savings reduce irrigation needs, while lower fertilizer requirements and reduced pruning and mowing decrease maintenance demands (Akat and Çakar, 2023b). Additionally, reduced surface runoff lessens the burden on infrastructure systems. In this context, lower maintenance costs along with the role of preserving infrastructure contribute to reduced labor and energy costs (Meek and Larson, 2019).

7. CONVERSION OF CLASSICAL LANDSCAPES INTO XERISCAPES

Global climate change, urbanization pressures, and the continuous depletion of water resources have necessitated a reevaluation of classical landscape practices (Pirli et al., 2023). Classical landscape areas often feature expansive turfgrass, exotic plants with high water demands, and systems requiring intensive maintenance. However, such practices conflict with sustainability principles and place significant strain on environmental resources (Meek and Larson, 2019). From the perspective of sustainable water management, these applications lead to the rapid depletion of resources in the long term. This situation particularly complicates water management in urban areas, causing reductions in water supplies and disruption of ecological balances (Çetin et al., 2018).

The issue of drought has become more pronounced especially in rapidly and uncontrolled urbanizing cities. Worldwide, with priority given to water-scarce cities, the demand for ecologically based and sustainable planning approaches is continuously increasing (Yazici & Gülgün, 2021; Pirli & Yazici, 2022). Therefore, considering the ongoing climatic changes that also affect our country, the preference for water-efficient design approaches such as xeriscaping in urban open green spaces — where water consumption is intensive — and the conversion of existing designs to this approach represent a crucial alternative solution to water scarcity (Çöp & Akat, 2021; İlhan et al., 2024b). Indeed, it is known that landscapes designed with xeriscape principles can achieve water savings of between 20% and 50% compared to classical landscape designs (Taner, 2010).

In converting classical landscape areas into xeriscapes, it is first necessary to reduce turfgrass, which has high water consumption, and instead use plant species adapted to xeric conditions. Reducing turfgrass areas significantly decreases both irrigation needs and maintenance costs

(Çöp & Akat, 2021; Ayanoğlu and Demirel, 2023). Instead, local and low-water groundcover plants, perennial herbaceous plants, shrubs, and succulents should be preferred, and plant patterns should be planned in accordance with the natural landscape structure (Çetinkale Demirkan &Akat, 2017; Akat Saraçoğlu, 2023). Furthermore, organic or inorganic mulching applications should be encouraged to reduce surface evaporation and preserve soil moisture (Ertop, 2009). Irrigation systems should be converted from traditional methods to efficient and controlled techniques such as drip irrigation, and sustainable water management approaches like rainwater harvesting and greywater reuse should be integrated into landscape planning. These changes both contribute to conserving water resources and support ecological landscape design (Akat Saraçoğlu and Çakar, 2023a).

7.1. Application Examples from Türkiye

The growing awareness of sustainable water use in landscape design has led to the increasing adoption of xeriscaping practices across various cities in Türkiye. Several municipalities and institutions have initiated transformative projects aimed at reducing water consumption, minimizing maintenance requirements, and enhancing ecological resilience in public green spaces. The following examples illustrate successful applications of xeriscape principles in different regions of the country, highlighting their environmental and economic benefits.

Ankara: In 2020, a study conducted in Yıldırım Beyazıt Park in Etimesgut, Ankara, established two experimental plots of 1 m^2 each—one designed with a classical landscape layout and the other with a xeriscape layout. Based on the collected data, it was determined that converting the site to xeriscape design could result in a water savings of 33.85% (Metin & Koçan, 2020).

Antalya: In 2021, in the city center of Antalya, replacing turfgrass areas in intersections and medians with mulch materials led to savings of 50% in water and electricity and 30% in pesticides and fertilizers (TOB, 2024).

Burdur: In 2022, xeriscape practices implemented by Bucak Municipality in Burdur province at intersections and medians achieved an annual average water savings of 25,000 tons. During the application, 13,000 low-water-use plant species were used, along with 96 tons of stone, 66 m³ of tree bark, and 6,000 m² of mulch cover. The implementation resulted in a 50% reduction in water use, 30% in electricity consumption, and additional savings in maintenance, repairs, and labor costs (TOB, 2024).

Muğla: In 2023, a project in Ortaca Culture Park, Muğla, aimed to convert existing landscape areas into xeriscapes by replacing high water-demand plants with low-water-demand species. As a result, 99.81% of the plant palette consisted of drought-tolerant species, significantly reducing irrigation needs (İlhan et al., 2024).

İzmir: In 2024, ESBAŞ İzmir (Aegean Free Zone Development and Operating Co.) converted a 3,534 m² landscape area based on the xeriscape approach and reported an annual water savings of 400 tons (ESBAŞ, 2025).

8. CONCLUSION AND RECOMMENDATIONS

In classical landscape designs, the presence of large turfgrass areas with high water requirements and the preference for ornamental plants with excessive irrigation needs instead of native species prevent these landscapes from being considered sustainable (Akat & Çöp, 2019). Considering the changing climate conditions and the diminishing availability of water resources, classical landscape approaches—characterized by aesthetics-focused designs, intensive plant use, and expansive lawn surfaces—are no longer viable. Instead, xeriscape designs, which prioritize sustainability and aim to preserve both the landscape and ecological balance, have become increasingly important (Hersek, 2019; Akat Saraçoğlu & Çakar, 2023b). The most fundamental difference between xeriscape and classical landscape approaches lies in the reduced water consumption and the associated savings in irrigation requirements (Barış, 2007; Akat Saraçoğlu, 2023). Taking into account the decreasing water resources and rising maintenance costs, the xeriscape approach offers environmentally friendly and long-term solutions. Replacing traditional turf-centric landscaping with designs that preserve urban ecological balance while maintaining aesthetic and functional value is of critical importance for achieving sustainable landscapes.

Large-scale public green spaces such as university campuses, parks, and roadsides serve as significant implementation areas for xeriscaping. Through xeriscape practices applied in these spaces, both ecological awareness can be increased and economically sustainable landscapes can be achieved (İlhan et al., 2024a).

In recent years, as in many parts of the world, xeriscape applications have gained increasing importance due to seasonal droughts observed in many cities across Türkiye. While the implementation of xeriscape principles can be readily planned in new landscape design projects, it is also of great importance to initiate efforts to convert existing urban open green spaces in order to ensure efficient water use (İlhan et al., 2024b).

It is crucial to recognize that the xeriscape approach is a key tool in creating more livable environments for future generations.

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An Integrated Green Infrastructure Approach in Slow Cities: The Case of Uzundere

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1. INTRODUCTION

In the twenty-first century, amidst the rapid homogenisation induced by globalized lifestyles, alternative planning models grounded in local values and principles of sustainable development are garnering increasing significance. Within this context, the Cittaslow (Slow City) movement, which originated in Orvieto, Italy in 1999, has emerged as an international governance paradigm that holistically addresses the multifaceted objectives of enhancing urban quality of life, safeguarding cultural identity, and ensuring environmental sustainability (Özgeriş and Karahan, 2021a; Özgeriş and Karahan, 2021b).

The concept of the slow city transcends a mere lifestyle preference; it constitutes a strategic planning approach that enables the redesign of urban and rural spaces, the conservation of local resources, and the implementation of ecologically grounded development policies (Karahan and Özgeriş, 2021a). Türkiye joined this global movement in 2009 with the membership of Seferihisar, and within a short span, numerous municipalities began to express interest in adopting this model. As of today, Türkiye ranks as the country with the highest number of Cittaslow cities after Italy (Cittaslow International, 2025). Uzundere, the first and only settlement in the Eastern Anatolia Region to hold this designation, joined the Cittaslow network in 2016, thereby becoming one of the symbolic towns representing the regional sustainability vision (Özgeriş and Karahan, 2021c; Özgeriş et al., 2024).

Located in the northeastern part of Erzurum, the district of Uzundere is characterised by a rural settlement fabric embedded within the transitional Black Sea climate zone, rich in biodiversity and interwoven with elements of cultural heritage. One of the district's most prominent natural assets, the Tortum Waterfall, stands out as not only the tallest in Türkiye but also among the highest in Europe, serving as a significant geotourism destination (Orhan, 2019). Furthermore, natural and cultural landscape assets such as the Yedigöller Basin, Engüzek Castle, Öşvank Monastery, and Tortum Lake constitute key components that deepen Uzundere's potential for nature-based and rural tourism (Karahan and Özgeriş, 2021a).

The preservation of these landscape values for transmission to future generations necessitates the establishment of a sustainable governance framework grounded not only in the protection of natural attractions but also in planning principles and methodologies. In recent years, the proliferation of nature-based tourism activities, particularly under conditions of unplanned development, has exerted significant pressures on ecosystems, leading to disturbances in natural equilibrium, habitat loss, and infrastructural challenges (Pırnar, 1993).

The district of Uzundere, with its V-shaped valley morphology, fragmented land use patterns, and settlements constrained along riverbanks, embodies various physical limitations for spatial development. Settlements situated along the Tortum River are exposed to multifaceted environmental threats such as flood risks, degradation of riparian ecosystems, and uncontrolled construction. The obsolescence of existing zoning plans, their failure to incorporate ecological criteria, and the diminishing coherence with local vernacular architecture threaten the district's unique identity.

Addressing these challenges necessitates the coordinated engagement of landscape planning, architecture, and environmental governance disciplines. Within this framework, the European Commission's (2013) Green Infrastructure Strategy offers spatial planning approaches supported by nature-based solutions that present viable alternatives for rural settlements such as Uzundere. Furthermore, the connection established between the sustainability principles of the Cittaslow movement and this approach can provide a novel framework for regional planning (Pauleit et al., 2017).

The spatial development of Uzundere district is shaped by its V-shaped valley morphology, mountainous topography, fragmented land use patterns, and settlement models compressed along riverbanks. The primary settlements are concentrated along the Tortum River, a configuration that entails multidimensional risks such as development pressures, flooding hazards, and the degradation of riparian ecosystems (Orhan, 2019).

Rural infrastructure, particularly road networks, has significantly exacerbated ecological fragmentation and exerted detrimental impacts upon habitats. In this regard, it is well documented that road projects in Türkiye have produced fragmented yet enduring effects within rural landscapes. Furthermore, the lack of integration between transportation infrastructure and natural landscapes has led to patterns of parcel fragmentation and uncontrolled development.

The obsolescence of current zoning plans, the neglect of ecological considerations within planning notes, and the incompatibility of rural development with local architectural identity constitute significant threats to Uzundere's distinctive character. Tourist attraction areas along the riverside are characterized by unoriginal parking arrangements and a lack of pedestrian and bicycle pathways, thereby undermining landscape quality and complicating sustainable management (Orhan, 2019).

These multifaceted issues necessitate a multi-scalar and coordinated planning approach. The green infrastructure strategies proposed by the European Commission offer crucial instruments for mitigating physical risks in rural areas, enhancing ecological connectivity, and facilitating the planned development of recreational spaces (European Commission, 2025a). Kabisch et al. (2017) identified that green infrastructure enhances both ecological resilience and social benefits, a finding that can be instructive for environmentally sensitive areas such as Uzundere.

Furthermore, the sustainability principles introduced by the Cittaslow philosophy, which preserve local identity and quality of life, constitute a functional framework for regional planning in Uzundere (Pauleit et al., 2017).

The aim of this book chapter is to develop an integrated rural planning model based on green infrastructure for Uzundere district. The principal research question is:

“How can a green infrastructure approach integrate Uzundere’s natural and rural tourism potential with its spatial identity, and can it offer solutions to its multi-scalar planning challenges?”

Sub-questions:

- ✓ *How can the components of green infrastructure be harmonized with Uzundere’s existing landscape structure and vernacular architectural character?*
- ✓ *How can the relationships among nature-based tourism, riverbank restoration, and local architecture be re-established?*
- ✓ *How can Cittaslow criteria be integrated with green infrastructure strategies?*
- ✓ *How can exemplary practices from Europe be adapted to the context of Uzundere?*

In the subsequent sections, alongside the conceptual foundations, the physical and ecological characteristics of the area, existing challenges, and the proposed green infrastructure solutions will be examined in detail. The objective of this study extends beyond offering an academic contribution; it also seeks to develop actionable strategic guidance for local administrations and implementing actors.

2. CONCEPTUAL FOUNDATIONS: GREEN INFRASTRUCTURE, IDENTITY, AND RURAL TOURISM

The multifunctionality offered by green infrastructure unites objectives such as ecosystem-based climate adaptation, human health, and economic vitality under a single framework (Kabisch et al., 2017; EEA, 2025a). The comprehensive literature review by Tzoulas et al. (2007) reveals that green space networks enhance not only biodiversity but also indicators of societal well-being, such as psychological health and active lifestyles. Ahern (2007), on the other hand, advances the concept of the "*resilient landscape matrix*" in planning, emphasising that corridors connecting rural and urban areas seamlessly can reduce disaster risks.

In rural regions, the success of green infrastructure decisions necessitates integrated planning with local identity, architectural heritage, and economic activities. The MaGICLandscapes Project's Manual for Creating Evidence-Based Green Infrastructure Strategies (Interreg Central Europe, 2020) provides step-by-step methodologies for the simultaneous conservation of agricultural production areas, small-scale tourism, and historical fabric. Benedict and McMahon (2012) systematised this multi-layered structure through the conceptual set of "*corridors, core areas, buffer zones, and gateways*", thereby establishing an applicable framework for rural planning.

Particularly in settlements designated as Cittaslow, the integration of slow living principles—such as local production and the preservation of cultural heritage—with green infrastructure approaches offers novel opportunities for spatial coherence and enhanced quality of life (European Environment Agency, 2025). Mell (2016) asserts that the production of maps by local governments that explicitly define ecosystem services clarifies budgetary priorities and facilitates public participation. Naumann et al. (2011), in their examination of cost–benefit analyses of green infrastructure projects within the framework of EU rural development programmes, demonstrated the long-term economic returns of nature-based solutions.

Landscape identity constitutes a perceivable character shaped by the natural features, historical processes, and user experiences of a given place. In rural areas, this identity is formed through elements such as agricultural mosaics, local building materials, traditional architectural typologies, settlement patterns harmonized with topography, and ritual or cultural sites. These components carry not only aesthetic significance but also nurture the sense of belonging, lifestyle, and economic cycles of the local community (Çakmak, 2006).

In the specific context of Uzundere, this identity becomes more evident within spaces where natural landscape assets and cultural heritage are interwoven. However, in recent years, increasing rural construction, tourism-oriented country house investments, and trends of uncontrolled development along coastal zones have led to the disintegration of the local architectural fabric (Özgeriş, 2020). This degradation represents not merely a physical transformation but also a rupture in terms of cultural continuity.

In this context, green infrastructure serves not only as a means of establishing natural corridors but also as a planning tool that supports the continuity of rural architecture and spatial coherence. Particularly in settlements such as Slow Cities (Cittaslow), such integrative planning approaches enable the simultaneous preservation of both ecological and cultural landscapes (Karahan and Özgeriş, 2022). European landscape conservation policies likewise emphasize the necessity of addressing cultural landscapes in a holistic manner.

The Cittaslow philosophy regards tourism not merely as an activity for economic gain but as an experiential realm that enhances local quality of life and harmonizes with both nature and culture (Çakmak, 2006; Özgeriş, 2020). This perspective redefines sustainable tourism within the framework of cultural heritage conservation, social integration, and environmental harmony.

The development of rural tourism in slow cities is generally structured around three fundamental principles:

Slowness and Locality: In tourism practices, it is essential to offer experiences aligned with the rhythm of local life rather than rapid consumption. This encompasses authentic encounters rooted in local values such as traditional cuisine, handicrafts, and oral culture (Lane and Kastenholz, 2015).

Ecological Balance: Tourism infrastructure must be designed in harmony with the environment, taking into account carrying capacities and prioritizing nature-based solutions, such as green infrastructure and bio-corridors (European Commission, 2025a).

Community Participation and Local Development: Participation of local communities in decision-making processes and the direct economic benefits derived therefrom constitute core elements of the Cittaslow philosophy. Practices such as cooperative formation, producer markets, and local guiding systems support this process (Karahan and Özgeriş, 2022).

A rural tourism model in which these principles are addressed holistically is characterized by an approach that is nature-based, slow, and identity-oriented. In small settlements such as Uzundere, the implementation of this model holds strategic significance not only for tourism planning but also for the preservation of cultural landscape integrity and spatial resilience.

However, for the sustainability of this approach, it is imperative to integrate the following dynamics into the planning process:

Accessibility and Transportation: Slow mobility systems (pedestrian and bicycle pathways), opportunities for access to public transportation.

Orientation and Awareness: Nature walking trails, ecological awareness boards, guided tours.

Local Capacity Building: Rural tourism entrepreneurship, women's cooperatives, local producer networks.

Spatial Coordination: Integrated planning of tourism infrastructure with nature conservation areas and rural settlement patterns.

Green infrastructure plays a critical role in achieving the social, environmental, and spatial sustainability objectives that underpin the Cittaslow identity, by providing both the physical framework (corridors, natural buffer zones) and the managerial foundation (planning coherence, ecosystem services) of these systems.

3. THE PHYSICAL AND SOCIO-CULTURAL LANDSCAPE OF UZUNDERE

The district of Uzundere is located in the northeastern part of Erzurum, within a zone adjacent to the Black Sea climatic belt of the Eastern Anatolia Region. Its geographical positioning, situated within a transitional corridor where the Eastern Black Sea Mountain range intrudes inland, endows it with both climatic and topographical transitional characteristics (Davardoust and Karahan, 2021). The region's physical structure is characterized by deep valleys, rugged mountain ranges, and steep slopes. This topography has led to the development of settlements predominantly within narrow valleys or along riverbanks, while agricultural production and tourism activities have correspondingly been shaped in a decrescendo manner by these natural constraints (Karahan et al., 2011).

One of the district's most prominent natural features, the Tortum River, originates from the Yedigöller Basin in the north and flows southwards to Tortum Lake, forming a powerful river system fed by numerous tributaries. Throughout history, this system has played a fundamental role not only in irrigation activities but also in shaping settlement patterns. However, these rivers have simultaneously constituted primary determinants of natural disaster risks such as flooding, erosion, and landslides (Kopar and Çakır, 2013).

The flora of Uzundere constitutes an ecological transition zone where the Black Sea forests extend inland. At lower elevations, mixed deciduous forests, shrublands, orchards, and agricultural mosaics prevail, whereas higher slopes and elevations are characterised by the presence of pine, juniper, and oak species. This biological diversity is a strategic resource not only in terms of ecological value but also for landscape aesthetics, climate regulation, and ecotourism potential (Karahan and Özgeriş, 2022).

Nevertheless, in recent years, increasing construction and tourism pressures have threatened habitat integrity, particularly in riparian zones and along riverbanks. The disappearance of traditional buffer areas has led to the disruption of microclimatic balances, increased soil erosion, and the degradation of aquatic habitats. This situation has raised urgent challenges in green infrastructure planning, including fragmentation, visual degradation, and the loss of ecosystem services (Karahan et al., 2017).

Throughout history, the district of Uzundere has developed a linear settlement pattern parallel to the Tortum River valley. This configuration, situated around agricultural lands irrigated by the river, represents a typical reflection of traditional rural planning that optimises the relationship between production and slope, as well as facilitating access to water resources (Özgeriş and Karahan, 2021b). Two-storey courtyard houses constructed from stone and timber, along with granaries and water mills, exemplify vernacular architectural forms designed in harmony with local climatic conditions (Sezen et al., 2015).

However, over the past decade, the increasing prevalence of reinforced concrete transformations and unregulated second-home developments has posed significant threats to the continuity of the rural fabric. Tourist facilities, particularly those observed near the Tortum Waterfall, have narrowed the coastal line and disrupted ecological corridors (Özgeriş et al., 2024). Outdated zoning plans and permitting processes that fail to incorporate ecological sensitivities constitute principal factors accelerating the loss of architectural identity (Özgeriş and Karahan, 2020).

In European rural conservation planning, this coherence is addressed under the concept of "*vernacular landscape integrity*," wherein the preservation of settlement patterns and the use of local building materials through green infrastructure strategies are regarded as essential components of sustainable tourism (Plieninger and Bieling, 2012). In order to ensure spatial resilience in Uzundere, it is necessary to preserve architectural heritage and the local landscape mosaic through holistic planning approaches alongside nature-based tourism practices (Özgeriş and Karahan, 2021c).

The socio-cultural landscape of Uzundere exhibits a complex network structure at the intersection of local actors' everyday life practices and the region's historical modes of production. While agriculture and animal husbandry were the dominant activities throughout the twentieth century, ecotourism, nature guiding, and local product marketing have emerged as the prevailing economic forms in recent years (Davardoust and Karahan, 2021).

The municipality, village headships, women's cooperatives, and civil society organisations constitute the principal stakeholders of rural development; however, the lack of institutional coordination and limited participation in spatial planning processes hinder the achievement of sustainable development objectives (Özgeriş and Karahan, 2021d). The tendency of the young population to migrate to major cities weakens cultural transmission and creates vulnerabilities in landscape memory.

Uzundere's cultural landscape is not limited to its residential fabric; cemeteries, religious structures, water mills, agricultural terraces, and traditional vegetable gardens are integral components of this heritage. UNESCO's definition of Cultural Landscapes imposes a responsibility to preserve the entirety of human-shaped and natural elements (UNESCO, 2024). These assets should be positioned at the core of planning as "*spatial memory carriers*" representing local identity.

The European Green Deal emphasises that green infrastructure policies at the local level can only generate lasting impact when integrated with cultural values (European Commission, 2025b). In Uzundere, cultural landscape elements can serve as "*guiding structures*" in green corridor planning, forming the basis for route selection, wayfinding, and the design of ecotourism trails (KUDAKA, 2012). In this way, the continuity of natural ecosystems is maintained while the cultural capital of local communities is integrated into the economy.

As recommended by rural development strategies (UKKS, 2024), local producer networks and women's cooperatives should strengthen the economic pillar of a green infrastructure-supported tourism model, while public–civil cooperation mechanisms should ensure active participation in spatial planning decisions (Özgeriş and Karahan, 2022).

4. PLANNING CHALLENGES IN THE TORTUM RIVER AND RIPARIAN ECOSYSTEMS

The district of Uzundere is situated within a geography distinguished by its rich natural landscape values and dynamic river systems. The Tortum River, forming the backbone of the district along with its tributaries, has historically been a determinant not only of ecological processes but also of socio-cultural settlement patterns (Orhan, 2019). However, today these waterways are under considerable ecological pressures due to unplanned tourism practices, ecologically incongruent recreational interventions, and uncontrolled riparian use (Özgeriş and Karahan, 2021a).

One of the most critical issues is the disappearance of natural buffer zones along the riverbanks. Restaurants, parking areas, and tourist facilities established within these zones have increased erosion risks and destroyed riverside vegetation, leading to the extinction of local microhabitats (Özgeriş, 2022). Irregular infill activities along the banks of the Tortum River disrupt slope stability and flow regimes, resulting in the deterioration of both hydromorphological balance and the water cycle (Sezen et al., 2015).

In this valley stretching towards Tortum Lake, riparian constructions developed outside the discipline of planning are among the primary factors disrupting the visual integrity of the landscape. Frequent instances of construction within floodplains not only heighten flood risks but also create safety concerns for local residents and visitors. Moreover, increasing recreational use along the riverbanks causes direct environmental degradation, including flora trampling, the displacement of wildlife from urban fringes, waste accumulation, and habitat fragmentation (Özgeriş and Karahan, 2021b).

In this context, all riparian arrangements along the Tortum River should be based on green infrastructure principles; riverfront corridors should be redefined with biodiversity-supporting buffer zones and controlled access points. As envisaged by the European Green Deal, nature-based solutions represent an effective planning approach that ensures the protection of water resources while integrating their use with communities (European Commission, 2025b).

Zoning and Planning Challenges: Incompatible Developments and Tourism Pressures

An examination of Uzundere district's planning history reveals that the current zoning plans are largely incomplete, incompatible, and devoid of practical applicability. The planning documents prepared for rural areas predominantly delineate construction boundaries while neglecting environmental components such as ecosystem services, micro-watershed scale water management, biodiversity corridors, or disaster risk analyses (Özgeriş and Karahan, 2022). This situation results in both the fragmentation of the natural landscape and a decline in public trust towards planning processes (Özgeriş, 2022). Figure 1 presents an unmanned aerial vehicle image depicting the general zoning status of Uzundere district.

One of the most striking areas of concern is the tourism development around the Tortum Waterfall. In recent years, this area has witnessed a proliferation of bungalow-style structures, container-based temporary accommodation units, and superstructure facilities incongruent with the natural slope, all positioned without any connection to the local architectural fabric. Unfortunately, the majority of these structures are built upon terraces and artificial ground infills that disrupt the natural slope system. Such interventions result in the disturbance of hydrological balance and the destruction of vegetation cover (Özgeriş et al., 2024).

Figure 1. Unmanned aerial vehicle image of Cittaslow Uzundere

The most profound consequence of this construction pressure is the problem of loss of identity. Design approaches that fail to integrate with the landscape, lack cultural continuity, and disregard the relationship between local materials and spatiality diminish both the visual landscape quality of the region and its alignment with Cittaslow criteria (Özgeriş and Karahan, 2021d). Therefore, any planning approach proposed for Uzundere should serve not only physical management objectives but also the reproduction of local identity.

Loss of Identity and Visual Pollution

One of the core principles of Cittaslow cities—architectural harmony and aesthetic integrity—is under severe threat in the case of

Uzundere. Instead of the traditional stone-based structural systems and timber-integrated façades, there is a rapid proliferation of reinforced concrete buildings featuring steep, regionally incongruent roof forms, plastic window frames, incompatible colour schemes, and artificial cladding materials, all of which become alien elements unable to integrate with the natural landscape (Özgeriş and Karahan, 2021d).

This phenomenon undermines not only the touristic perception but also the sense of belonging of local residents. In landscape literature, this is defined as the deterioration of "*fragile aesthetic thresholds*," leading to a dissolution of identity at both visual and emotional levels (Nassauer, 1995; Sezen et al., 2015).

In Uzundere's town centre and rural neighbourhoods, billboards, signage, waste containers, electrical lines, and distribution networks are frequently installed without adherence to any visual planning principles. Such elements interrupt panoramic depth and create visually chaotic effects, particularly along nature walking trails, viewing terraces, and landscape-oriented vantage points (Özgeriş, 2020).

At the local level, reducing such visual pollution elements entails not only physical improvement but also the reproduction of landscape aesthetics. According to the Cittaslow philosophy, this is directly linked to respect for place, liveability, and a sense of belonging to local identity (Cittaslow International, 2019).

Therefore, in addition to green infrastructure planning, the development of architectural design guidelines, façade control systems, visual corridor analyses, and the design of wayfinding elements in accordance with standards are essential for achieving both aesthetic and functional sustainability in Uzundere.

Infrastructure and Superstructure Incompatibility

In rural settlements such as Uzundere, which have embraced the Cittaslow identity, one of the fundamental issues arising during tourism development is the construction of superstructure facilities (accommodation, food and beverage, recreation, etc.) independently of underlying infrastructure systems (sewerage, potable water, energy, stormwater drainage, etc.). This structural disconnect engenders serious problems not only in terms of economic sustainability but also regarding the continuity of ecosystem services.

Particularly, rural accommodation units often lack waste management infrastructure compatible with ecological systems. The absence of widespread greywater treatment systems results in wastewater being directly discharged into surface waters or underground aquifers. Such practices cause enduring impacts that disrupt hydrological cycles and destroy the ecosystem functions of water resources (Yılmaz et al., 2020; UNEP, 2022).

Moreover, the tourism model dependent on motor vehicles has become prevalent due to the absence of green mobility infrastructure such as walking paths, cycling routes, and nature corridors. This leads to problems including not only carbon emissions but also noise and light pollution, as well as habitat fragmentation for fauna (EEA, 2025b). In accordance with nature-based tourism principles, it is critically important to reduce such pressures in sensitive areas such as "quiet zones" and "*ecotone areas*" to safeguard landscape integrity (Tuğaç, 2021).

All these issues reveal that in the case of Uzundere, the green infrastructure approach should be evaluated not merely within the framework of landscape planning, but also through ecological engineering, environmental governance, and sustainable rural development. The implementation of integrated planning tools such as water management, ecological transportation, habitat restoration, and local energy systems will pave the way for a long-term, participatory rural transformation aligned with Cittaslow principles.

5. GREEN INFRASTRUCTURE-BASED INTERVENTION AND PLANNING PROPOSALS

5.1 Slow Mobility and Green Connectivity Corridors

In line with Cittaslow principles, the development of slow mobility systems as alternatives to motorised vehicles holds considerable importance for Uzundere. In particular, pedestrian and cycling routes connecting Tortum Waterfall to Yedigöller and subsequently to Uzundere town centre would not only reduce carbon emissions but also provide visitors with opportunities to intimately experience the local landscape. The integration of such green mobility networks within rural landscapes contributes significantly not only to environmental sustainability but also to socio-cultural sustainability (European Commission, 2025a).

Green connectivity corridors should function not merely as transportation routes but also as habitat corridors for biodiversity. Alongside these corridors, integrated features such as hedgerows composed of native species, small wetlands, and birdwatching stations can be planned. Such structures create multifunctional spaces that encompass the "*natural, cultural, and functional values*" of the landscape, as defined in the European Landscape Convention (Council of Europe, 2005). Moreover, these corridors, planned within the framework of nature-based solutions, foster areas resilient to climate change while also carrying educational and aesthetic value for local residents and visitors (Kabisch et al., 2017).

In the specific context of Uzundere, the route selection for these slow mobility corridors should take into consideration slope, scenic impact, cultural landscape elements (such as historic stone bridges and mill ruins), biodiversity values, and safety criteria. Additionally, "*green routes*" should be designed with smart solutions including informational panels at designated stops, wayfinding signage, and digital guidance systems utilising QR codes. In this way, a participatory and innovative planning model can be established that preserves traditional knowledge while embracing technology. Similar practices in Türkiye, such as the Lavender Route and Lake Path projects implemented in the Eğirdir district of Isparta, have demonstrated the direct contribution of nature-compatible tourism infrastructure to local development (Durak, 2019).

5.2 Integration of Rural Development with Biological Networks

Planning rural development patterns in harmony with surrounding biological networks contributes not only to nature conservation but also to enhancing rural quality of life and ensuring spatial sustainability. In this context, newly constructed rural buildings should be designed according to principles that enable them to be "*camouflaged within the landscape*", situated away from corridor areas and in alignment with natural topography and micro-ecosystems. At the architectural scale, this approach should be supported by the use of local materials (such as stone, timber, adobe) and horizontal, low-density building formations, ensuring that structures do not compromise the visual, ecological, and cultural character of their surroundings (Antrop, 2005; Council of Europe).

It is also possible to transform existing buildings through nature-friendly interventions. In particular, the use of natural materials in roofs, façades, and gardens, alongside nature-based solutions such as green roofs and green wall systems, can support biodiversity while contributing to energy efficiency and thermal regulation (Kabisch et al., 2017). Such practices are frequently associated with rural sustainability policies in

Europe and are endorsed in line with the "*living landscape*" principles of the European Landscape Convention.

Moreover, semi-natural landscape elements such as agricultural terraces, rain gardens, and natural hedgerow systems can be regarded as supporting components that strengthen ecological connectivity. These structures are significant not only for water management and soil erosion control but also for sustaining traditional agricultural practices and preserving the character of rural landscapes. Rain gardens and natural hedgerows facilitate habitat connectivity, enabling fauna movement while creating visual continuity within rural landscapes. This holistic approach strengthens the agriculture–tourism nexus, thereby enhancing both the economic and ecological carrying capacity of rural landscapes (Pinto-Correia and Kristensen, 2013).

In conclusion, it must be remembered that in rural areas with high natural landscape value, such as Uzundere, development is not merely a matter of physical transformation but also one of ecological and cultural continuity.

For sustainable rural development aligned with Cittaslow principles, planning must encompass not only physical infrastructure but also ecological functionality, cultural identity, and socio-economic continuity. Within this framework, a multi-layered planning approach should be designed to integrate biological corridors, cultural landscape elements, and green infrastructure components (Benedict and McMahon, 2012).

Green infrastructure should not be regarded merely as a tool for conserving natural systems but also as a multidimensional planning instrument that fosters public participation, enhances spatial quality of life, and supports social equity. This approach targets social integration alongside environmental sustainability, thereby highlighting the cultural and social functions of green spaces in addition to their ecological roles. In small settlements such as Uzundere, the establishment of such integrated systems not only yields environmental benefits but also enables the formation of local economic networks that support rural development (Walker et al., 2021).

Furthermore, the design of green infrastructure systems should be grounded in parameters such as local climatic conditions, vegetation, topography, and hydrological dynamics. In areas with steep slopes, techniques such as bio-swale systems, rain gardens, and terracing can be implemented to achieve both erosion control and the recharge of groundwater resources (Vale and Vale, 2000).

Additionally, for nature-based tourism areas, modular infrastructure solutions—such as portable wooden structures, dry toilet systems, and solar-powered lighting—both reduce ecological burdens and conform to the aesthetic principles of Cittaslow (Gössling and Hall, 2021). When all these components are combined, they lay the foundation for a respectful, identity-oriented, and sustainable development model in rural areas such as Uzundere.

6. COMPARATIVE ANALYSIS AND TRANSFERABILITY OF BEST PRACTICE EXAMPLES

6.1. Successful Green Infrastructure Practices in European Cittaslow Towns

In Europe, where the Cittaslow movement originated, numerous small towns and rural settlements have embraced green infrastructure principles, offering pioneering examples in spatial planning. The first of these is Orvieto, the founding town of the movement. By planning organic agricultural belts and nature walking trails at its urban fringes, the town has achieved urban–environment integration; the principle of "*living in harmony with nature*" has enhanced both its touristic appeal and local quality of life. Moreover, agricultural cooperatives, nature guiding training programmes, and rural architectural conservation projects demonstrate that green infrastructure is perceived as a vehicle for socio-economic transformation (Cittaslow International, 2023).

Similarly, in Middelburg, the integration of canal systems into the town centre, rainwater harvesting ponds, urban gardens enclosed by natural hedgerows, and landscape management sensitive to migratory bird routes stand out. In this way, the town's green fabric has been transformed into a continuous ecological corridor, ensuring the sustainable management of urban–agricultural transitional zones (Gemeente Middelburg, 2025).

The coastal settlement of Levanto, aiming to preserve its sensitive sea–mountain landscape, has developed walking trails, nature observation terraces, biological corridors, and small observation towers constructed from local stone. Construction activities are conducted under strict architectural control, utilising regional materials and sustainable techniques; a "*green connectivity belt*" extending from the sea to the mountains secures biodiversity (Comune di Levanto, 2022). Considering Uzundere's sloping topography and multi-layered water system, the Levanto model emerges as instructive in many respects.

6.2. Examples from Protected Areas Preserving Rural Landscape Identity in Türkiye

In recent years, various successful initiatives have emerged in Türkiye aimed at preserving rural landscapes. One such example is Seferihisar in İzmir, Türkiye's first Cittaslow settlement. Here, biological transition zones have been established between agricultural and residential areas, while local seed centres, producer markets, and rural architectural conservation plans have been developed (Seferihisar Municipality, 2025). Furthermore, social events such as "*local seed* *exchange festivals*" held in rural neighbourhoods have supported nature-based cultural continuity. These practices offer significant references for areas like Uzundere, where the agriculture–tourism relationship is strong.

Another noteworthy example is Safranbolu, recognised across Türkiye for its conservation of rural architecture and street texture. The stone–timber building forms, local material utilisation, and the functional adaptation of traditional structures provide inspiring insights into how rural architectural design guidelines might be developed in Uzundere. Additionally, the tourism management models implemented alongside Safranbolu's inscription on the UNESCO World Heritage List offer strategic lessons on how to balance visitor pressures (UNESCO, 2025; Karabük Governorship, 2020).

Moreover, the nature-based tourism practices conducted around Yenice Forests (Karabük) stand out for their visitor management, wayfinding systems, and tourism structures based on principles of minimal intervention. The ecotourism routes, nature education areas, biological monitoring stations, and participatory conservation activities implemented in the region constitute models for similar approaches that could be developed around Tortum Waterfall and Yedigöller in Uzundere (Ministry of Forestry and Water Affairs, 2013; Nature Conservation Centre, 2025).

6.3 Aspects Adaptable to the Uzundere Context

Continuity of Ecological Corridors

As clearly demonstrated in the examples of Levanto (Italy) and Middelburg (Netherlands), the planning of continuous and interconnected green corridors along river systems not only ensures physical integrity among natural landscape elements but also contributes significantly to biodiversity conservation, enhances habitat connectivity, and strengthens climate resilience (Comune di Levanto, 2022; Gemeente Middelburg, 2025). Such corridors facilitate access for species sensitive to habitat connectivity—including birds, small mammals, and pollinators—to their feeding, breeding, and migration habitats, thereby ensuring the continuity of both local and regional ecological networks.

Moreover, these green belts established along rivers act as natural buffers against the impacts of climate change through floodplains and riparian zones, balancing local microclimates and enabling nature-based protection of settlements against extreme heat, flooding, and drought events. These integrated approaches demonstrate that ecological planning constitutes a fundamental component not only of environmental sustainability but also of social and economic sustainability.

Local Architectural Conservation

The harmonious integration of stone and timber materials observed in the example of Safranbolu not only offers historical aesthetic value but also represents a robust model of sustainable architecture in terms of climatic resilience and the utilisation of local resources. This serves as an exemplary model for the development of local architectural design guidelines in Uzundere. In particular, the systematic documentation and transfer into new applications of elements such as authentic façade proportions, eaves details, and colour palettes compatible with the natural context are of paramount importance for preserving architectural continuity and cultural memory (UNESCO, 2025).

In parallel, encouraging the use of natural materials supports local production chains, thereby contributing to the regional economy, while also enhancing the bioclimatic compatibility of buildings with the local climate. This approach, emphasised in the conservation and promotion documents prepared by the Governorship of Karabük, forms the foundation of identity-based planning approaches in rural areas such as Uzundere. Within this framework, the documentation of local architectural heritage, creation of digital inventories, and incorporation into zoning plans are essential for a holistic conservation–design process.

Sustainable Tourism Infrastructure

Successful rural conservation and tourism practices in Türkiye offer instructive models for the development of sustainable tourism infrastructure. Notably, the minimal intervention principles applied in Yenice Forests involve the placement of infrastructure elements such as walking trails, observation points, and rest areas in ways that harmonise with the natural landscape without disrupting its integrity. This approach mitigates ecological pressures and enables the control of visitor carrying capacities (Nature Conservation Centre, 2025).

Similarly, the modular and temporary accommodation systems developed in Seferihisar incorporate innovative building technologies that integrate principles such as low carbon footprints, energy efficiency, and natural light and thermal control. These systems provide accommodation solutions without compromising the visual integrity of local architecture and the natural environment (Seferihisar Municipality, 2025). Such systems not only safeguard the environmental sensitivity of sustainable tourism destinations but also enhance the cost-effectiveness of infrastructure investments through flexible structures suited to seasonal use.

These examples demonstrate that tourism investments in rural destinations sensitive to green infrastructure, such as Uzundere, can be realised according to balanced planning principles that integrate environmental sustainability, cultural integrity, and economic vitality. Within this framework, it is recommended that proposed physical projects prioritise criteria such as modularity, low energy consumption, use of recyclable materials, and integration with nature.

Slow Mobility Systems

The integrated walking and cycling networks in Orvieto have significantly reduced dependence on motorised vehicles by creating continuous, safe, and aesthetically rich routes between the historic urban fabric and the surrounding rural landscape. This network includes detailed components such as integrated transfer points with public transport stops, e-bike stations in hilly sections, and shaded resting areas, thereby facilitating access for users of varying ages and abilities. Consequently, in addition to reducing the carbon footprint in daily mobility and tourist routes, it has deepened visitor experiences by enabling direct engagement with cultural and natural landscapes (Cittaslow International, 2025).

This model offers a viable roadmap for rural destinations such as Uzundere, which possess sloping topography and rich landscape features: route selection should consider biological corridors and cultural heritage focal points, while slow, clean, and inclusive mobility infrastructure should be strengthened through e-bike support stations and smart wayfinding systems. In this way, not only is local access to sustainable mobility options enhanced, but nature-based tourism experiences are diversified, thereby reinforcing the Cittaslow identity of the region.

Participatory Planning and Lifelong Learning

A detailed examination of various best practice examples reveals that the fundamental determinant of success lies in the active inclusion of local actors—such as cooperatives, youth initiatives, women’s organizations, and civil society platforms—within the planning process. This inclusive participation should not be confined merely to initial needs assessment meetings but should extend throughout the stages of decision-making, implementation, monitoring, and evaluation, thereby establishing a genuinely collaborative governance model. As emphasized by the Ministry of Forestry and Water Affairs of Türkiye (2013), sustaining such participation throughout the project ensures the integration of local knowledge into planning processes, enhances community ownership, and increases the flexibility and adaptive capacity of plans.

Furthermore, strengthening the technical and managerial competencies of participating actors through on-site training workshops, citizen science activities, and capacity-building programmes guarantees the long-term sustainability of planning outcomes. Involving local communities in Geographic Information Systems (GIS)-based monitoring, operating feedback mechanisms transparently via digital platforms, and continuously motivating youth through online learning modules institutionalises dialogue between decision-makers and users. In this way, planning practice ceases to be a top-down design process and evolves into a flexible and learning system nourished by local values.

Activities Harmonised with Nature Culture

The ecological festivals extending from the coast to the foothills in Levanto offer multi-layered activity programmes that enable the integrated experience of natural landscapes and cultural heritage. These include local seafood tasting stalls, marine birdwatching, agroecological workshops in vineyards, and forest-based art walks (Comune di Levanto, 2022). Similarly, in Yenice Forests, nature observation days, botanical and birdwatching tours, nocturnal bat counts, "*little explorers*" activities for children, and flora–fauna photo safaris led by local guides engage visitors in experiences centred on scientific awareness and conservation (Nature Conservation Centre, 2025).

These approaches present an inspiring framework for ecological festivals, landscape workshops, and nature-based art gatherings that could be planned in Uzundere. A “*green route festival*” designed along the natural corridor stretching from Tortum Waterfall to the Yedigöller Basin could be enriched with local product markets, biodiversity-themed workshop tents, nocturnal skywatching sessions, and exhibitions of traditional handicrafts. Additionally, within the scope of landscape workshops, activities such as nature sketching, stone–wood sculpture practices, and habitat restoration projects can be organised to increase both visitor participation and the visibility of local artists and artisans.

Such events not only invigorate the ecotourism economy but also transform the cultural capital of local communities into contemporary productions, bringing together traditional cuisine, music, and storytelling with nature conservation themes. Consequently, festivals and workshops organised in Uzundere would become multifunctional events that simultaneously support ecological awareness, identity consciousness, and social cohesion, exemplifying sustainable tourism practices.

7. POLICY RECOMMENDATIONS AND PLANNING STRATEGIES

7.1. Multi-Level Governance: Collaboration among Municipal, Provincial, and Ministerial Authorities

In rural settlements with Cittaslow status such as Uzundere, establishing multi-level governance structures is essential to ensure the sustainability of a green infrastructure-based development model. Green infrastructure is not confined merely to the conservation of natural areas; rather, it constitutes a multidimensional domain requiring integrated management across sectors such as transportation, tourism, zoning, and culture.

In this context, local authorities, including municipalities and district administrations, must possess the capacity to align their zoning practices and tourism investments with green infrastructure principles. However, the development of this capacity necessitates effective coordination with provincial actors such as directorates of environment and urban planning, provincial agricultural directorates, and regional offices of the State Hydraulic Works (DSİ). At the ministerial level, central authorities including the Ministry of Environment, Urbanisation and Climate Change, the Ministry of Culture and Tourism, and the Ministry of Agriculture and Forestry play a critical role through supportive legislative arrangements and funding mechanisms (van Oosten et al., 2020).

Moreover, within this multi-level structure, stakeholders such as non-governmental organisations, universities, cooperatives, and the Cittaslow Türkiye network should assume active roles, ensuring that strategic plans are developed through participatory processes. This governance model should encompass not only vertical hierarchies but also horizontal collaborations, such as knowledge and experience sharing between Uzundere and other Cittaslow towns with similar dynamics (Benedict and McMahon, 2012).

7.2. Integration of Green Infrastructure into Zoning Plans

The sustainability of green infrastructure can be secured not merely through physical projects but through long-term spatial planning documents. Therefore, the explicit integration of green infrastructure components into zoning plans is imperative (European Commission, 2025a). In particular, master zoning plans at the 1:5000 scale and implementation zoning plans at the 1:1000 scale should define the boundaries of green infrastructure corridors, buffer zones, natural threshold areas, and ecological transportation routes, with clear stipulations on development restrictions within these areas.

This integration process should also be supported by Environmental Impact Assessments (EIA), Strategic Environmental Assessments (SEA), and rural settlement guidelines, with interdisciplinary contributions from landscape architects, environmental engineers, and ecology experts during the planning stages. As highlighted in the European Green Deal and Türkiye's Climate Change Strategy Document, reflecting natural infrastructure elements in urban planning constitutes the foundation of resilient and environmentally friendly settlements (EEA, 2025a).

In the specific context of Uzundere, the initial steps of this integration should include transforming into planning decisions the designation of ecological corridors along the Tortum River and hillside forests, development limitations in areas with high natural character, and the criteria for site selection of rural recreation areas.

7.3. Nature-Based Education and Visitor Awareness Programmes

The success of green infrastructure planning is contingent not only upon physical implementations but also upon the elevation of societal awareness levels. In this context, it is essential to institutionalise nature-based education programmes and visitor awareness activities in Uzundere (Raymond et al., 2017).

Firstly, extracurricular educational modules should be organised for primary through secondary school levels, encompassing topics such as local flora and fauna identification, sustainable agriculture, waste management, and landscape literacy. Furthermore, collaborative projects with universities should be promoted, including summer schools, nature camps, and biological observation stations aimed at youth engagement (Merelender et al., 2016).

For visitors, innovative information systems should be introduced, such as ecotourism guiding certification programmes, QR-coded landscape interpretation panels, slow tourism experiential routes, and experience areas narrating the stories of local products. Through these initiatives, Uzundere’s green infrastructure values will not only be conserved but will also become comprehensible and internalised by all users (Ghasemi et al., 2024).

7.4. Rural Architecture Guidelines and Landscape Control Mechanisms

For development in rural areas to evolve in a manner that is both harmonious with nature and reflective of local identity, rural architecture guidelines and landscape control systems should be developed, with municipalities implementing a series of regulations to prevent unplanned construction activities (UN-Habitat, 2025).

Rural architecture guidelines should establish standards for all new constructions, including roof forms, façade colours, building materials, parcel layout, and building heights. These guidelines must be formulated to ensure aesthetic, ecological, and cultural compatibility and integrated into the building permit processes as mandatory components.

Landscape control mechanisms, meanwhile, should function at scales beyond individual buildings, regulating broader dimensions such as land use patterns, limits on interventions within natural areas, and planting schemes. In this regard, a landscape monitoring unit could be established within Uzundere Municipality, with periodic landscape character analyses conducted through technical support from local universities.

8. CONCLUSION

The analyses presented in this book chapter demonstrate that in a rural settlement as multi-layered in its natural, cultural, and touristic dimensions as Uzundere, sustainable development is achievable only through a holistic approach grounded in green infrastructure. When the ecosystems of the Tortum River basin, rural settlement fabric, architectural heritage, and tourism infrastructure are considered collectively, green infrastructure emerges not merely as an environmental tool but as an agent of social, economic, and cultural transformation (Merenlender et al., 2016; European Commission, 2025a).

Such a comprehensive approach offers effective solutions to multi-scalar planning challenges, while laying the groundwork for a development model that maintains a low carbon footprint, preserves local identity, and harmonises with nature. This model is also strongly aligned with Cittaslow principles. Balancing Uzundere's geographical vulnerabilities (such as slope, water presence, and forest pressures) with its socio-cultural values (including local architecture and production practices) is assessed as enhancing the settlement's long-term resilience (EEA, 2025b).

The green infrastructure approach has redefined the complex interrelationships among identity, tourism, spatial planning, and ecology in Uzundere. While the development of rural architectural guidelines safeguards spatial identity, proposals for nature-based tourism infrastructure align traditional production practices with sustainable tourism (Kusters et al., 2020). The incorporation of ecological thresholds and buffer zones into zoning plans has been shown to facilitate both landscape continuity and the mitigation of natural risks, underscoring the importance of strategic approaches in this regard (European Commission, 2025a).

Furthermore, by enhancing societal participation through nature-based education and slow mobility initiatives, steps can be taken to strengthen local governance capacity, enabling Uzundere to evolve not merely as a tourism destination but as a spatial model of harmonious living with nature (Raymond et al., 2017).

The conceptual framework outlined in this chapter points to a multidimensional research programme to support green infrastructure planning in Uzundere's rural context. Initially, NDVI-based vegetation monitoring, land use/land cover (LULC) analyses, and habitat connectivity modelling should be conducted concurrently to map the temporal dynamics of the ecological network in detail (Muhar et al., 2002). These spatial outputs will generate decision support layers for local authorities while enabling quantitative monitoring of the environmental sustainability of rural development investments.

Simultaneously, community-based qualitative research should investigate local perceptions of nature, tendencies in green infrastructure use, and motivations for participation (Schuttler et al., 2018). Such data provide the foundation for developing participatory tools (e.g., co-design workshops, cooperative models) that will increase social acceptance of design and management strategies.

At the planning scale, it is recommended to propose an evaluation matrix for the systematic integration of Cittaslow criteria into existing zoning and environmental plan documents (Cittaslow International, 2023). The matrix would assess the alignment of land use decisions with "*slow city*" principles, thereby clarifying spatial quality standards and fostering a shared language in multi-level governance.

Finally, ecosystem services analyses—particularly assessments of carbon offset potential, contributions to landscape economy, and the monetary or functional valuation of cultural services—should be calculated using contemporary numerical models and integrated into planning decisions (Ghasemi et al., 2023). This approach will elucidate the tangible contributions of green infrastructure investments to climate policies and local income diversification.

In practice, it is proposed that the methodology presented here be tested within pilot sites identified in Uzundere, with the findings providing feedback into national rural development policies. Furthermore, international partnerships established through the Cittaslow network and EU Green Deal funding will strengthen the financing and technical capacity of physical projects, consolidating the region's sustainable development vision.

In conclusion, Uzundere's natural, cultural, and spatial resources can be both conserved and transformed into carriers of sustainable development through rational strategies and holistic approaches. This model offers an applicable framework for all Cittaslow towns and rural areas across Türkiye.

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Applying Artificial Intelligence in Decision Support Systems in Landscape Architecture

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INTRODUCTION

In the 21st century, in parallel with technological developments, lifestyles, the structure of cities, and design approaches have also undergone a transformation. The process of digitalization has not been limited only to the integration of technological devices or systems operating with software into daily life; it has also led to paradigm shifts in many areas, from access to information to decision-making processes, from problem-solving approaches to forms of interdisciplinary interaction (Pirli, 2020). Especially the necessity of coping with complex problems such as the climate crisis, biodiversity loss, natural disasters, migration, dense and irregular urbanization, and sustainability has directly affected the discipline of landscape architecture. Technologies such as artificial intelligence (AI), machine learning, deep learning, big data analytics, and numerical modelling have begun to be used effectively at every stage of the design process, together with their components. While traditional approaches prioritized expert opinion and observation-based decision-making methods, with digital transformation, data-driven and algorithmic decision support mechanisms have developed. This innovative approach requires landscape architects to simultaneously utilize both creativity and analytical thinking skills (Sağlık & Yetişir, 2024).

Landscape architecture is a professional discipline that manages the interaction between nature and humans, shaping spaces in line with aesthetic, functional, and ecological criteria (Gülgün et al. 2015). However, today these interactions are becoming increasingly complex; changing climatic conditions, rapid population growth, social demands, and spatial constraints are pushing design decisions into a framework that involves more uncertainty (Pirli et al., 2023). At this point, decision support systems allow planners and designers to analyze many variables simultaneously, produce scenarios, and develop more rational solutions. These AI-based systems process both quantitative and qualitative data to create predictive models, thus ensuring efficiency in terms of both time and resources during the design process.

The use of decision support systems in landscape architecture creates a transformation that affects not only the technical dimension of these systems but also the intellectual framework of the discipline. These systems support traditional intuition- and experience-based decision-making processes with data-based, transparent, and repeatable constructs. For instance, in many subtopics such as plant selection, surface water management, accessibility analysis, and microclimate evaluations, more sustainable, functional, and holistic solutions can be developed through AI-supported decision systems. Additionally, the ability to model different scenarios provides designers with the opportunity to foresee the future and compare alternatives.

Especially in the context of Türkiye, it is observed that academic resources guiding the integration of artificial intelligence into landscape architecture, offering theoretical depth and supported by application examples, are limited. This study aims to fill this gap by approaching artificial intelligence-supported landscape design from a holistic perspective—starting from its theoretical foundations to the technologies used, decision support mechanisms, ethical discussions, and future projections.

Figure 1. Generative Artificial Intelligence in Landscape Design, From Sketch to Reality (Lobo, 2023).

1.MATERIAL AND METHOD

This study is structured using qualitative research methods to evaluate the integration of artificial intelligence (AI)-based decision support systems into landscape design processes. The research adopts a holistic approach, combining theoretical and practical insights through literature review, technical analysis of digital tools, and case study investigations. The study was carried out in three main stages.

In the first stage, a comprehensive literature review was conducted to explore the conceptual foundations, historical development, and digital integration of AI technologies in landscape architecture. This involved the examination of national and international peer-reviewed journals, academic theses, project reports, institutional documents, platform user manuals, and technical databases. A thematic analysis method was employed to classify AI tools and categorize them based on their intended use.

In the second stage, the role of decision support systems in landscape planning and design was assessed within the framework of multi-criteria decision-making (MCDM) methods, spatial analysis techniques, and user-oriented modelling. A variety of AI-based tools—such as ArcGIS Pro, Rhino-Grasshopper, Midjourney, DALL·E, Stable Diffusion, UrbanGPT, and Google Earth Engine—were analyzed. These tools were evaluated comparatively under categories such as functionality, accessibility, visualization capabilities, scenario generation, and real-time analysis, and their contributions to design processes were supported with specific examples.

In the third stage, a case study approach was employed to evaluate both national and international implementations of AI-supported decision support systems. The analysis focused on open-source data from TÜBİTAK-supported research projects and initiatives led by metropolitan municipalities such as Istanbul and Izmir. Particular emphasis was placed on Izmir's GIS-based analytical models for planning urban green infrastructure and Istanbul's AI-driven climate adaptation scenarios. Additionally, several international case studies were examined to provide comparative insights into the integration of AI technologies in landscape planning and decision-making processes.

International cases included data-driven decision systems developed in San Francisco for mitigating the urban heat island effect; AI-supported stormwater management scenarios in Rotterdam (ASLA, The dirt, 2018); Singapore's "AI Urban Greening Toolkit" for sustainable landscape planning(Arup, 2025); the "Machine Learning for Landscape Ecology" initiative supported by Natural England (UK) (Fraizer & Song, 2025; Varga, et al., 2024); and parametric modelling studies on urban transformation in Shenzhen, China. These (ALLPlan, 2021) examples were compared in terms of technological infrastructure, data inputs, user participation, and integration into decision-making.

Throughout the study, a descriptive analysis method was adopted to establish a coherent connection between the theoretical background of AI-based decision support systems and their real-world applications. The findings suggest that digital technologies not only serve as design tools but also foster a new way of thinking, enhancing transparency, innovation, and ethical responsibility in landscape architecture. As a result, these systems play a strategic role in shaping sustainable, inclusive, and data-driven planning practices.

Table 1. Flowchart of the study

DEVELOPMENT OF ARTIFICIAL INTELLIGENCE TECHNOLOGIES AND THEIR PLACES IN LANDSCAPE ARCHITECTURE	CONCEPTUAL APPROACHES AND TECHNOLOGICAL INFRASTRUCTURES	REFLECTIONS OF ARTIFICIAL INTELLIGENCE SUPPORTED DECISION SUPPORT SYSTEMS IN PRACTICE AND SAMPLE APPLICATIONS

2. FINDINGS AND DISCUSSION

2.1. The Concept of Artificial Intelligence

Artificial intelligence (AI), in its simplest definition, is a field of science concerned with the development of systems that mimic human intelligence. It encompasses the methods and technologies that enable computers or machines to acquire human-like capabilities such as thinking, learning, perceiving, reasoning, and problem-solving. This concept represents not only a technical advancement but also a multifaceted change in basic assumptions that signifies the transformation of human–machine interaction. The term "artificial intelligence" was first introduced by John McCarthy during the

Dartmouth Conference held in the United States in 1956. Since then, AI research has gone through various stages of development depending on the evolving technological conditions and data processing capacity of each period (Pirim, 2006).

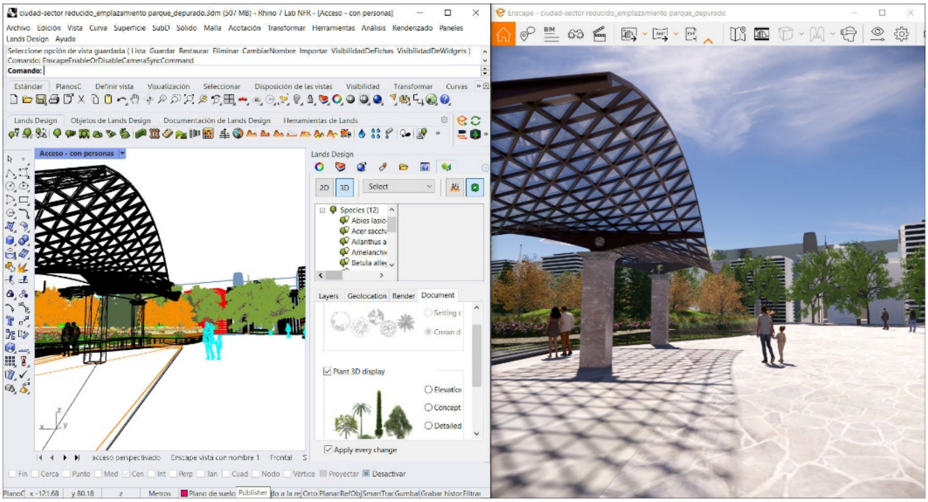

Figure 3. The rhino program for landscape design, (Rhino Website, 2025).

In the beginning, systems were developed based solely on predefined rules; however, today, thanks to multi-layered learning algorithms, it is possible to design systems that can update themselves, make decisions, and offer suggestions. Artificial intelligence stands at the intersection of various disciplines such as cognitive science, computer engineering, statistics, psychology, linguistics, and philosophy. In this context, it is considered not merely as an engineering product but also as a transformative tool that influences social structures within the frameworks of knowledge production, decision-making, and ethical debates (Kahvecioğlu, Ast, & Sağlık, 2024).

As artificial intelligence has evolved into a more autonomous, interdisciplinary, and adaptive technology, its scope of application has also broadened significantly. Today, artificial intelligence is associated with many sub-concepts and applications across different fields. Machine learning, deep learning, natural language processing, image recognition, and robotic systems are technological extensions that constitute the subcomponents of this concept. The use of artificial intelligence in a field like landscape architecture—where creative and analytical thinking coexist—represents a multilayered process that must be evaluated not only from a technological standpoint but also in socio-cultural, environmental, and ethical contexts (Sağlık & Yetişir, 2024).

2.2. AI-Based Tools Used in Landscape Studies

In recent years, the integration of artificial intelligence (AI) into landscape architecture has introduced a diverse array of tools and methodologies that significantly enhance the analytical depth, precision, and creativity of planning and design processes (Kensek, 2014; Chien et al., 2020). AI applications now permeate multiple layers of landscape design, ranging from data collection and interpretation to generative modeling and visualization.

Geographic information systems (GIS)-based AI tools support large-scale spatial analysis and environmental data interpretation. Platforms such as Google Earth Engine, ArcGIS with machine learning extensions, and eCognition enable tasks such as land use classification, vegetation indexing, soil moisture mapping, urban heat island detection, and disaster risk modeling with high accuracy (Gorelick et al., 2017; Drăguț et al., 2014; Blaschke, 2010). These systems allow planners to make informed decisions by automating the processing of vast and complex geospatial datasets.

In parallel, generative and computational design platforms like Rhino-Grasshopper, enhanced with AI-powered plugins such as Wallacei and Opossum, provide capabilities for parametric modeling, environmental simulation, and adaptive form generation (Jabi, 2013). Emerging tools such as UrbanGPT further facilitate the integration of urban-scale data and natural language processing to explore context-sensitive urban form alternatives (Xu et al., 2023).

Machine learning algorithms are employed to predict vegetation growth patterns, assess soil and hydrological conditions, detect land cover change over time, and simulate ecological processes under varying scenarios (Reichstein et al., 2019; Xie et al., 2021). This predictive capacity supports long-term, resilience-oriented planning strategies.

Moreover, AI-based image generation models, including Midjourney, DALL·E, and Stable Diffusion, are being utilized in early-stage design visualization. These tools convert textual prompts into visuals, enabling designers to quickly iterate and communicate conceptual ideas before entering detailed modeling phases (Ramesh et al., 2022; Saharia et al., 2022).

Collectively, these AI-driven tools facilitate the handling of complex, multidimensional data, enhance the capacity for scenario testing, and empower designers to explore sustainable, responsive, and innovative design solutions with increased efficiency and depth.

The use of artificial intelligence technologies in landscape planning is transforming traditional design practices and enabling both design and decision-making processes to be conducted in a more qualified, rapid, and predictable manner. AI-based tools contribute to the development of multi-layered design scenarios by being utilized in various domains such as data analysis, visualization, simulation, and modeling (Sağlık & Yetişir, 2024).

Figure 4. Generative Artificial Intelligence in Landscape Design, From Sketch to Reality (Lobo, 2023).

2.2.1. Ai based Visual Production and Design Tools

In the context of landscape architecture, visual representation is a critical component of both the design process and stakeholder communication. With the advancement of artificial intelligence, visual production tools have evolved to support designers in generating high-quality imagery, conceptual sketches, and scenario visualizations with unprecedented speed and flexibility. These tools not only accelerate the ideation phase but also enhance creative exploration, allowing designers to iterate through multiple aesthetic and functional possibilities in a short period of time. Particularly during the early stages of design, AI-based visualization technologies enable a seamless transition from abstract ideas to concrete visual forms.

AI-based visual production tools such as Midjourney, DALL·E, and Stable Diffusion play a significant role, particularly in the conceptual design process. These tools convert textual prompts provided by users into images, enabling the rapid generation of diverse design alternatives.

In landscape architecture, such tools are frequently utilized for generating visual proposals, enhancing project presentations, and supporting creative idea development (Kahvecioğlu, Ast, & Sağlık, 2024).

Figure 5. Dall-E 3 VS Midjourney 5.2 VS Stable Diffusion XL - Same Prompt, Different Results (Monge, 2023)

In addition to these, platforms like Adobe Firefly allow for precise text-to-image generation with design-oriented controls, while Runway ML enables video-based generative AI for dynamic visual storytelling. NVIDIA Canvas offers real-time landscape sketching supported by AI-powered style transfer, which is particularly useful for early-phase concept generation. Tools like DeepArt apply neural style transfer techniques to create artistically enriched renderings that help communicate the emotional tone of a design. Collectively, these tools contribute to a more engaging, efficient, and expressive design workflow in landscape architecture, especially in interdisciplinary and client-centered project environments.

2.2.2. Parametric and Computational Design Tools

With the integration of artificial intelligence technologies into design processes, parametric and computational design tools are becoming increasingly widespread and effective in the field of landscape architecture. These tools enable data-driven decision-making, rapid scenario generation, and design development based on environmental variables. Especially when supported by AI, such platforms offer significant advantages in modelling complex systems and optimizing design alternatives.

Among the most widely used tools is Grasshopper, a visual programming environment integrated with Rhinoceros 3D. When combined with AI algorithms, Grasshopper allows for the definition of diverse environmental and structural parameters, enabling the rapid generation of multiple design scenarios. AI-powered plug-ins such as Wallacei and Opossum, which run on Grasshopper, further support design optimization through genetic algorithms and machine learning techniques.

In addition to Rhino-Grasshopper, several other AI-assisted platforms are being utilized in design disciplines. Spacemaker AI (now integrated into Autodesk Forma) supports sustainable urban development decisions through AI-based analysis at the city scale. Hypar offers a new generation of cloud-based, rule-driven design workflows, allowing for the automation of complex design logic. TestFit rapidly generates housing layout scenarios, while Esri CityEngine stands out with its parametric city modelling capabilities that integrate geographic data. Moreover, generative AI tools such as StyleGAN and DeepDream are used in conceptual design processes to explore aesthetic variations and form studies.

In landscape planning, these tools provide notable advantages in topographic modelling, planting schemes, microclimate analysis, and the integration of sustainable infrastructure (e.g., permeable surfaces, rain gardens). As a result, they enable more flexible, creative, and environmentally responsive design processes (Kahvecioğlu, Ast & Sağlık, 2024)

Figure 6. The rhino program for landscape design, (Rhino Website, 2025)

2.2.3. Geographical and Remote Sensing Based Systems

Artificial intelligence-supported geographic information systems (GIS) and remote sensing analysis tools—such as eCognition, ArcGIS AI extensions, and Google Earth Engine—make significant contributions to the interpretation of spatial data in landscape planning processes (Yazici & Gülgün Aslan, 2018). Through these tools, various spatial analyses such as land use classification, green space assessments, urban heat island detection, flood risk, and wildfire susceptibility mapping can be effectively conducted (Kahvecioğlu, Ast & Sağlık, 2024; Drăguţ et al., 2010; Gorelick et al., 2017; Yazici et al.,2017).

In addition, machine learning-based plugins integrated into open-source platforms such as QGIS—notably the Semi-Automatic Classification Plugin—enable users to analyze land cover changes using satellite imagery from sources such as Landsat and Sentinel (Congedo, 2016). Advanced image processing software such as ENVI, ERDAS Imagine, and TerrSet (IDRISI) allow for detailed classification and time-series analyses, especially on hyperspectral and multispectral imagery (Eastman, 2016; Jensen, 2015).

Google Earth Engine, with its cloud-based infrastructure, supports the processing of large datasets and enables users to perform powerful geospatial analyses without requiring high-end computing hardware. The platform facilitates high-resolution monitoring of global environmental phenomena such as carbon emissions, changes in the hydrological cycle, desertification trends, and deforestation through embedded algorithmic workflows (Gorelick et al., 2017).

Moreover, the AI-enhanced spatial analyses provided by these systems are not limited to assessing current conditions; they also play a crucial role in scenario-based planning and sustainability assessments. For instance, models that forecast future land use changes (e.g., Markov, CA-Markov, LCM) can be operated within TerrSet using AI-integrated modules, enabling simulation of the long-term impacts of planning decisions (Eastman, 2016).

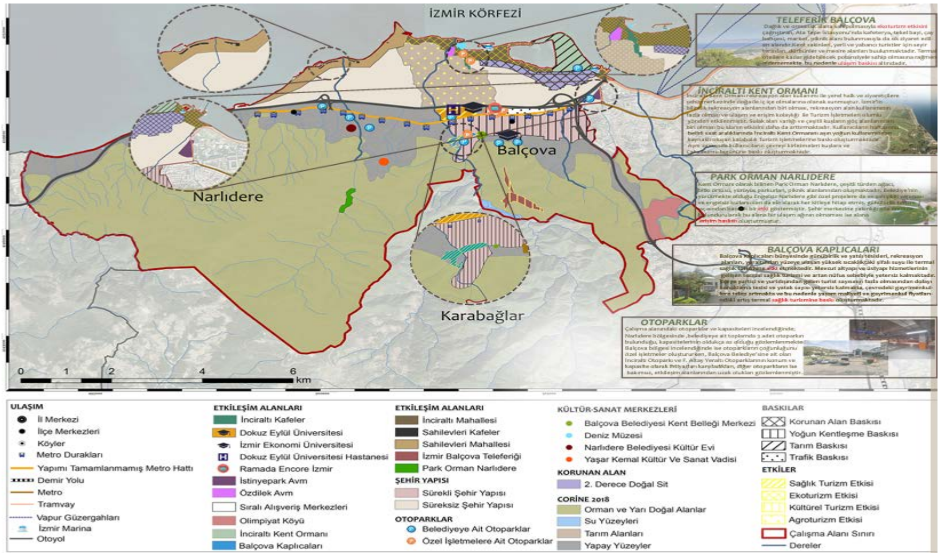

Figure 7. A landscape planning in ArcGIS program (Original, 2022)

2.2.4. Natural Language Processing and Planning Assistants

Next-generation planning assistants such as UrbanGPT are artificial intelligence systems capable of interpreting natural language inputs from users and generating meaningful, context-aware outputs within the domain of urban and spatial planning. These natural language processing (NLP)-based tools are particularly valuable in enhancing communication with non-technical stakeholders, supporting participatory planning processes, and automating the production of planning documents and regulations.

Such systems offer a wide range of functionalities—from drafting zoning notes and verifying compliance with planning codes to classifying and routing public feedback to relevant departments. For example, when an urban planner inputs a command like “propose a mixed-use zone with a density limit of 2.0,” UrbanGPT can translate this into a technical proposal or generate alternative scenarios based on the input constraints.

In addition, large language model (LLM)-based platforms such as ChatGPT, Claude, and Gemini serve as intelligent assistants for summarizing planning documents, conducting needs assessments, synthesizing policy documents, and formulating strategic recommendations. These tools not only generate text but also provide data-informed suggestions, support the justification of planning decisions, and facilitate multi-actor decision-making processes.

Particularly within municipalities, regional development agencies, provincial administrations, and planning consultancies, the use of AI-powered planning assistants significantly accelerates and streamlines workflows while promoting transparency and efficiency (Kahvecioğlu, Ast & Sağlık, 2024).

2.2.5. Climate and Ecosystem Modeling

Artificial intelligence-supported software tools are increasingly employed in modelling spatial transformations driven by climate change, calculating carbon emissions and sequestration capacities, and analyzing ecological thresholds and tipping points. These tools enable planners and designers to integrate climate-responsive strategies into landscape-based decision-making processes.

Specialized AI-driven models in this field—such as process-based vegetation simulators, carbon budget estimators, and habitat connectivity analyzers—facilitate the implementation of nature-based solutions by providing predictive insights into long-term ecological dynamics. For instance, AI algorithms can simulate land cover change scenarios under various Representative Concentration Pathways (RCPs), aiding in climate adaptation planning at local and regional scales (Reichstein et al., 2019; Runting et al., 2020).

Moreover, tools such as InVEST, TerrSet, and CLUE-S models are increasingly being integrated with machine learning techniques to support the assessment of ecosystem services, biodiversity sensitivity, and landscape resilience. These hybrid systems allow for multi-scalar analyses that account for both biophysical and socio-spatial components of landscapes.

Ultimately, the integration of AI-based tools into landscape planning represents not only a technological evolution, but also a transformative shift in how creative processes are supported, sustainable solutions are developed, and decision-making mechanisms are grounded in scientific evidence. These tools offer flexible and adaptive design solutions that align with the inherently multi-scale and multi-dimensional character of landscape architecture, thus reshaping professional practice.

2.3. Data-Driven Decision Support Mechanisms and Application Examples

In contemporary planning and design processes, data-driven approaches have become increasingly critical. In complex planning contexts—such as landscape architecture—where environmental, social, economic, and spatial variables must be considered simultaneously, traditional decision-making methods often fall short. Consequently, there is a growing need for systems capable of processing large datasets, generating alternative scenarios, and conducting multi-criteria analyses to guide decision-makers more effectively.

Decision Support Systems (DSS) provide planners with a structured, data-informed, and repeatable analytical framework, improving the transparency, consistency, and foresight of planning decisions. Rather than relying solely on professional intuition and experience, spatial decisions can now be informed by modeling, simulation, and real-time analytics (Gümüş & Durduran, 2020).

Techniques such as the Analytic Hierarchy Process (AHP), Analytic Network Process (ANP), TOPSIS, and PROMETHEE have been widely integrated into geographic information systems (GIS) to support land suitability assessments, conservation planning, recreational network design, and accessibility evaluations. These Multi-Criteria Decision Analysis (MCDA) methods are increasingly enhanced by AI-based learning algorithms that expand the capabilities of intelligent DSS, allowing planners to interact with the system and receive adaptive, evidence-based recommendations (Malczewski & Rinner, 2015).

DSS platforms also play a crucial role in addressing complex datasets involving sustainability indicators, climate change projections, carbon footprints, accessibility scores, and ecological networks. By synthesizing these data layers, DSS tools present transparent, traceable, and justifiable decision alternatives, which are especially valuable in institutional settings such as municipalities, regional planning agencies, and private planning consultancies.

Ultimately, data-driven DSS tools support more informed, systematic, and sustainable decision-making processes across a wide range of landscape planning applications.

Figure 8. Image generation from text with Dall-E (Kahvecioğlu, Ast ve Sağlık, 2024).

2.3.1. What Are Decision Support Systems?

Decision Support Systems (DSS) are data-driven software and modeling tools developed to assist human decision-makers in addressing complex and multidimensional problems. These systems analyze data gathered from various sources and generate alternative solutions, thereby grounding the decision-making process in rational, transparent, and scientifically informed frameworks. In the discipline of landscape architecture, DSS are applied in diverse areas such as environmental planning, urban design, green infrastructure strategies, and risk management (Gümüş & Durduran, 2020).

Typically, decision support systems consist of the following key components:

- Databases and analytical modules,
- Integration with Geographic Information Systems (GIS),

- Artificial intelligence and machine learning algorithms,
- User-friendly interfaces and interactive reporting tools.

These systems make it possible to evaluate not only spatial data, but also a wide range of variables such as user behaviors, demographic characteristics, climate data, and natural disaster risks within a unified platform. This integrative capability greatly enhances the comprehensiveness and responsiveness of landscape planning and design processes (Gümüş & Durduran, 2020).

2.4. Examples of Application Areas of Decision Support Systems

2.4.1. Green Infrastructure Planning

The integration of green infrastructure into urban systems has become a key strategy for enhancing urban resilience, mitigating the impacts of climate change, and fostering human well-being (Yazici & Gülgün Aslan, 2016). Green infrastructure includes a wide range of elements such as parks, green roofs, urban forests, bioswales, permeable surfaces, and ecological corridors, which collectively provide essential ecosystem services such as stormwater management, air purification, carbon sequestration, and recreational opportunities (Benedict & McMahon, 2006; Tzoulas et al., 2007).

Decision Support Systems (DSS) facilitate the sustainable planning and spatial optimization of these green infrastructure components. By integrating GIS-based spatial analyses with environmental, social, and economic datasets, DSS tools assist planners in selecting optimal park locations, analyzing the connectivity of green corridors, evaluating urban heat island mitigation potential, and identifying areas with insufficient green coverage (Atanur & Mirici, 2020; Lafortezza et al., 2013).

Moreover, DSS applications can incorporate multi-criteria decision analysis (MCDA) techniques such as AHP or TOPSIS to weigh factors like population density, accessibility, land suitability, and ecosystem sensitivity in a systematic and transparent manner (Malczewski & Rinner, 2015). This allows urban designers and landscape architects to prioritize intervention areas and justify planning decisions based on both quantitative data and policy objectives.

Some DSS platforms also include scenario-based simulation tools, enabling planners to assess the long-term effects of different land use configurations or green infrastructure investments under future climate or urban growth projections. For example, tools like i-Tree, InVEST, and Nature Braid are increasingly used to quantify the ecosystem benefits of green infrastructure and to support evidence-based design interventions (Nowak et al., 2018; Sharp et al., 2016).

Ultimately, DSS-supported green infrastructure planning enables more adaptive, inclusive, and science-informed strategies that not only address current urban challenges but also anticipate future socio-ecological transformations.

2.4.2. Climate Adaptation Scenarios

In the Climate Adaptation Scenarios face of climate change, AI-enhanced Decision Support Systems (DSS) are becoming increasingly vital in guiding urban and regional adaptation strategies. These systems analyze complex meteorological data—including temperature trends, precipitation regimes, wind directions, and humidity levels—to simulate the potential impacts of climate variability and to propose context-sensitive planning responses (Gümüş & Durduran, 2020).

One of the key contributions of these systems is their ability to model and mitigate the urban heat island (UHI) effect by identifying priority intervention zones for urban greening, reflective surfaces, and ventilation corridors. Additionally, they support flood risk management by integrating hydrological models with land use and topography data to predict vulnerable areas under various rainfall scenarios. In arid and semi-arid regions, drought risk analysis is conducted using AI algorithms that evaluate soil moisture, evapotranspiration, and vegetation indices over time (Fasihi et al., 2021).

DSS platforms also play a pivotal role in evaluating the climate compatibility of plant species, ensuring that urban greening strategies are ecologically resilient in the face of future climate scenarios. Furthermore, these systems assist in mapping and optimizing carbon sink potentials, guiding afforestation and land restoration projects based on maximum sequestration potential and habitat integrity (Nowak et al., 2018; Chaplin-Kramer et al., 2015).

Advanced tools such as TerrSet's Land Change Modeler, InVEST, SLEUTH, and AI-integrated SWAT models allow planners to simulate climate adaptation scenarios by integrating biophysical, climatic, and socio-economic data. These simulations help stakeholders assess trade-offs between different adaptation strategies, fostering proactive and evidence-based climate resilience planning.

2.5. Case Studies

2.5.1. TÜBİTAK-Funded Projects in Turkey

Numerous research projects funded by The Scientific and Technological Research Council of Turkey (TÜBİTAK) have yielded valuable insights into the integration of artificial intelligence-based Decision Support Systems (DSS) in landscape planning and design. These projects have particularly focused on smart city themes, addressing topics such as green infrastructure planning, disaster risk management, and sustainable mobility scenarios. A notable example includes the use of DSS in the mapping of urban heat islands (UHIs) and the identification of context-specific shading strategies aimed at reducing surface temperatures in high-risk urban areas. These systems utilize high-resolution satellite imagery, meteorological data, and land use patterns to produce scenario-based interventions that inform urban climate adaptation planning (Gümüş & Durduran, 2020).

In other TÜBİTAK-funded studies, DSS platforms have been employed to evaluate flood vulnerability, optimize the distribution of urban green spaces, and assess the accessibility of public services under various urban growth projections. The integration of artificial intelligence allows for the processing of multi-layered geospatial and temporal data, enabling planners to simulate future scenarios, compare outcomes, and prioritize investment areas based on sustainability metrics.

These examples demonstrate how AI-enhanced DSS tools are actively shaping evidence-based landscape planning practices in Turkey, while also contributing to broader efforts to align national planning strategies with climate resilience, environmental justice, and digital transformation objectives

2.5.2. Public Sector Applications in Turkey

Across Turkey, particularly within metropolitan municipalities, there is a growing institutional culture of data-driven decision-making in urban planning. As part of this transformation, several AI-supported planning initiatives have been implemented by local governments to address challenges related to climate adaptation, green infrastructure, and environmental justice.

Istanbul Metropolitan Municipality (IMM) has utilized AI-supported spatial analysis tools as part of its Green Space Master Plan to increase the amount of green space per capita. By leveraging Geographic Information Systems (GIS) and spatial datasets, the municipality has produced planning strategies aimed at equitably distributing urban greenery, prioritizing underserved neighbourhoods, and strengthening ecological connectivity.

Izmir Metropolitan Municipality, within the framework of its Climate Change Adaptation Strategy and Action Plan, has employed AI-enhanced modelling to assess flood risk zones and urban heat island (UHI) intensity. These models have guided the optimization of existing infrastructure systems, including drainage networks, permeable surfaces, and urban shading interventions, contributing to the municipality's broader climate resilience goals (İBB, 2025).

These initiatives illustrate the increasing reliance on AI-based technologies by local governments to inform proactive, transparent, and scientifically grounded planning decisions. Furthermore, they demonstrate how municipal-scale DSS applications are contributing to the operationalization of national-level sustainability frameworks and international commitments such as the EU Green Deal, Sendai Framework, and UN Sustainable Development Goals (SDGs).

2.5.3. International Examples of AI-Enabled DSS in Landscape Planning

Building-Level Urban Heat Vulnerability Mapping – Delhi, India: Nonprofits SEEDS and Chintan, supported by Microsoft, have developed an AI model called Sunny Lives to map heat stress risks down to individual buildings—especially within low-income neighbourhoods in Delhi. This model integrates satellite imagery, building materials, and indoor/outdoor temperature data to identify and prioritize interventions in the most vulnerable areas (Vincent, 2024).

Ecosystem Management Decision Support (EMDS) – USA: The EMDS platform, developed by the U.S. Forest Service, is a spatial decision support system integrating GIS with logic-based reasoning. It supports multi-scale planning tasks—such as watershed assessment, wildlife habitat conservation, and ecological restoration—providing adaptive planning workflows and decision analytics (USDA, 2024)

Digital Twin and AI for Climate Resilience – Global Cities: Cities including Houston, Amsterdam, and Singapore are piloting digital twin systems augmented with AI and real-time data. These platforms support real-time environmental monitoring (heat islands, flood risk), infrastructure optimization, and scenario testing—though documentation is dispersed across municipal and industry sources (McDonell, 2024).

I-Driven DSS for Ecosystem Management – Federal Agencies: Platforms like EMDS are used within U.S. federal level programs to assess ecological trends, model wildland fire hazards, prioritize restoration strategies, and integrate expert knowledge into large-scale decision-making frameworks (USDA, 2024).

Rotterdam – AI-Supported Stormwater Management: The city of Rotterdam utilizes AI-enhanced hydrological modelling systems to address flood risks caused by climate change. These systems integrate data on rainfall, land use, and topography to generate predictive flood scenarios. AI enables the identification of priority areas for intervention, such as green roofs and permeable surfaces, thereby supporting adaptive water management strategies. **DSS (Decision Support System) Role:** Provides spatially explicit flood risk maps and scenario-based outputs to inform municipal planning decisions.

Singapore – AI Urban Greening Toolkit: Singapore's "AI Urban Greening Toolkit" is a digital platform designed to mitigate the urban heat island (UHI) effect through nature-based solutions. The tool uses satellite imagery, temperature data, and urban morphology to identify zones with high cooling potential and proposes greening interventions accordingly. AI-driven analytics enhance precision and efficiency in urban green infrastructure planning. **DSS Role:** Supports decision-makers with visualized prioritization maps and optimization models for greening interventions.

United Kingdom – Machine Learning for Landscape Ecology: This initiative, supported by Natural England, applies machine learning algorithms to classify habitat types, assess biodiversity patterns, and predict ecological changes under different climate scenarios. The AI models are integrated with spatial decision support systems to guide conservation planning and habitat restoration efforts. **DSS Role:** Enables evidence-based, multi-scale ecological decision-making by combining predictive models with GIS-based tools.

Shenzhen, China – Parametric Modelling for Urban Transformation: In Shenzhen, parametric design approaches enhanced by AI algorithms are used to model urban transformation scenarios. Factors such as density, shadow patterns, mobility, and microclimate are analyzed to produce optimized urban form alternatives. These models support collaborative decision-making among designers, planners, and stakeholders. **DSS** Role: Offers scenario-based parametric design tools that integrate AI outputs with participatory planning frameworks.

3. DISCUSSION AND CONCLUSION

Landscape architecture is a unique discipline that historically redefines the relationship between nature and humans, integrating aesthetic, functional, and ecological components of space. Through its multifaceted relationships with the fields of art, science, and engineering, landscape architecture remains a discipline open to both theoretical and practical transformation. However, the complex issues of the 21st century—such as climate change, biodiversity loss, urban sprawl, social inequalities, and disaster risks—require the discipline to enhance its problem-solving capacity through more systematic, data-driven, and cross-scalar approaches. At this point, the integration of artificial intelligence (AI) technologies and decision support systems (DSS) marks a strategic turning point for landscape planning and design.

AI is not merely a tool that enhances computational capacity; it also offers a technological ecosystem capable of analyzing multidimensional data, recognizing patterns, forecasting outcomes, and adapting through learning algorithms. Decision support systems, on the other hand, are structured tools that process spatial and thematic data from multiple scales, generate planning scenarios, and provide decision-makers with alternative outputs. The integration of these two technological layers fosters more holistic and responsive decision-making processes within landscape architecture. AI-powered DSS excel in multi-criteria decision-making, scenario modeling, data visualization, natural language processing, and simulation.

In practice, the synergy between these systems yields tangible benefits at various scales. For example, in green infrastructure planning, AI can analyze vegetation patterns using high-resolution imagery, while DSS combines this data with socio-demographic variables to identify priority intervention areas. Similarly, environmental risk factors such as flood hazards, urban heat islands, or carbon emissions can be mapped automatically by AI algorithms, and DSS can translate these outputs into spatial planning scenarios that support evidence-based policy making.

The integration of these technologies leads not only to technical but also conceptual transformations. It is not enough to simply deploy digital tools; the ethical, social, and environmental values that underpin these tools must also be critically examined. The integration of AI into landscape architecture should not be viewed solely as an innovation in terms of efficiency, speed, or optimization. Rather, it should provoke fundamental questions: for whom are we designing, whose needs are prioritized, and which social groups are being excluded? Digital transformation must therefore extend beyond enhancing technical capacities to building a new value system that fosters more just, transparent, participatory, and ecologically responsible decision-making processes.

In the specific context of Turkey, although the integration of these technologies remains visible in a limited number of applications, it reflects a growing trend with considerable potential. Projects supported by TÜBİTAK, climate action plans developed by metropolitan municipalities, research projects conducted in universities, and investments in open data infrastructures all point to the increasing institutionalization of this process. Nonetheless, significant challenges remain in terms of conceptual clarity, interdisciplinary collaboration, original data production, and ethical frameworks. Addressing these gaps will not only enhance the quality of professional practice but also ensure that digitalization is balanced with principles of social justice, inclusivity, and environmental equity.

In conclusion, AI-integrated decision support systems represent more than just a digitally augmented version of landscape architecture; they constitute the foundation of a new paradigm in thinking, designing, and managing landscapes. This transformation positions landscape architects not only as users of digital technologies but also as strategic actors who can anticipate the ethical, environmental, and social consequences of these systems. In the future, the development of AI tools that are more inclusive, open-source, ethically grounded, and user-centred will elevate the professional and societal status of landscape architecture. To successfully navigate the digital era, the discipline must not only transform its tools but also redefine its decision-making values and sense of societal responsibility.

Future research and practice in this field must embrace more holistic, participatory, and data-driven approaches. In this context, strengthening interdisciplinary collaboration, ensuring the ethical and transparent use of AI tools, promoting data sharing, and developing open-source infrastructures will constitute essential building blocks in responding to the demands of the digital era within landscape architecture.

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New Trends in Design: Sensory and Nature-Inspired Applications Using Sustainable Biomaterials

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1. INTRODUCTION

Current developments in landscape architecture show a shift away from the use of industrial and synthetic materials toward a sustainable design approach that reconnects with the cycles of nature. This transformation involves biomaterials that appeal to the senses with their ecological origins and create living spaces. This concept essentially translates the multidimensional definition of sustainability into landscape design practice. Sustainability is a process of producing products and services that are sensitive to ecological balance and non-polluting resources, using an approach that encompasses three main components: environmental, economic, and social (Çüçen & Solak, 2022; Yazici, 2017; Yazici et al., 2017). Due to the multifaceted benefits provided by sustainable materials, there are important applications that support climate change adaptation efforts in urban landscapes. An example of this is the provision of permeable concrete infiltration for surface runoff water in cities (Özeren Alkan et al., 2021; Aşur & Akpınar Külekçi, 2020). The use of permeable surfaces is vital for ecological balance and rainwater management in urban landscapes (Kaçmaz, 2021a). This reduces the risk of flooding in cities caused by excessive rainfall. Due to the many benefits that similar new trends will provide, it is among the important practices that support climate change adaptation efforts in urban landscapes (Ankaya & Pirli, 2023; Aşur et. al., 2022; Akat Saraçoğlu et al., 2022). This approach aligns with designs made with biomaterials that are sustainable in terms of their environmental, economic, and social dimensions, reintegrating them into the cycles of nature. It also reflects a holistic perspective that increases resilience and livability by utilizing ecosystem services to combat climate change through nature-based solutions (Kaçmaz, 2021b; Özgeriş et. al., 2024).

The repurposing of water in urban landscapes and the development of designs integrated with ecological systems form the basis for the production of sustainable materials and spaces based on cooperation between nature and humans. (Pirli et al., 2023). In this regard, both the conservation of natural resources and the use and dissemination of sustainable materials in landscape applications focused on water management are important in achieving sustainable city goals (Kaylı & Güneş Gölbey, 2020). Despite the fast pace of urban life today, there is still a tendency to connect with nature; people prefer nature-based daily recreation areas (Altuğ Turan et al., 2024; Yazici & Gülgün, 2016). In addition, consumption habits shaped by the misconception that natural resources are unlimited have become one of the main causes of environmental degradation, threatening the sustainability of ecosystems (Gülgün et. al., 2015; Yazici & Gülgün, 2019; Nükte, 2025). The preference for sustainable alternatives over traditional materials is important in terms of reducing environmental impact and increasing efficiency in resource use (Akpınar Külekçi et al., 2022). Sustainable materials must be obtained from natural components as much as possible in order to avoid creating sources of chemical pollution (Kaçmaz Akkurt & Şemsiyeci, 2024). Therefore, it is of great importance that materials do not have toxic effects in terms of both human health and environmental systems. Considering that harsh chemicals are used intensively in the production processes of certain materials, such as fabric and paper, it is necessary to evaluate the production methods and the substances contained in any material before it can be considered sustainable (Çamuşoğlu, 2023). Ecological sustainability is also important in terms of microclimate regulation and efficient use of natural resources (Yazici et al., 2018).

2. BIO – DESIGN/MATERIALS AND RETURN TO NATURE

The concept of “material” which etymologically derives from the Latin word “materia” refers to substances obtained from nature or by artificial means and shaped to fulfill a specific function (Addington & Schodek, 2005). Throughout history, each era has been associated with a defining material, which has been accepted as a fundamental element guiding the social, economic, and technological developments of the period. It is stated that the material is not only structural but also a cultural and symbolic carrier. From ancient times to the present day, materials such as stone, wood, and clay have been associated with sacredness, naturalness, or durability in different cultures. Over time, they have acquired symbolic and aesthetic meanings that extend beyond their functionality (Semper, 1989). The widespread use of new and sustainable materials not only represents technical progress but also brings about a transformation in aesthetic understanding, production methods, and spatial organization (Pirli et al., 2022). Moreover, the use of sustainable and natural materials contributes to both environmental responsibility and user psychological comfort (Yazici & Gülgün, 2019).

In architecture, materials are not merely structural components, but also elements that appeal to the senses, carry cultural meaning, and shape the spatial experience. Similarly, from a landscape architecture perspective, materials are not only a design component but also a means of sensory experience. Sensory approaches inspired by nature and the use of sustainable biomaterials strengthen not only aesthetics but also environmental responsibility in design processes (Aşur & Yazici, 2020). Through its physical and psychological interaction with the user, material shapes our perception of space (Güneş et al., 2013). In this context, the “language of material” encompasses much more than an objectified entity; it contains multiple narratives about time, space, and the user (Pallasmaa, 2005). The language of materials has become a vehicle not only for designers and buildings, but also for the spirit of the age, global responsibility, and aesthetic perceptions. In landscape architecture, this transformation is embodied in an approach to material selection that appeals to the senses, is culturally contextual, and is ecologically responsible.

Biomaterials, which are natural products synthesized and catabolized by different organisms through biotechnological applications, have the potential to both reduce negative environmental impacts and naturalize the material-space relationship in the context of sustainable architecture and landscape design.

Rammed earth wall has regained importance in contemporary sustainable structure technologies due to its low carbon footprint, high heat storage capacity, and local/soil-based nature (Jaquin et al., 2007). Although this material has been used for centuries, it is now being reinterpreted and integrated into contemporary landscape structures. The architecture office, designed by Equipo de Arquitectura (2017), was built using three basic materials; earth, wood, and glass, with a focus on harmony with nature and natural materials. The architects built the 45-square-meter cube-like earthen structure themselves. They sifted the soil to remove rocks, roots, and large particles, mixed it with cement, placed it in molds, and compacted it. When the 30 cm-thick compressed earth blocks reached sufficient hardness, the team stacked them on top of each other to form walls.

The result is an earthen structure that blends seamlessly into the natural environment with its red and orange tones. A large glass skylight window combined with a window fills the interior with natural light while also reducing the energy consumption of the bioclimatic structure (Figure 1).

Figure 1. The architecture firm called Earth Box, Caja de Tierra (Equipo de Arquitectura 2017).

Mycelium is a biologically grown (natural and organic) structure material obtained from the root-like fibrous structure of mushrooms *(Ganoderma lucidum, Pleurotus ostreatus, Fomes fomentarius*, etc.) (Sarıay et al., 2023). Lightweight, compostable, durable, and non-toxic, it is particularly effective for temporary structures that are biodegradable. Its structural properties have been tested in recent years by research institutes and architecture/engineering disciplines, and it is being integrated with natural construction techniques (Elsacker et al, 2021).

Bio-design/construction refers to a regenerative approach that aims to directly integrate materials derived from living organisms (such as fungal fibers) into design. It advocates systems that can be integrated into natural cycles and are biodegradable, as opposed to the use-and-throw cycle. Mycelium biocomposites are one concrete example of this approach; they provide both thermal and acoustic insulation and are biodegradable at the end of their useful life (Kırdök et al, 2024).

Mycelium biocomposites demonstrate that innovative materials science can meet environmental, structural, and aesthetic needs simultaneously. Figures 2 and 3 are examples of this.

Figure 2. Italian architect Carlo Ratti cultivated a circular series of arched architectural structures from mushroom mycelium at Milan Design Week (Hitti, 2019).

Considering the environmental damage caused by traditional materials, their inability to decompose in nature, and their incompatibility with the environment, mycelium-based biomaterials are being considered as an alternative for the construction of sustainable, sensory, and living surfaces in landscape architecture (Alaneme et al., 2023). In addition, these nature-friendly materials offer significant potential for sustainable landscape design as low-cost, environmentally friendly building elements that reduce resource consumption and replace fossil fuel-based materials.

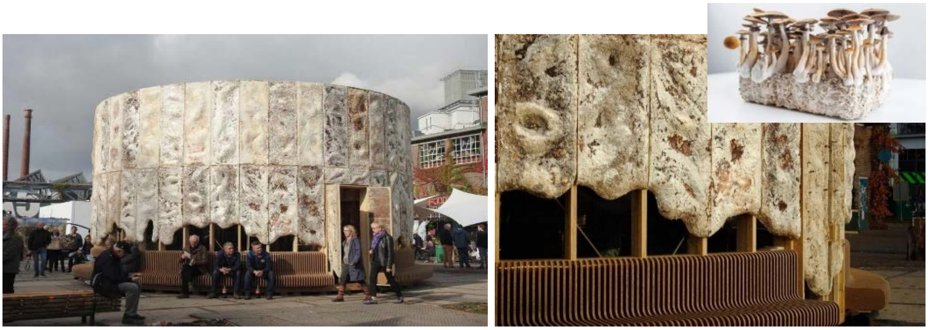

Figure 3. The pavilion design grown from mycelium (Pascal Leboucq and Erik Klarenbeek) was used as a pop-up performance space at Dutch Design Week (Pownall, 2019)

The increasing use of plastics every day brings with it environmental problems. Due to the depletion of existing oil reserves and the increase in greenhouse gases, **bioplastics** developed from biological sources are considered environmentally friendly products and have an important place in use due to their compostability and biodegradability properties (Köksal et al., 2019). Bioplastics, defined as plastics obtained from renewable carbon sources or biologically derived polymers, are biological materials produced by living organisms such as plants, animals, fungi, algae, or bacteria (Luengo et al., 2003; Rajendran et al., 2012; Reddy et al., 2012). Although bioplastics are seen as a new development in today's world, they were used in the early 19th century to coat candies, but since their biological origin brought additional costs during the cultivation phase, they were not considered very important at that time (Özdemir & Erkmen, 2013). Plastic is one of the most important materials in architecture. Although plastic has always been seen as an important part of the architectural process, many architects have become aware of its negative impact on the environment. Bioplastics have begun to play a major role in promoting the industry with a more sustainable alternative and are working to encourage the growth of “green architecture” to reduce the harmful effects of construction projects on the environment. In 2013, students and professors at the University of Stuttgart developed a project called ArboSkin to demonstrate the potential of bioplastics used in the construction industry for unlimited architectural creations (Figure 4). The thermoformable bioplastic sheets used represented an efficient alternative to petroleum-based plastics, glass, or metal in terms of sourcing. Bioplastics produced from partially renewable sources offer the advantages of high processability and recyclability of plastics (gaiagreentech, 2022).

Figure 4. Bioplastic ArboSkin pavilion project by students and professors from Stuttgart University (gaiagreentech, 2022)

Bamboo *(Bambusa vulgaris)* and **hemp** *(Cannabis sativa L.)* have emerged as two important natural fiber sources at the center of sustainable design in recent years. In the fields of architecture and landscape architecture, bamboo is particularly favored for temporary structures, urban furniture, and flooring due to its high mechanical strength and natural aesthetic appeal. Similarly, hemp fiber is utilized in green roofs, permeable surfaces, and natural insulation systems due to its lightweight properties and moisture-regulating characteristics.

Bamboo is a fast-growing natural resource that can be harvested within 3–5 years. Thanks to its lignocellulosic structure, it stands out as a sustainable material alternative in both architecture and landscape architecture (Figure 5). Other fiber sources such as hemp also offer ecological design solutions with low water consumption, biodegradability, and carbon-negative production cycles. (Hasan et al., 2023). The natural color, texture, and scent of these materials also enhance the sensory experience in urban landscapes. In particular, the warm tones of bamboo and the matte, fibrous texture of hemp allow users to experience a sense of unity with nature.

Figure 5. The Bamboo Garden, Atelier REP (2015) (Archdaily, 2025)

In landscape architecture, applications of bamboo and hemp include examples such as bamboo-reinforced concrete panels, lightweight and natural-looking walkways, grass grids reinforced with highly permeable hemp fiber, and mycelium and bamboo-flax composite surface panels that provide sound insulation.

Olive (*Olea europaea)* pits are one of the rich plant waste resources of the Mediterranean region. These pits, which are produced at the end of industrial processes, have long been considered only as a source of biomass. However, in line with global environmental concerns and circular economy approaches, their use as building materials is now being considered (Başboğa et al., 2024). Biomaterials obtained from olive pit waste have significant potential not only in terms of environmental sustainability but also in terms of sensory experience and design aesthetics. In architectural applications using natural and recycled materials, such materials are seen as innovative design ideas. According to Boukhelkhal et al. (2021), olive pit-based materials can be used in non-load-bearing structural elements, yet they provide high levels of thermal insulation. These findings support the potential of this material to produce creative and functional solutions in architecture, landscape architecture, and interior design.

Organic waste-based materials have the potential to both preserve ecological balance and ensure resource circularity in today's sustainable architecture and landscape design. Biodegradable materials such as agricultural residues, fibrous plant stems (e.g., corn cobs, sunflower stems), and food waste are being utilized to create innovative building elements that reduce the environmental footprint (Demir et al., 2020). For example, mushroom-based panels or biocomposites produced from agricultural waste can be applied in both interior spaces and temporary landscape structures; they are compatible with circular economy principles by being integrated into recycling processes (Yalçınkaya & Karadeniz, 2022). In landscape architecture, these materials are preferred in temporary urban furniture, vertical gardens, or rain garden systems due to their soil-compatible structures and natural aesthetics. Additionally, the use of these organic waste-derived materials supports nature-based solutions such as land restoration and erosion control (Ankaya & Pirli, 2020). Thanks to their permeable, lightweight, and biodegradable structures, these materials are among the innovative solutions that provide both structural support and ecological compatibility in the creation of sustainable urban landscapes and application areas in alternative urban agriculture spaces (e.g., on roofs, facades, or in temporary modular systems in cities) (Pirli & Yazici, 2022).

3. DESIGNING WITH ORGANIC MATERIALS IN MIND: ÇEDBİK SUSTAINABLE IDEA COMPETITION 'GREEN EXHIBITION PAVILION 2022' PROJECT

This third section focuses on an application example that integrates the potential of organic materials into architectural design within the framework of sustainable design. The idea competition project developed by architect Meliha Karcı Hoşyılmaz is a concrete example of sustainable design approaches that use natural and recyclable materials in creative ways. This project highlights not only technical solutions but also the design language of materials that emphasize sensory experience and ecological responsibility. Therefore, these applications have made significant contributions to the practice of architecture and landscape architecture by demonstrating the possibility of designing with organic materials.

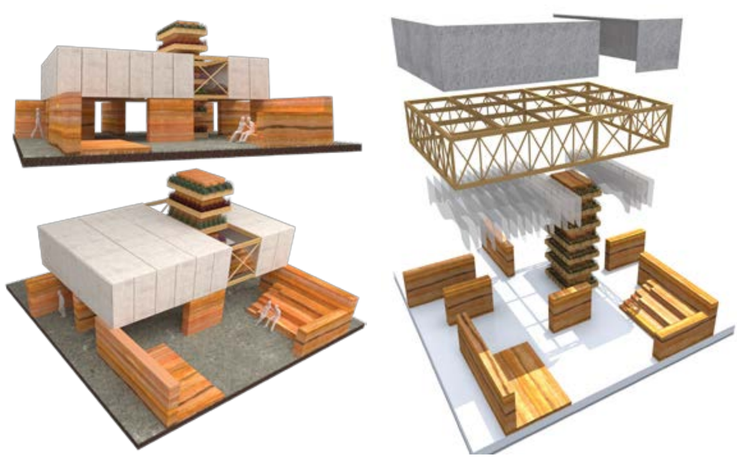

Figure 6. General structure of Green Exhibition Pavilion Design

The pavilion design aims to provide shelter not only for people but also for plants, animals, and various living creatures. The design concept is based on the idea of reminding people that nature is where they belong. The protective and embracing meaning of the concept of "home" is directly reflected in the design of the space. The pavilion's arms, which open in all four directions, create an inclusive form that envelops its surroundings and visitors from every angle, inviting all living beings inside (Figure 6). This structure aims to reconnect humans, who have drifted away from natural materials, with nature and materials derived from nature.

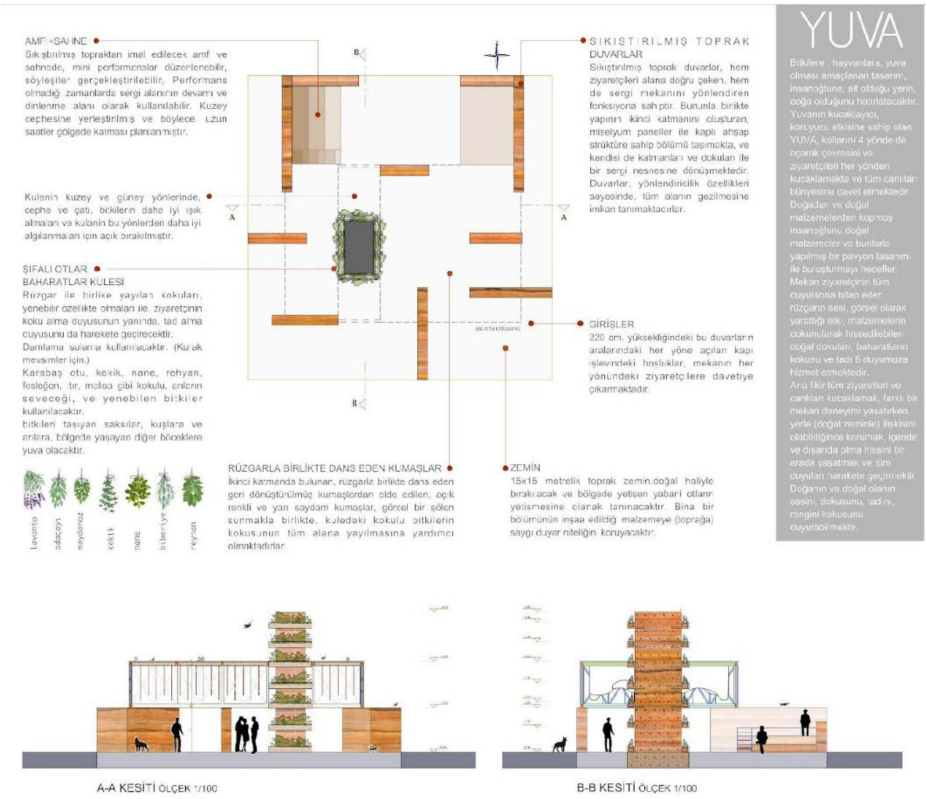

Figure 7. Green Exhibition Pavilion Design Poster

The design consists of three main components. The first component is load-bearing walls constructed with rammed earth. The second component is a structure built on top of these walls, consisting of a wooden frame system covered with mycelium material (Figure 8). At the same time, recycled fabrics are also used as a supporting component in the interior of this section. The third component is the tower form, which makes the structure visible even from a distance. This tower is not only a visual focal point, but also serves as a spice and flower garden that provides a habitat for birds, bees, insects, and medicinal plants.

Figure 8. Mycelium Production Process (modified)

Figure 9. Green Exhibition Pavilion Design Sectional Views

The section drawings clearly illustrate the spatial organization of the structure and the material layers (Figure 9). During the design process, the goal was to use building materials with a low carbon footprint. In this regard, sustainability criteria have been prioritized. The ceiling surfaces made of recycled fabrics used in the interior carry the effects of the wind into the space, offering visitors a dynamic and lively atmosphere. In this way, users experience the relationship with nature not only physically but also sensually while in the space. One of the main objectives of the pavilion is to stimulate users' sensory awareness. The sound of the wind, the visual rhythm created by the movement of the fabrics, the tactile properties of natural materials, the scent and taste of spices—all these elements transform the space into a holistic experience that simultaneously stimulates the senses of hearing, sight, smell, touch, and taste. The new experiences and forms of expression offered by digital culture have led to digital tools such as animation and posters gaining importance as communication tools that enhance both conceptual transfer and environmental awareness in sustainable architectural design processes (Pirli, 2020).

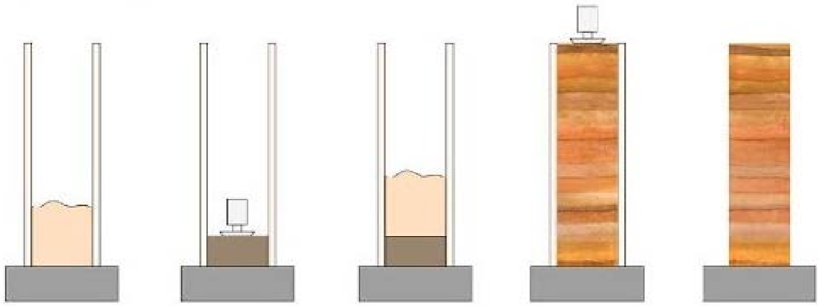

Figure 10. Rammed earth wall manufacturing process

In the rammed earth wall manufacturing process, (1) Moist soil mixture is filled into plywood molds along with concrete, gravel, and clay layers. (2) The soil is compacted using a pneumatic filling compactor. (3) The next layer is added, and the process is repeated. (4) New moist soil layers are added and compacted. (5) Once the wall has dried, the plywood formwork is removed, revealing the finished wall with its soil layers (Figure 10). Figure 11 also shows the roof plan and circulation diagram of the work area.

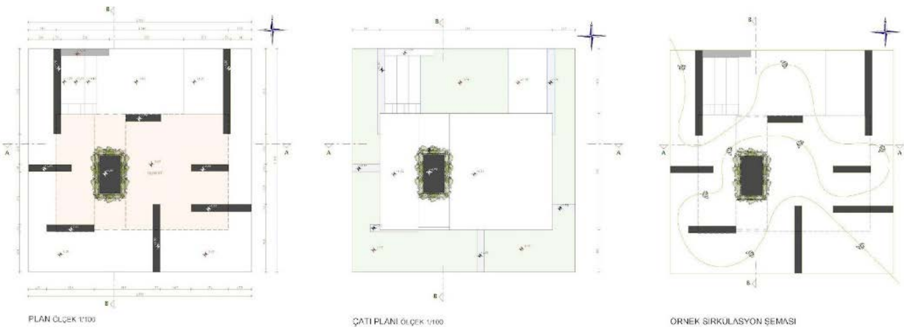

Figure 11. Roof plan and circulation diagram

4. CONCLUSIONS AND RECOMMENDATIONS

In order to prevent the increase in energy and resource consumption that causes today's environmental problems, it is necessary to promote the use of sustainable and natural materials in architectural activities. Although it is possible to see examples of buildings and designs with effective design approaches, they are not widespread enough. The reuse and recycling of waste materials depend on the architect/designer and the customer. Designs should serve as examples and be preferred in this regard. Natural materials such as mycelium, bamboo, and hemp used in design contribute to increasing environmental awareness by creating temporary, modular, and flexible usage areas in the city. Additionally, the sensory, biophilic, and natural textures of these materials deepen the connection with the space, supporting the creation of healthier and more livable public areas within the city. In line with sustainable city goals, this approach should be embraced not only as a technical solution but also as part of a new lifestyle culture.

In conclusion, reintroducing organic waste into the material cycle is not only important from an environmental perspective but also necessary for social and economic sustainability. In this context, innovative material uses developed in collaboration with nature have become an indispensable component of design strategies aimed at making cities more resilient and livable.

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Explaining the Climate Crisis to Children and Promoting Climate Literacy

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1. INTRODUCTION

Contemporary human activities induce enduring alterations in climate systems, with the climate crisis manifesting through increasingly destructive and irreversible effects. Addressing this global issue necessitates not only technical solutions but also interdisciplinary and holistic approaches. In this context, education plays a crucial role in both mitigating the effects of climate change and facilitating societal adaptation to these changes (Lombardi, 2022). The significance of education in combating climate change-related challenges is growing daily. However, the potential of education to effectively contribute to mitigation and adaptation processes has not yet been fully integrated into policy frameworks. Realizing this potential is closely linked to the implementation of a comprehensive approach that spans from early childhood to higher education (UNESCO, 2012b). The intention here is not merely to highlight the close relationship between climate change and education, but to emphasise the importance of fostering awareness about the issue, which is critical for understanding the climate change problem today. In this context, the focus should be on examining climate literacy.

Climate change presents a distinct challenge compared to historical social issues, as its impacts vary significantly across regions and temporal scales. Addressing these effects necessitates swift and comprehensive transformations by nations, international organisations, and local communities. Although individuals, institutions, and communities with expertise in various fields endeavour to devise solutions, the complex and interdisciplinary nature of climate change complicates the assessment of these efforts in isolation. Consequently, effective solutions must consider the diverse needs and interests of different groups, enhance the climate literacy of all stakeholders, and ensure their active participation in the process (Ledley et al., 2018). To effectively combat climate change, it is crucial to accurately comprehend both its causes and consequences (Kaçmaz, 2021). Such understanding fosters individuals' ability to critically evaluate their behaviours, make informed decisions, and develop solutions. However, awareness initiatives that solely focus on information dissemination are insufficient for fostering climate literacy. For these efforts to be impactful, they must be supported by participatory, action-oriented, and transformative approaches (Singh, 2020). Furthermore, the majority of adults today completed their education before climate change emerged as a global crisis, highlighting gaps in their knowledge regarding this issue in their daily lives (UNEP, 2011). Therefore, it is imperative to promote awareness from early childhood to ensure a more sustainable world for both current and future generations.

The issue of climate change represents a critical challenge that necessitates a comprehensive approach. The awareness of this problem among individuals is a significant factor that will influence its future trajectory. Consequently, initiating climate literacy from childhood is imperative for both the present and future. The initial section of this study, grounded in a literature review, examines the concept of climate literacy. The subsequent section delineates four subsections concerning the development of climate literacy in children: methods for explaining climate issues to children, the integration of climate education into school curricula, the role of digital tools, and the importance of family education and social participation.

2. WHAT IS CLIMATE LITERACY?

The concept of literacy has evolved significantly beyond the basic skills of reading and writing, particularly when examined through a historical lens. Over the past fifty years, the expectations of a literate individual have expanded considerably, encompassing the ability to comprehend societal issues, make informed decisions, and take appropriate actions (McBride et al., 2013). United Nations Educational, Scientific and Cultural Organization (UNESCO), for instance, does not confine literacy to reading and writing skills alone. Instead, it defines literacy as the capacity to recognize, understand, interpret, and communicate with written and printed materials across various contexts. Consequently, literacy is viewed as an ongoing learning process that empowers individuals to achieve their objectives, enhance their knowledge, and engage effectively in society (Miler & Sladek, 2011). In this regard, the term literacy has been increasingly incorporated into the literature through emerging concepts such as computer literacy, cultural literacy, environmental literacy, and ecological literacy (McBride et al., 2013). Notably, the notion of climate literacy is gaining prominence as a new term within the academic discourse. However, despite its growing significance, the term encounters several semantic challenges, as it remains in its nascent stages.

The concept of climate literacy was initially defined in 2009 in the document "Climate Literacy: The Essential Principles of Climate Science" (USGCRP, 2024). However, the semantic clarity of climate literacy remains elusive, as its content has not been definitively established, and consensus has yet to be achieved. Consequently, climate literacy, a relatively novel concept, is still in the process of development, despite its inclusion in studies across various disciplines (Miler & Sladek, 2011). Although the term is associated with a new era, it signifies an important area of focus due to the profound implications it encompasses.

Climate literacy refers to the capacity of individuals to comprehend the functioning of the climate system, the ways in which their actions alter this system, and the impact of climate on both individuals and other natural components of the world. This knowledge is crucial not only at the academic level but also in everyday life, as it is asserted that individuals who grasp the causes, processes, and consequences of climate change are better equipped to take action to mitigate emerging risks. A climate-literate society possesses the capability to develop and implement effective climate solutions. Research indicates that enhancing climate literacy not only fosters positive changes in individual behaviours but also expedites planning processes. It is anticipated that climate literacy will be further enhanced by incorporating local and cultural knowledge into education, alongside scientific information. In this context, being climate literate is assessed as understanding fundamental concepts rather than complex scientific information and utilizing this knowledge to devise solutions to problems. Consequently, individuals begin to perceive climate issues not solely in environmental terms but also in social, psychological, and economic contexts (USGCRP, 2024). Therefore, the awareness fostered through climate literacy will underscore that climate issues are not merely environmental phenomena but rather comprehensive challenges encompassing a multitude of problems.

The significance of climate literacy should be understood in terms of its dual contribution: enhancing individuals' knowledge and playing a pivotal role in addressing climate-related issues. This is because climate-related challenges are both influenced by human actions and have the most significant impact on people. Consequently, the responsibility for resolving these issues should rest with individuals. To comprehend climate, climate change, and their derivatives, it is essential to grasp the intrinsic aspects of these phenomena (Arslan & Arı, 2021). Climate change should be viewed as both a cause and a consequence of the events experienced (Kaçmaz, 2021). Therefore, the awareness of individuals, who are both responsible for and affected by this process, is crucial in combating climate change (Cüre, Dayanğan, & Duman, 2022).

To equip individuals to address climate change in daily life, it is imperative to cultivate climate literacy knowledge and skills within educational settings (Karakuş & Akbaş, 2024). The emphasis here is on the inherent paradox of the climate issue, which is constructed by humans and yet most acutely affects them. This issue underscores the notion that humans, as primary contributors to climate problems, must also assume the fundamental responsibility for resolving them. The realisation of this responsibility is intrinsically linked to the concept of climate literacy.

Climate literacy necessitates an understanding of the fundamental principles governing the global climate system, the capacity to critically assess scientific information pertaining to climate, and the ability to engage in informed actions concerning climate-related issues (Limaye et al., 2020). Consequently, a climate-literate individual is characterised by their ability to analyse anthropogenic climate change and access credible sources on the topic (USGCRP, 2024). This raises the pertinent question: “Should everyone be climate literate?” Achieving this level of literacy across all societal segments in the short term is undoubtedly challenging. Nonetheless, it is imperative to recognise that, in the long term, achieving at least a basic level of climate literacy among all individuals is crucial (Miler & Sladek, 2011). Although climate literacy lacks a long-standing tradition at the scientific level, its significance is underscored by the pivotal role it plays in fostering a consciousness beneficial to humanity. While the immediate cultivation of this awareness may seem improbable, it is essential to acknowledge that climate literacy will be instrumental in addressing the climate challenges confronting the world.

3. PROMOTING CLIMATE LITERACY AMONG CHILDREN

3.2. How Should Climate Be Explained to Children?

The questions of what, how, and to what extent children should be informed about climate change, which examples should be provided, and how they should interpret natural events or changes in their environment are central to climate literacy. Establishing enduring awareness in this domain cannot be achieved by merely addressing the topic superficially or presenting examples that are disconnected from children's daily experiences. To create a genuine impact, climate literacy must be integrated into children's lives. In other words, it should encompass a multifaceted approach that enables children not only to acquire information but also to develop environmental awareness and take action (MoNE, 2021). Therefore, the awareness imparted to children within the framework of climate literacy should transcend a mere information-laden reality. In this context, multifaceted trends that support climate literacy should be considered (Figure 1).

Figure 1: Strategies to prepare children for climate change and to enhance their climate literacy (UNESCO, 2024b).

Currently, there is no robust institutional framework that addresses the unique sensitivities of children to climate change. Plans such as National Adaptation Action Programs seldom incorporate children's knowledge, skills, and potential contributions in this area. However, sustainable development issues, which encompass fundamental topics such as human and child rights, disaster risk, climate change, and social equality, equip children with the skills to critically evaluate both sustainability and their societies (UNICEF, 2013). Indeed, children, as the decision-makers of the future, represent the most critical link in this awareness-raising process. The primary concern here is how to explain climate to children and how to cultivate climate-literate individuals. This is because climate, by its nature, involves both a complex system and psychological conditions such as fear and anxiety. In this context, the significance of education, one of the most fundamental issues, becomes apparent. Other aspects that require meticulous attention and are closely related to this include the use of digital tools, family education, and social participation.

3.3. Climate Education in School Programs

Education serves as a strategic instrument in addressing climate change and preparing for its impacts. Consequently, educational policies and curricula should be designed to enhance awareness of the causes and effects of climate change. Additionally, adaptation strategies must be developed. Climate education should also empower children to comprehend the impact of their consumption habits on the climate (UNEP, 2011). In essence, the primary objectives in integrating climate issues into education should be to foster a sustainable future and to impart practical skills at both individual and societal levels. Thus, the goal extends beyond merely imparting scientific knowledge; it also involves effecting tangible changes in children's attitudes and behaviours in accordance with this information. In this regard, climate change education assumes a critically important role (Uyar & Uyar, 2023). This form of education should aim to sensitise children to environmental issues and contribute to their development of a conscious and responsible lifestyle (IPCC, 2021).

In the context of climate change, current educational approaches require reevaluation to equip students with the skills necessary to adapt effectively to a rapidly changing world. The educational system's response to climate change should not be limited to the inclusion of new subjects in the curriculum. Instead, education should adopt a more holistic and transformative approach that seeks to cultivate critical climate-related knowledge and skills (UNESCO, 2012b). In this context, climate change education should be integrated into the curriculum at all educational levels to provide a comprehensive understanding of the subject. The multidimensional nature of climate change should be addressed not only through scientific data but also through a holistic approach that encompasses various disciplines such as politics, law, ethics, sociology, economics, and culture (UNESCO, 2012a). This is because climate education embodies meanings far deeper than merely being an environmental issue. The necessity of addressing climate challenges from an interdisciplinary perspective exemplifies the profound dimension that its inherent meaning attains.

The primary objective of climate change education is to cultivate children's competencies in accessing, critically evaluating, and making informed decisions regarding climate-related information. Furthermore, it is imperative that climate change education remains current, as both challenges and solutions evolve in tandem with the changing world (Uyar & Uyar, 2023). Consequently, it is essential to equip children with new knowledge and skills to adapt to this rapidly changing environment. For this process to be effective, policymakers must formulate strategies and policies pertinent to climate education (UNESCO, 2012a). There is a broad consensus among international organisations, society, and educators that schools should prioritise climate change education.

School-based education is regarded as one of the most effective platforms for children to comprehend climate issues and develop problem-solving skills (Lambert, Lindgren & Bleicher, 2011). Similarly, numerous international organisations underscore the global threat posed by the climate crisis and highlight the importance of raising awareness and educating children on this matter (Figure 2). This emphasis is also reflected in the 2015 Paris Agreement, where Article 12 explicitly mandates collaborative efforts in climate change education, training, public information, and participation (UNFCCC, 2015). These examples illustrate the significant position that climate issues and climate literacy, which actively address these issues, have gained prominence on the global agenda.

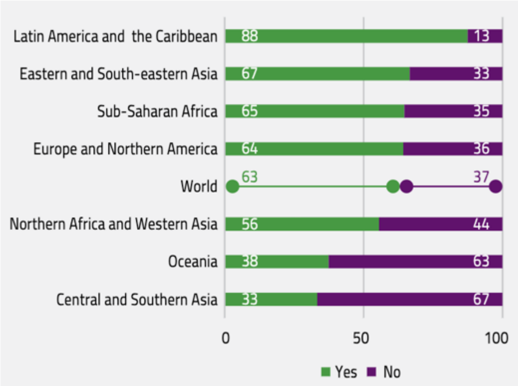

Figure 2: A comparison of the emphasis placed on climate change in teacher education curricula across different continents (UNESCO, 2023a).

In parallel, United Nations Children's Fund (UNICEF) is actively working to integrate climate change adaptation and disaster risk reduction into the education system, guided by child-friendly school principles. This approach is designed to incorporate climate, disaster, and environmental issues into all educational components, including policy, legislation, curriculum, teacher training, school infrastructure, and management (UNICEF, 2013). UNESCO, with its expertise in education, culture, and social sciences, similarly emphasises the role of education in climate change adaptation and mitigation. It views education as a means to impart knowledge, skills, and capacity, as well as to shape the values and behaviours necessary for sustainable living. UN Environment Programme (UNEP), on the other hand, stresses the importance of education in facilitating countries' transition to low-carbon growth, reducing deforestation, enhancing climate awareness, and strengthening public consciousness (UNEP, 2011). Although international organisations possess significant influence over educational policy directions, they lack the authority to directly intervene in national curricula, thus assuming a more advisory role (Dawson et al., 2022). Despite their limited scope of authority, each organization contributes to the advancement of climate literacy. The central issue remains how climate education is integrated into national curricula and the measures taken by official educational institutions in this regard.

The integration of climate change into educational curricula by curriculum developers globally is imperative not only to align with contemporary demands but also to shape future generations (Dawson et al., 2022). Nevertheless, within formal educational institutions, climate change education is predominantly confined to the instruction of atmospheric composition and processes from a natural science perspective. Traditionally, climate science is taught within geography and earth sciences courses. In this context, climate change education is delivered at primary and secondary school levels through science curricula in numerous countries. However, climate change education transcends the confines of climate science alone, possessing an interdisciplinary nature that encompasses a broad spectrum of fields (UNEP, 2011). Consequently, climate change education should incorporate diverse components to facilitate an effective and comprehensive learning process. This education should be approached with an interdisciplinary perspective, integrating mutually supportive elements from various fields such as science, social studies, and environmental education. The objectives and outcomes presented to students should be articulated in a manner that avoids misconceptions. Furthermore, experiential learning opportunities should be provided to enable a profound understanding of the process. The impacts of climate change should be contextualized within local and regional settings. Simultaneously, engaging teaching materials should be employed to enhance environmental responsibility (Barak & Gönençgil, 2020; UNESCO, 2009). Another critical aspect of the discourse on climate education is the correlation between the educational content and the age group of the learners.

The determination of the appropriate age and educational level for introducing climate science is a significant consideration (Miler & Sladek, 2011). In this context, preschool children should be instructed in an accessible manner about the value of the environment, their responsibilities in maintaining environmental cleanliness, and methods to identify and mitigate environmental risks encountered in daily life. Primary school students should be provided with foundational knowledge, including basic concepts of climate change and environmental responsibility, the significance of natural resources, and ecological cycles. Additionally, instruction should cover methods to identify and prevent environmental risks, basic disaster preparedness, and the environmental impact of individual actions. Secondary school students should be educated on topics such as climate change adaptation and mitigation, the protection of local ecological cycles, and the interplay of these cycles with social, environmental, and economic factors. Furthermore, concepts of environmental responsibility, such as the life cycle of consumer products, recycling, and resource conservation, should be addressed. Topics such as disaster preparedness, risk and vulnerability assessment, the exacerbation of risks by inequalities, and the evaluation of diverse solutions should also be included (UNICEF, 2013). In light of these considerations, it is evident that climate education should commence at the preschool level, fostering a sense of responsibility in individuals as they progress through their education.

Global advancements in climate change education are increasingly evident. For instance, South Korea has incorporated climate change education across all educational levels, including preschool, since 2007. In France, climate change education was initially introduced into the educational system in 2013 and was further strengthened by the “Climate Change and Resilience Law” in 2021. Similarly, Chile has integrated climate change into early childhood, primary, and secondary education as part of the “National Environmental Education Strategy” of 2023. In the United Arab Emirates, climate change topics are included not only in curricula but also in teaching materials and voluntary programs that support educational institutions, aiming to embed climate and environmental awareness at every educational level. Norway’s “2021-2030 Climate Action Plan” underscores education as a pivotal tool in transitioning to a low-emission society, highlighting the role of schools in fostering climate and environmental awareness across all educational stages (UNESCO, 2023). Consequently, climate education has evolved to occupy a direct role in educational systems to enhance climate awareness.

Conversely, some countries emphasise experiential learning alongside curricular integration of climate change. In Ecuador, the 2018 “Manual of Good Environmental Practices for Educational Institutions” promotes both knowledge-based and practical learning through school-based campaigns, seminars, and environmental activities. In Morocco, approximately 6 million students have participated in planting seeds and saplings in school areas as part of the “One Student, One Tree, One School, One Forest” initiative. New Zealand’s “Prepare today, live well tomorrow” climate change program not only imparts information but also encourages student action. In Côte d'Ivoire, the "Green Pupil" project is designed to instil environmental awareness and eco-citizenship concepts in primary and secondary students, particularly through extracurricular activities. In El Salvador, the 2021 "National Higher Education Policy" advocates for these topics in elective courses and extracurricular activities, such as sapling planting, environmentally themed film screenings, youth climate clubs, and sustainable agriculture (UNESCO, 2023). Thus, in certain countries, climate education is evolving into a comprehensive program that encompasses both theoretical and practical dimensions.

Turkey is among the nations that prioritise climate literacy. In the 2022-2023 academic year, the "Environment Education and Climate Change" course was introduced as an elective in middle school curricula. This course is designed to facilitate students' comprehension of natural resource utilization and the production-consumption relationship; to assess environmental issues and climate change from a comprehensive perspective, ranging from local to global contexts; and to foster individual and social responsibility in addressing the climate crisis. Furthermore, the course seeks to enhance students' environmental awareness and responsibility, not only within the classroom but also during extracurricular activities and field trips (MoNE, 2022a). Additionally, the Turkish Preschool Education Development Association and the TEMA Foundation have developed the "Minik TEMA" program for preschool and early primary school children. This program is designed to cultivate awareness on topics such as the environment, soil, erosion, sustainable living, and climate change, through experiential learning (Şeker et al., 2018) (Figure 3).

Figure 3: This image from the video of the TEMA Foundation's "Mini TEMA Education Program" exemplifies the observation-based learning methodology employed to facilitate understanding of natural environments (TEMA Foundation, 2023).

Similar to many countries globally, Turkey has implemented various measures to promote climate education awareness. Consequently, the objective is to approach the climate issue from a holistic perspective that encompasses a social dimension, in addition to its cognitive aspects.

3.4.Use of Digital Tools

In contemporary society, there is a growing awareness of environmental and climatic issues, leading to a conscious effort towards the rediscovery of nature and progress in this domain (Ankaya et al., 2018). Consequently, innovative solutions are being proposed to address the preservation of ecological balance and biodiversity in response to environmental challenges and climate change (Gülgün et., 2015; Yazici et. al., 2017). The 21st century is characterised by both the intensification of environmental problems and the rapid advancement of digital transformation in education. As such, issues like climate change and sustainability have become fundamental necessities for ensuring the well-being of future generations, while digital tools present significant potential for facilitating transformative changes in education (Vinuesa et al., 2019). Furthermore, technological advancements have increasingly integrated digital platforms into daily life, resulting in positive impacts across various sectors, including social and cultural structures, the economy, health, the environment, and energy consumption. Education is one of the domains where this digital transformation is most rapidly and effectively experienced. The integration of digital tools into educational processes and the enhancement of interaction in teaching amplify the influence of digitalization in education (Arslan & Karakuş, 2024). Consequently, it has become imperative for children to acquire skills such as information retrieval in digital environments, information synthesis, and safe usage. Thus, equipping students for the digital era and appropriately utilizing technology should be fundamental objectives of a successful education system (Altinsoy & Boyraz, 2024). The digital transformations occurring are closely linked to the education system, particularly in establishing connections with climate education.

The increasing role of digitalization in education has significantly contributed to climate change education, making complex global issues like climate change more comprehensible. This development has facilitated children's understanding of intricate environmental processes (Aydoğan et al., 2022) (Figure 4). Presently, rapid advancements in artificial intelligence and educational technologies are emerging as innovative tools for fostering climate literacy competence. These advancements offer children more interactive, data-driven, and personalized climate education experiences, surpassing traditional methods (Institute for Development Impact, 2025).

Figure 4: This visual from the NASA Climate Kids platform addresses fundamental issues related to climate literacy, encompassing the scientific evidence of climate change, its effects on the oceans, the greenhouse effect, and the necessity for future research (NASA, n. d.).

The development of digital games, Web 2.0 tools, and artificial intelligence-supported teaching materials to enhance climate literacy has become an essential requirement (Vinuesa et al., 2019). Web 2.0 applications utilized in education provide a range of digital tools that render learning processes more interactive and creative. Social media platforms such as YouTube, WhatsApp, Instagram, and Facebook facilitate communication and sharing, while digital mind maps like Mindmeister, Coggle, and Bubbles aid in organizing thoughts. Children can visualize content using digital boards (Padlet, Lino It) and word clouds (WordaRT, Tagul). They can also develop creative writing skills through cartoon (Toondoo, Sketch toy), story, and book writing (Storybird, Book Creator) tools. Furthermore, online learning is supported by distance education platforms such as Edmodo, Google Classroom, and Adobe Connect. These tools render the learning process active, participatory, and multifaceted (Çelik, 2024). Evidently, the evolving nature of digitalization has transformed child education into a multifaceted reality.

Additionally, mobile technologies for individual use have become pivotal in accessing these new-generation digital learning environments (Aydoğan et al., 2022). Indeed, games specifically developed for mobile devices enable learning on the go. For instance, the Earth Hero application allows users to monitor their carbon footprint and set sustainable goals (Institute for Development Impact, 2025). Consequently, the proliferation of education-focused mobile applications and their accessibility to all individuals enhance awareness of globally significant issues such as climate change. Moreover, it supports sustainable education by making open educational content accessible to a broader audience (Aydoğan et al., 2022). Another notable outcome is that, through social media platforms and online communities, children can share climate projects, collaborate with peers, and communicate with experts. Hashtags such as "#ClimateAction" and "#SustainableSchools" motivate environmental action by connecting young individuals to global environmental movements (Institute for Development Impact, 2025). Therefore, the integration of digital technologies into the education system has significantly contributed to raising awareness of climate issues.

Recent advancements in digital technologies have evolved into complex digital ecosystems, enabling children to profoundly engage with environmental crises and actively contribute to these issues. These tools not only enhance motivation for learning but also bolster climate literacy, a crucial competence for comprehending global crises such as climate change. In this context, six notable digital tools emerge as essential components shaping the future of climate challenges (WINSS, 2025):

1) Virtual and Augmented Reality (VR/AR): VR and AR technologies transcend traditional learning methods, offering

opportunities to virtually experience phenomena such as melting glaciers or disappearing forests through applications like Google Expeditions.

2) Gamification and Interactive Applications: Gamification facilitates not only knowledge transfer but also behavioural transformation. Next-generation applications such as EcoChallenge 2.0 encourage children to analyze their carbon footprint and make environmentally conscious decisions. Applications like “WWF Together” and “Recycling Summary” both entertain and enhance children’s environmental awareness.

3) Artificial Intelligence and Big Data-Based Environmental Monitoring: Artificial intelligence provides a personalized, data-driven learning experience in sustainability education. NASA’s “GLOBE Observer” and Microsoft’s ‘AI for Earth’ initiative enable children to directly collect and analyze environmental data.

4) E-Learning Platforms and Online Courses: Platforms such as Coursera and the UNESCO-supported “Earth School” have the potential to offer equitable access to education globally.

5) Citizen Science and Crowdsourcing: Platforms like iNaturalist, which contribute to biodiversity, or Litterati, which combats global plastic pollution through data-driven efforts, exemplify concrete citizen science platforms and mobile applications that transform learning into direct action.

6) Smart Agriculture and the Internet of Things (IoT): In agriculture-based sustainability education, IoT technologies provide children with opportunities to analyze various variables, from soil moisture to crop growth. Microsoft’s FarmBeats platform illustrates the convergence of digitalization and environmental awareness in agricultural production.

Conversely, certain nations are independently advancing initiatives to enhance climate literacy and cultivate environmentally conscious individuals. For instance, the digital platform Astrid, developed in Iceland, provides a comprehensive educational framework designed to heighten children's awareness of climate change, encourage proactive engagement, and assist in managing climate-related anxiety through scientifically grounded content (UNESCO, 2023). In South Korea, the "Data-Driven Carbon Literacy" project enables students to assess their carbon footprints by monitoring energy consumption at home and school, thereby fostering environmentally sensitive and solution-oriented individuals. The "EducoNetImpact" project in Belgium facilitates student awareness of the environmental impact of digital technologies. Similarly, in the United Kingdom, artificial intelligence is employed to enhance the efficiency of waste separation processes, integrating this subject into educational curricula and instilling a green vision among students (UNESCO, 2024a). The education systems in these countries, bolstered by digitalization, not only augment environmental awareness among children but also enhance their problem-solving capabilities.

In Turkey, there is a growing interest in digital education for addressing critical issues such as climate change. Initiatives like the "Digital Content Preparation and Augmented Reality Supported Global Warming and Climate Change Applications Trainer Training" by TUBITAK aim to deliver effective education on this subject. Additionally, "the Climate TEMA education Platform" developed by the TEMA Foundation serves as a significant resource leveraging digital technologies for climate and environmental education (Figure 5). Furthermore, the Ministry of National Education's (MoNE) Climate Change Action Plan underscores the efficacy of digital technologies in education to elevate climate change awareness. The plan seeks to develop cartoons, animations, books, brochures, and digital content, integrate climate-related modules and games into platforms such as EBA and ÖBA, and organize activities enabling students to calculate waste digitally (Kenan, Hazar & Akyol, 2024).

Figure 5: The visual from the *Let's Talk About Climate* [*İklim Hakkında Konuşalım*] e-book, available on the "Mini TEMA Education Platform", elucidates the effects of climate change for children through simple and comprehensible metaphors (TEMA Foundation, 2021).

Consequently, digital tools not only enrich educational processes but also provide substantial opportunities for children to cultivate climate literacy, environmental awareness, and sustainable life skills. This technological transformation allows education to transcend a passive information transfer process, fostering individuals who are environmentally conscious, critically thinking, and solution-oriented (WINSS, 2025). Therefore, an analysis of the relationship between digital elements and climate literacy reveals the active role they play in the education system. It is thus evident that individuals sensitive to environmental damage have become more attuned to climate literacy through digital tools.

3.5. Family Education and Social Participation

The family constitutes the primary social milieu where children initially acquire knowledge, skills, attitudes, and values. Within this context, children cultivate their responsibilities towards the environment and establish the groundwork for societal participation (Halstead, 1999). These formative experiences significantly influence the perspectives that children will develop regarding the environment, society, and life (Ritter, 2020). Consequently, fostering climate literacy awareness at an early age is crucial for nurturing children into individuals who are sensitive, conscious, and solution-oriented towards environmental challenges. This early education not only imparts knowledge but also enables children to mature into individuals who will assume responsibility for the climate crisis (Monte & Reis, 2021). Thus, a prominent factor in climate education, which encompasses numerous components, is the family environment and social engagement.

As climate change education increasingly permeates schools globally, understanding parents' attitudes and approaches to this issue becomes imperative. This is because children continue to learn not only in school but also at home. Parents' beliefs, values, and daily practices concerning climate change directly influence children's awareness and motivation to engage with this issue (Madden et al., 2023). Therefore, it is essential for adults to recognise the importance of collaborating with schools on environmental and climate matters. The involvement of parents and adults in school life should extend beyond children's education to encompass societal engagement. In this context, schools should undertake the responsibility of fostering relationships with families (UNICEF, 2013). These considerations underscore that establishing a robust synthesis between school, child, and family is a prerequisite for effective education. The family environment, much like the school, plays a crucial role in climate literacy.

The development of resilience against climate change, environmental degradation, and disasters is of paramount importance for children in early childhood and their caregivers (UNICEF, 2022).

(Figure 6). However, the role of parental support in addressing the complex and long-term crisis of climate change remains inadequately defined, as guiding children in this context represents a relatively novel responsibility for families (Sheffield & Landrigan, 2010). Although parents recognise the significance of supporting their children through the climate change process, they often lack the necessary guidance, which hinders effective communication on this issue. This uncertainty complicates the continuation of climate-related discussions within the family (Dayton et al., 2022). To ensure the efficacy of this responsibility, community support, awareness initiatives, quality early childhood education, and the provision of appropriate tools are essential (UNICEF, 2022). Consequently, emphasising the power of community action is crucial for enhancing family communication on climate change. While individual efforts are impactful, large-scale policies and social change are imperative for effectively addressing the climate crisis (Fawzy et al., 2020).

Figure 6: This visual represents a comprehensive educational trend that promotes children's engagement with sustainable living practices, including waste management and recycling within the family context (Sorial, 2024).

To resolve climate change and environmental challenges, technical knowledge and cultural awareness must operate in tandem (Pirli et al., 2023). Programs and policies should encourage families to adopt sustainable lifestyles and actively engage in combating climate change. As fundamental societal units, families require access to adequate information and resources to fulfil this role. This access will enable families to better comprehend climate risks, implement protective measures for their well-being, and engage in constructive dialogues with their children based on accurate information. Furthermore, it will enhance their climate literacy, enabling them to discern false climate information, establish open communication with their children, and support them in managing climate-related concerns (Cuartas et al., 2025). Therefore, the enhancement of climate literacy within the family environment should be regarded as an inclusive and competent approach that encompasses not only children receiving education from their parents but also the parents themselves.

The report titled "Climate Change and Families," published by the United Nations Department of Economic and Social Affairs (DESA), underscores the pivotal role families play in achieving sustainable development goals. When families are educated about climate change and sustainable living, they can transmit this knowledge and these values across generations. This dynamic positions families as significant social actors in the creation of a sustainable environment (UN DESA, 2021). In this context, the concept of family literacy emerges as a critical issue. Family literacy is regarded as an integral component of the 17 Sustainable Development Goals of the United Nations. Communities worldwide adapt these goals to their local contexts and devise solutions tailored to their needs. Family literacy projects are instrumental in enhancing societal resilience and mitigating potential risks. Presently, numerous countries are implementing family-focused, applicable, and community-integrated educational models to address the climate crisis and similar global challenges (Taylor, 2020). It is imperative to examine the extent to which the inclusion of families in climate literacy efforts can be actualized.

The United Nations urges its member states to bolster global collaborations to address the climate crisis and other global threats. To this end, it promotes multilateral literacy projects targeting families, not only at the inter-state or local level. However, according to a 2011 UNESCO report, many countries, ranging from Canada to Cuba and Uganda, are implementing family literacy programs tailored to the local needs of families. These countries aim to empower local communities through family-based learning models, viewing education as a component of social development rather than solely an individual endeavour (Taylor, 2020). Countries in the Arab Gulf and MENA regions are also striving to actively involve families in the process of combating climate change. In this context, communication campaigns, educational programs, and inclusive policies are being developed. For instance, Jordan is endeavouring to ensure the participation of women and children in the formulation of climate policies through the "Stakeholder Engagement Plan (SEP)" developed within the framework of the 2022-2050 National Climate Change Policy. Similarly, in Iraq, the "Climate Resilience and Environmental Justice Initiative" in Southern Iraq program establishes local committees to identify the needs of families affected by climate change, with a particular focus on the participation of women (Cuartas et al., 2024). The aforementioned countries exemplify efforts to position the family unit as a central subject in climate education. Consequently, family literacy has become a recognised necessity for the sustainability of climate education.

In Turkey, the significance of family involvement in addressing climate change is underscored. The Climate Action Plan, published in 2022 by the MoNE, highlights that climate change and environmental awareness should extend beyond children, advocating for a multi-actor learning environment that includes families and educators. Parents are informed about climate change through family seminars, and the entire school community is engaged in the environmental awareness process through activities such as exhibitions, forums, panels, and competitions involving children (MoNE, 2022a). The report by the Yuva Association further emphasises that families are crucial actors who can assume responsibility for the climate crisis both individually and socially. In this context, families are encouraged to discuss climate change with children, adopt habits to reduce energy and water consumption at home, and participate in recycling by sorting waste. Additionally, they are advised to engage in local decision-making on environmental issues and to opt for climate-friendly transportation methods such as cycling, public transportation, or walking in daily life. These actions not only enhance children's climate awareness but also reinforce the understanding of sustainable living within the family (Yuva Association, 2024). Furthermore, the "Zero Waste Education Platform" program, initiated in 2019, serves as a digital education platform aimed at fostering zero waste awareness among children, teachers, and families. Emphasizing the conscious use of natural resources and waste prevention, the platform seeks to transform consumption habits through the 5D model, which includes the principles of "Think, Don't Consume If Not Necessary," "Consume Less," "Evaluate, Reuse," "Change, Use for Different Purposes," and "Transform, Let Nature Win." Educational materials comprise recycling games, puzzles, zero-waste checklists for home, weekly waste tracking charts, and various activities that children can engage in with their families. Thus, the learning process extends beyond the school environment and is bolstered by family participation (TEMA Foundation, 2024; MoNE, 2022). Through these educational approaches, the issue of climate change is addressed in a comprehensive manner, both intellectually and practically. Within this framework, the concepts of child, family, and education form an interconnected synthesis.

Consequently, while the awareness fostered for climate literacy initially appears to manifest at an individual level, it ultimately reflects a social dimension through holistic education.

4. CONCLUSION

The environmental and climatic damage resulting from global changes initially manifested on a local scale. However, particularly in the last century, with the increase in intercontinental mobility, this damage has escalated to a global level (Yazıcı, 2024). Factors such as uncontrolled population growth, migration, industrialisation, environmental pollution, and the unsustainable consumption of natural resources have precipitated significant challenges across all communities. These developments have heightened concerns regarding the future (Atıl, et al., 2005). Consequently, in light of the events of the past century, taking substantial steps towards sustainability has become crucial for both current and future generations (Yazıcı & Gülgün 2016).

Projections of future climate data indicate significant increases in daily temperatures, prolonged heatwaves, and more severe weather events over the next 50 years (Kaçmaz Akkurt & Şemsiyeci, 2024). Raising public awareness about climate risks, vulnerabilities, and the increasing trends of these threats, as well as educating on solutions to mitigate these risks, is vital for fostering a society resilient to climate change. In this regard, education and awareness programs should be tailored to the needs of local, national, and international stakeholders (UNESCO, 2012b). The imminent threat posed by environmental degradation is a matter of concern for all societies. It is imperative to implement necessary measures to address the crises induced by climate conditions. At this point, education and awareness, particularly climate literacy, are essential components of these measures.

Education serves as a crucial tool for individuals to make informed decisions about climate and to acquire the skills necessary to adapt to evolving environmental conditions. Indeed, education significantly contributes to enhancing social awareness by fostering climate literacy (Lombardi, 2022). However, scientists indicate that awareness levels regarding climate change remain low, highlighting a paucity of studies on climate literacy (Miler & Sladek, 2011). This situation underscores the necessity of integrating climate literacy into contemporary education. Effective climate literacy is inherently solution-oriented, aiming not only to impart fundamental concepts but also to equip children with the knowledge to develop concrete solutions to the climate crisis. This approach prioritises a practical, solution-focused understanding over theoretical knowledge (Corner et al., 2015).

One essential condition for addressing the challenges posed by climate change is the integration of technological advancements, which are increasingly significant (Nükte, 2025). Digital tools provide a powerful and transformative platform for climate education, extending access to information beyond geographical and socioeconomic barriers. These platforms, which transcend traditional classroom-based methods, offer children a comprehensive understanding of the climate system, the causes and effects of change, and potential solutions (Pirli, 2020). Through visualizations, simulations, and multimedia content, complex scientific data becomes more comprehensible. Concurrently, they provide a more participatory and inclusive learning opportunity for understanding climate change (Sustainability Directory, 2025). Consequently, climate literacy empowers individuals and communities to take informed actions against environmental issues. Individuals who become aware play a crucial role in safeguarding both current and future generations (Radzi, Osman & Said, 2022). Another factor contributing to the well-being of future generations and enhancing climate literacy is family education and social engagement. Parents must assume a critical role in modeling sustainable lifestyles for their children, fostering critical thinking, and encouraging a connection with nature. This must be grounded in effective communication between parents and their children regarding climate change (Dayton et al., 2022).

Ultimately, nature, while being harmed by human activities, remains a vital domain that requires restoration. Furthermore, climate change should not be viewed solely as an environmental issue but as a complex problem necessitating interdisciplinary solutions. The challenges posed by this issue require a concerted effort involving several elements. These steps include enhancing climate literacy through education and awareness, integrating the positive aspects of technological advancements into the solution framework, and fostering a strong awareness in children through family education and social participation.

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Preservation of Cultural Heritage and Museum Villages: Examples from Turkey and Around the World

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1. INTRODUCTION

The concept of cultural landscape can be defined as areas with a multi-layered cultural dimension, characterised by individuals or communities in a region, bearing witness to the relationships between them and their environment from the past to the present, and shaped by local cultures, practices, beliefs and traditions (Atik, 2019). In this context, rural areas, which are an integral part of the cultural landscape as a result of the interaction between the environment, humans and nature, have given rise to the concept of 'cultural heritage' (Altun, 2019). The understanding of cultural heritage, which is also considered as living heritage, ensures the continuity of the experiences, traditions and customs that people have accumulated throughout history. Architectural works, sculptures, paintings, archaeological works, inscriptions, as well as weddings and ceremonies, customs and traditions, and everything else that has universal historical or artistic value is considered cultural heritage.

The concept of museum villages, which has emerged in recent years, has begun to transform into spaces that go beyond being mere venues for displaying objects and cultural features, instead serving as places that tell the stories of people's cultures and ways of life, and provide learning opportunities for visiting guests. Today's museum villages can be thought of as sustainable systems for local and regional development, created with the participation of the public and guided by cultural, environmental, ecological, and economic indicators, while preserving cultural heritage and promoting innovative, applicable cultural employment systems that are in harmony with the environment (Negri, 2012). In this context, museum villages act as a bridge between cultural heritage and cultural landscape. This study emphasises the role of village museums in preserving and promoting rural culture, highlighting their importance in the past and present, and underscoring their critical role in the preservation and sustainability of cultural heritage through successful national and international examples. Recommendations are made to enhance the social and cultural benefits of village museums.

Tangible cultural heritage (material culture); Material cultural heritage can be observed as long as its presence in the living environment is known and protected, and it provides accurate information about the past and identity of the community in which it is found. Our country attracts the interest of both its citizens living in this geography and the world's inhabitants with its historical past and geological richness as material cultural heritage. The term ‘material’ in material culture refers to natural or manufactured objects shaped by human hands in their environment (Sarıtaş, 2019). This includes buildings, monuments, clothing, works of art, machines, historic cities, and archaeological sites.

Intangible heritage; The common heritage of humanity is not limited to material cultural assets. To disregard this part of cultural heritage is considered to be a loss. This part, which includes the narratives, practices, and performances surrounding and shaping the formation process of tangible cultural heritage assets, is an integral part of tangible cultural heritage (Aydoğdu, 2024). Looking at UNESCO's work in recent years, the criteria for evaluating cultural heritage have changed, and cultural heritage is no longer limited to structures and objects. It also includes cultural diversity and intangible heritage, such as oral narratives, performing arts, social practices, ceremonies, festivals, traditional crafts, and practices related to nature and science. Intangible cultural heritage is only recognised as heritage as long as it is community-based and recognised by the community (Oğuz, 2018).

2. THE CONCEPT OF MUSEUM VILLAGE IN TURKEY AND EXAMPLES

Museums shed light on a society's cultural values, changes and stages of development. In this way, they show society its historical consciousness and temporal dimension. The concept of museums in our country is developing, and there are many museums of international importance. Among the purposes and functions of museums, art, archaeology, ethnography, children's, open-air museums, or museum villages can be evaluated from this perspective (Güngör, 2016). Museum villages are a type of museum that not only preserves, stores, and exhibits a society's cultural heritage under appropriate conditions but also aims to ensure its transmission from generation to generation through a participatory approach. This approach aims to convey traditional village life to visitors through experience. Traditional village houses and domestic life are recreated in detail, and daily activities such as agriculture and livestock farming, kitchen and food culture, marriage traditions, as well as oral narrative elements like folktales, proverbs, and idioms, along with various handicrafts particularly weaving are actively showcased within the museum (Eres et al., 2010).

In museum villages, the first examples of which appeared in Europe at the end of the 19th century, houses collected from rural areas within geographical or administrative boundaries are transported to the designated museum site and rebuilt, with the aim of exhibiting the life of a village with all its furnishings and objects. The aim of such museums was to introduce medieval European peasant life to a modernising society. At the beginning of the 20th century, in order to explain prehistoric European cultures to society, village museums consisting of 1:1 scale prehistoric building models based on house types identified through the examination of findings from excavations began to be established. Indeed, while creating European museum villages, the concern of preserving historical structures that could not be preserved in rural areas in a museum environment was also carried alongside the aim of introducing peasant culture (Eres, Z., 2006).

2.1. Sepetçiler Museum Village (Kocaeli/İzmit)

The museum village, built by the Izmit Municipality, was created to preserve the cultural changes in village life from centuries ago to the present day for future generations, forming a memory of the village spanning approximately 200 years. There are 200 objects in the village museum. In addition, there are items such as a cradle made in 1883, a meat scale from 1924, a mill from 1929, and a millstone used in 1935. The museum also features objects used in village life, ranging from sickles to scythes, from ploughs to harrows, from ox carts to tractors, and from oil lamps to gas lamps (Url-1)(Fig. 1).

Figure 1. View of Sepetçiler Museum Village (interior) (Url-2)

2.2 Ahmet Kutsi Tecer Cultural Centre and Museum Village (Erzincan/Kemaliye)

It is known that the famous Turkish poet Ahmet Kutsi Tecer wrote his poem Orda Bir Köy Var Uzakta (There is a Village Far Away) in reference to Apçağa Village. The village, located in the Kemaliye district of Erzincan, is one of the first examples of a village museum in Anatolia. Apçağa Village, one of the villages that has managed to preserve its rich cultural heritage and unique architectural fabric intact to this day, was declared a ‘protected area’ in 2003 for the preservation and continuation of the traditional Eğin architectural fabric (Özgünaydın, 2006). The structure, built as a cultural house in 2014, features rooms designed as living spaces, adorned with old photographs, Eğin carpets, and sofas. There is a tandir room and an Eğin room to reflect village life (Url-3). There are many ethnographic objects that are part of village culture, such as agricultural production tools, toys, old cameras, and traditional clothing (Fig.2).

Figure 2. View of Ahmet Kutsi Tecer Museum Village (interior) (Url-4).

2.3. Cumalıkızık Ethnographic Museum Village (Bursa)

Cumalıkızık Village, which is listed on the UNESCO World Heritage List and has become a universal treasure, has a history dating back 700 years. Its traditions and customs, as well as its renovated ethnography museum, are being passed on to future generations. The Cumalıkızık Museum, which showcases the history, customs, and way of life, the museum displays a total of 240 items, including earthenware pots, candlesticks, lanterns, and agricultural tools used by the villagers in their daily lives (Meral, 2022). The sections where these items are displayed are shown in Fig. 3.

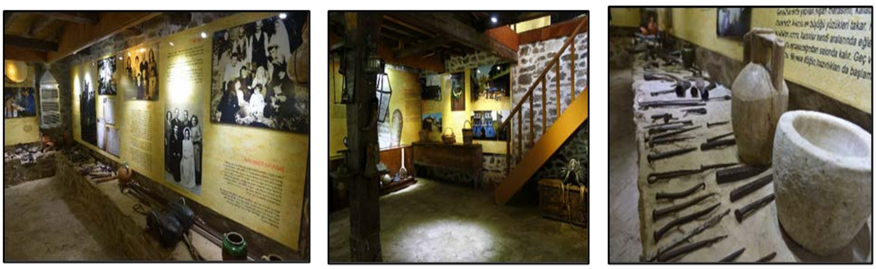

Figure 3. View of Cumalıkızık Museum Village (interior) (Url-5).

2.4. Altınköy Open Air Museum Village (Ankara)

Located in the Altındağ district of Ankara and open to visitors since 2015, this museum village differs from other museums in that it has a dynamic structure where daily activities continue to be carried out (Aysen et al., 2017; Yıldız, 2019). Altınköy, which can be seen as an escape from the boring and overwhelming city life, serves visitors on an area of over 500 acres. In the village square, there is a mosque and a fountain, as well as a blacksmith's workshop, a tinsmith's workshop, a weaving workshop, and a carpenter's workshop where traditional crafts are introduced. It is known that on certain days of the week, the relevant craftsmen openly produce their work in their workshops for visitors to see (fig.4). Events such as harvest festivals and village weddings are organised for visitors (Acıelma and Güngör 2021, Öztekin 2022).

Figure 3. View of Cumalıkızık Museum Village (interior) (Url-5).

3. THE CONCEPT OF MUSEUM VILLAGE AROUND THE WORLD AND EXAMPLES

The concept of museum villages was first introduced by the International Council of Museums (ICOM) in Athens in 1931 at the First International Conference of Architects and Technicians Concerned with the Preservation of Historic Monuments. The year 1964 marked an important turning point with the Venice Charter, which incorporated the protection of rural and urban areas into the approach to the protection of monumental works, based on the principle of in situ conservation (Eres, 2013). In 1975, as part of the "European Year of Architecture" events, the "Amsterdam Declaration" referred to rural heritage in the field of conservation, stating that "architectural heritage includes not only outstanding individual buildings and their surroundings, but also urban and rural areas with historical and cultural significance." By including landscape and natural environment within the scope of rural conservation, this declaration can be regarded as a significant step toward a rural heritage approach (Güler, 2016). In 1999, at the ICOMOS General Assembly Meeting, the article "Let's Protect Our Historic Villages" in the "Traditional Architectural Heritage Charter" and in 2000, under the "European Landscape Convention" by the Council of Europe, rural heritage began to be addressed as a whole within the framework of the concept of "cultural landscape" and intangible cultural heritage values. (Gökalp, 2019, Güler, 2016). Thus, the concept of a national or international museum village was formed with the idea of rebuilding old village houses in their natural environments and exhibiting them in all their aspects in order to "preserve tradition" and "educate future generations about traditional life." In 1891, Skansen, the world's first open-air museum village, was opened.

3.1. Skansen Museum Village (Sweden/Stockholm)

Located on Djurgarden Island in Stockholm, Skansen Museum Village provides a glimpse into lifestyles between 1720 and 2000. It is the world's first open-air museum village and was opened in 1891. The museum displays 150 farmhouses, including wooden houses, barns, stables, and other structures related to traditional farming life, some of which were transported to Skansen and others of which were replicated because they could not be moved. The museum aims to introduce the public to the traditional agricultural culture based on manual labour, which is now being lost. It also provides an opportunity to witness the craftsmanship of artisans (Fig.5). Additionally, tourists visiting the museum village can see animals native to Scandinavia. Celebrations for Lucia Day, the longest night of the year, Walpurgis Night, and the Summer Solstice are held in Europe and Scandinavian countries (Skansen, 2024).

Figure 5. View of Skansen Museum Village (Url-6).

3.2. Dimitrie Gusti National Museum Village (Romania/Bucharest)

It is an open-air ethnographic museum located in Herăstrău Park in Bucharest, the capital of Romania. Covering an area of 10 hectares, the museum contains village structures built between the 17th and 20th centuries. The structures represent Romanian rural architecture. There are 62 examples of local architecture (Fig.6). The buildings contain authentic objects such as carpets and furniture. The museum is also the third village museum in Europe (Url-7).

Figure 6. View of Dimitrie Gusti National Museum Village (Url-7).

3.3. Hida Folk Museum Village (Takamaya/Japan)

Located in the mountainous region of Gifu Prefecture near Takayama. The houses were built during the Edo period (1603-1868) and were relocated to their current location in 1971 to create a museum. The gassho-zukuri houses, which are designated as World Heritage Sites and represent the traditional wooden architecture of Japan's mountainous regions, are carefully preserved. Tools and utensils used in daily life in the past are on display (Fig. 7). The fireplaces inside the buildings are lit every morning, transforming the extraordinary museum village into a feast not only for the eyes but also for the nose. The museum also houses the Hida Takayama Handicrafts Experience Centre, where workshops on local handicrafts are held. Visitors can learn how to make local handicrafts at this centre (Utrl-8).

Figure 7. View of Hida Folk Museum Village (Utrl-8)

4. CONCLUSIONS AND RECOMMENDATIONS

The concept of cultural heritage ensures the continuity of the experiences, traditions and customs that people have accumulated throughout history. In this respect, living museums preserve the culture and way of life of the region and society in which they are located, offering visitors of all ages the opportunity to experience them. Museum villages perform these general functions at a more specific level, focusing on local values and unique cultural heritage. Beyond being mere exhibition spaces, museum villages keep local cultural memory alive by bringing traces of the past into the present. These museums shed light on the history and traditions of the local people, contributing to the development of social identity and a sense of belonging, while also enabling visitors to connect with this unique cultural heritage. Thus, museum villages play an educational role in preserving cultural heritage for future generations and promoting culture.

Museum village projects, which are more common around the world, have also been developing in our country in recent years. Studies show that although museum villages preserve and display traditional village structures in situ, they also continue to protect national values (Alkan, 2024, Subaşı, 2022, Altun, 2019; Yazici et al., 2017). Although these areas are tourism-oriented, they bear the traces of local architecture and provide historical and cultural education to visitors for informational purposes (Eres, 2020, Eres, 2013, Güler et al., 2019; Gülgün et al., 2015). Additionally, the preservation of cultural heritage is also the preservation and continuation of urban culture and urban identity. The objects exhibited in museum villages are part of the study of human history and form a concrete basis for all kinds of cultural and scientific ideas (Tunçer 2017; Yazici, 2017;Yazici & Gülgün, 2019). They also encompass the economic, cultural, social, educational, and other dimensions of local community development (DROPS, 2020). Furthermore, the entire natural and cultural landscape of the regions where museum villages are located should also be included in the process. It is useful to examine successful museum village applications selected from different geographical areas to see how different cultures preserve and exhibit village life. These museums should be designed not only as places that present and exhibit the past to us, but also as dynamic spaces that keep social memory, cultural diversity, and rural lifestyles alive. The sustainable solutions used in their design should align with innovative design criteria applied in a rural context. The functionality of village museums as spaces for social interaction and education must be strengthened (Ibrahimova, 2024; Pirli et al., 2023). Through spatial organization and technological integration in these areas, museum villages can be made more sustainable and accessible.

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Perception of The Concept of Sustainability in Landscape Architecture Education; The Role And Effects of The Education Process

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1. INTRODUCTION

Today, it is important to strike a balance between development and the sustainability of ecological, economic and social changes in human settlements. With more than 50% of the world's population living in cities and this trend set to increase, urban design and management approaches are becoming increasingly important (Ambrose et al., 2020). This process is changing the structure of cities in terms of both quality and quantity, and bringing its own unique problems in rural areas. On the other hand, the picture is further complicated by global environmental crises, which have emerged for complex reasons and whose existence is recognized by everyone. With the impact of these crises, all living environments are experiencing ecological, functional and social deterioration (Özgür, 2017). With the increase in construction in the world and the development of technology, green areas in cities have greatly decreased and the mentioned ecological deterioration has accelerated. However, green areas are critical areas that strengthen the relationship between human and nature and contribute to achieving sustainable development goals with the protection of ecological balance. For this reason, the planning, design, management and utilization of green spaces in cities are important (Emir, 2023). In this framework, professional groups serving in the field of space planning and design have great responsibilities (Atanur et al., 2020).

Landscape architecture, one of these professions, is a discipline that promotes environmental improvement, social and economic sustainability by combining urban and rural areas with human needs in line with the criteria required by natural processes (Güzel, 2020). It also draws attention as a profession that works on the creative transformation of the natural and built environment according to the expectations of today's society (Atanur et al., 2020). Landscape architects assume an important responsibility in protecting natural and cultural heritage and developing sustainable ways of living (Chen & Wu, 2009) to meet the expectations of 21st century societies and offer solutions in accordance with changing conditions (Gül & Eraslan, 2010).

As a fundamental stepping stone in the delivery of these solutions, higher education institutions play a crucial role in the development and delivery of quality education that contributes to the achievement of the "2030 Agenda for Sustainable Development" and the related "Sustainable Development Goals", while at the same time proposing an integrative path towards sustainability that takes into account social, environmental and economic well-being (Agirreazkuenaga, 2020). Given the huge impact of the built environment industry on global emissions and climate change, integrating environmental sustainability awareness into landscape architecture education is an important tool to achieve such goals (Boarin and Molina, 2022).

This integration between the concept of sustainability and landscape architecture education is critical for achieving a more sustainable future. In this context, it is emphasized that education is the most effective way to promote processes of changing and developing awareness among individuals in situations that require major change (De Haan, 2006). This understanding aims to increase individuals' knowledge and participation in sustainability by promoting the development of policies and programs that support education for sustainable development (De Haan and Harenberg, 1999).

More recently, the concept of sustainability has become more prevalent in educational curricula, reinforcing the efforts of educational systems to align with sustainability goals. Landscape architects of the future will play an important role in creating a more responsible, resilient and sustainable built environment, and to achieve this goal, they must master advanced technical skills and environmental strategies and integrate these competencies into their designs. Sustainability-oriented educational approaches that have developed in recent years have aimed to respond to contemporary needs in the field of sustainable design. In this context, increasing the level of knowledge and skills of landscape architects will make a great contribution to the sustainable spatial development of our country.

The main purpose of this study is to determine the perception, attitude and behavior levels of landscape architecture students regarding the concept of sustainability and to analyze how this perception is shaped by the educational process. In addition, the effects of students' socio-demographic characteristics on sustainability awareness were also examined. The findings draw attention to the necessity of supporting future landscape architects with sustainability-based education models and provide an opportunity to evaluate the current situation in this field.

2. MATERIALS AND METHODS

2.1. Material

The material of the study consisted of a total of 368 1st, 2nd, 3rd and 4th grade students studying in Atatürk University Landscape Architecture Department.

2.2. Method

The questionnaires prepared to determine the level of sustainability perception and awareness in the Landscape Architecture department and how this level will change with education were applied to the determined audience through Google Forms and statistical analyzes were made. The survey questions used in the study were modified according to the needs of the research by utilizing the scales suggested by Kopuz and Mülayim (2024).

Using the sampling formula used by Cochran (1977) and Saunders et al. (2009), the total number of people to be surveyed was determined as 188. Participation in the survey was 194 people.

The questionnaire was prepared on a 5-point Likert scale (strongly disagree, disagree, undecided, agree, strongly agree). The questionnaire consists of 3 sections. The first section includes demographic information. In the second part, there are open-ended questions to help measure the level of sustainability perception, environmental awareness and educational awareness, and in the last part, there are multiple choice questions to get information about the level of education.

In the statistical analysis of the questionnaires, frequency analysis and Chi-Square test were performed using SPSS version 20.0. In the light of the data obtained, students' level of knowledge about the concept of sustainability, environmental protection awareness and awareness levels in education were determined. The opinions of the students about the education process were taken.

3. FINDINGS

3.1. Distribution According to Demographic Characteristics

The demographic characteristics of the 194 respondents are presented in the table below. According to Table 1, 76% of the participants are female and 24% are male. Table 1 also shows that the majority of the respondents (68%) were aged 20 years and above.

Table 1 shows that the highest participation rate is among first graders (35%), while the participation rate of fourth graders (12%) is lower. And the majority of the participants reside in the province.

Table 1. Data on Demographic Characteristics of Participants

Gender	**F**	**%**	**Mother's Education Status**	**F**	**%**
Woman	147	75,8	Primary School	63	32,5
Male	47	24,2	Middle School	46	23,7
Total	194	100,0	High School	55	28,4
Age	**F**	**%**	University	52	26,8
17	8	4,1	Other	4	2,6
18	12	6,2	**Father's Education Status**	**F**	**%**
19	42	21,6	Primary School	33	17,0
20 and above	132	68,1	Middle School	40	20,6
Classroom	**F**	**%**	High School	75	38,7
Class 1	69	35,6	University	43	22,2
Class 2	56	28,9	Other	3	1,5
Class 3	45	23,1	**Income Level**	**F**	**%**
Grade 4	24	12,4	0-20.000	46	23,7
Settlement Location	**F**	**%**	20.000-40.000	80	41,2
Village	19	9,8	40.000-70.000	53	27,3
Town	1	0,5	70,000 and above	15	7,7
District	55	28,4	**Number of Households**	**F**	**%**
Province	119	61,3	2	5	2,6
			3	16	8,2
			4	66	34,0
			5 and above	107	55,2

3.2. Descriptive Information to Measure the Perception of Sustainability in Education

3.2.1. Sustainability Awareness

The findings in Table 2 reveal that the level of knowledge and awareness of Atatürk University Landscape Architecture students about sustainability is generally high. 75% of the participants stated that they care about the concept of sustainability, which shows that students' interest in the subject is strong. However, the fact that 43.8% of the participants stated that they had sufficient knowledge about sustainability, while 25.8% were undecided shows that the level of knowledge is not equally reflected in every student. This situation points to a disconnect between knowledge and behavior. The majority of students agree that the use of renewable energy sources should be widespread (78%), and the rate of those who support the preference of energy-saving products is also quite high (77.4%). However, the rate of those who think they have sufficient knowledge about renewable energy production is lower at 39.2%. These findings indicate that students support the principles of sustainability in theory, but lack knowledge in practice. 74.2% of the participants think that the concept of sustainability is important not only in environmental but also in social and economic terms, which shows that the concept is perceived in a holistic way. On the other hand, 53% of the students stated that sanctions and activities supporting sustainability are insufficient throughout the country. The perception that ecological products and structures are not sufficient (44%) and that there is a lack of understanding of ecology and sustainability in landscape architecture (59.8%) reveal that the perception of systemic deficiency has an important place in student awareness. Students also have a high level of awareness about the protection of green spaces. 70.1% of the participants argue that green areas should not be sacrificed for the sake of urbanization and industrialization. In addition, 64.4% stated that sustainable living plays an important role in reducing environmental impacts.

Table 2. Level of Sustainability Awareness

Questions	Strongly Disagree	Disagree	Undecided	I agree	Strongly Agree
I have sufficient knowledge about the concept of sustainability.	21	18	50	85	20
	10.8%	9.3%	25.8%	43.8%	10.3%
I care about the concept of sustainability	27	7	15	92	53
	13.9%	3.6%	7.7%	47.4%	27.4%
I think that the sanctions and activities supporting sustainability in our country are sufficient.	39	63	48	29	15
	20.1%	32.5%	24.7%	14.9%	7.7%
I follow the activities carried out to raise awareness on sustainability across the country.	27	53	55	43	16
	13.9%	27.3%	18.4%	22.2%	8.2%
Sustainable living plays an important role in reducing environmental impacts.	24	13	32	73	52
	12.4%	6.7%	16.5%	37.6%	26.8%
The concept of sustainability is also important from a social and economic perspective	23	9	18	65	79
	11.9%	4.6%	9.3%	33.5%	40.7%
I have sufficient knowledge about renewable energy production.	18	22	54	76	24
	9.3%	11.3%	27.8%	39.2%	12.4%
The use of renewable energy sources should be expanded (solar, wind, water, etc.)	24	8	11	63	88
	12.4%	4.1%	5.7%	32.5%	45.4%
Energy-saving products should be preferred for long-term use of energy resources	23	11	10	62	88
	11.9%	5.7%	5.2%	32.0%	45.4%
Sustainable or green efforts are highly effective in ensuring that natural resources will continue to be available in the future.	27	6	13	55	93
	13.9%	3.1%	6.7%	28.4%	47.9%

Green spaces are important for a sustainable environment and should not be sacrificed for urbanization and industrialization	27	17	14	58	78
	13.9%	8.8%	7.2%	29.9%	40.2%
I think that ecological products or ecological structures are sufficient in our country.	36	49	50	43	16
	18.6%	25.3%	25.8%	22.0%	8.2%
I think there is a lack of understanding about ecology and sustainability in the field of landscape architecture in our country.	28	19	31	67	49
	14.4%	9.8%	16.0%	34.5%	25.3%

3.2.2. Sustainable Environmental Awareness

According to the findings obtained in Table 3, the evaluation made in line with the sustainable environmental awareness data shows that the level of environmental awareness of Atatürk University Landscape Architecture students is generally high. Most of the participants (79%) stated that they have individual responsibility for the protection of the environment and the sustainability of green areas. In addition, 70% of the participants argue that people who harm the environment should be sanctioned. This shows that students have a conscious approach not only at the level of awareness but also in terms of environmental ethics and control mechanisms. Attitudes towards the use of environmentally friendly products are also striking. 63.9% of the participants stated that they prefer such products. However, it is seen that students are less responsible for using second-hand products and reducing the use of environmentally harmful products such as plastic bags, straws and bottles. For example, only 49% of the respondents were careful not to use such plastic products. This reveals that students have not fully integrated some sustainability behaviors into their daily lives. In the data on recycling practices, 75% of the students stated that they would use recycling bins if there was sufficient infrastructure. This rate shows that students are conscious about recycling; however, current physical conditions play a decisive role in transforming this consciousness into behavior. Regarding participation in afforestation activities, 73.8% of the students stated that they were volunteers, indicating a strong desire for direct environmental actions.

Table 3. Data for Measuring Sustainable Environmental Awareness

Questions	Strongly Disagree	Disagree	Undecided	I agree.	Strongly Agree
Activities of governmental and non-governmental organizations working to create a sustainable environment should be increased.	33	7	9	66	79
	17.0%	3.6%	4.6%	34.0%	40.7%
For the protection of biodiversity, any intervention that adversely affects wildlife should be sanctioned.	26	14	17	70	67
	13.4%	7.2%	8.8%	36.1%	34.5%
When buying a vehicle, I believe that vehicles with the least impact on the ecological balance should be preferred.	26	12	19	70	67
	13.4%	6.2%	9.8%	36.1%	34.5%
I think that increasing the use of public transportation has a positive impact on the environment.	25	9	26	73	61
	12.9%	4.6%	13.4%	37.6%	31.4%
Everyone should take responsibility for afforestation and tree protection for the protection of the environment and the sustainability of green areas	25	10	6	65	88
	12.9%	5.2%	3.1%	33.5%	45.4%
If activities are organized for afforestation and protection of trees, I will participate.	22	12	17	75	68
	11.3%	6.2%	8.8%	38.7%	35.1%
If there is/were sufficient infrastructure in our country, I would throw waste into recycling bins so that it can be recycled	22	12	13	68	79
	11.3%	6.2%	6.7%	35.1%	40.7%
In my personal life, I buy second-hand goods.	30	39	45	53	27
	15.5%	20.1%	23.2%	27.3%	13.9%
I take care not to use plastic bags, plastic straws, plastic bottles, etc.	28	22	49	59	36
	14.4%	11.3%	25.3%	30.4%	18.6%
I take care to classify garbage when I throw it away.	24	17	37	64	52
	12.4%	8.8%	19.1%	33.0%	26.8%
I buy cleaning materials by checking whether they contain harmful chemicals	24	32	41	61	36
	12.4%	16.5%	21.1%	31.4%	19.6%
I try to use more environmentally friendly products	24	17	29	65	59
	12.4%	8.8%	14.9%	33.5%	30.4%
Environmentally friendly energy sources should be explored instead of fossil fuels and dependence on fossil fuels should be minimized.	23	11	13	70	77
	11.9%	5.7%	6.7%	36.1%	39.7%
I would prefer to use less harmful biofuels instead of fossil fuels.	18	24	32	65	55
	9.3%	12.4%	16.5%	33.5%	28.4%
In my personal life, I try to conserve water by not turning on the tap unnecessarily	24	10	16	68	76
	12.4%	5.2%	8.2%	35.1%	39.2%

3.2.3. Education and Awareness

When the data on education and awareness are analyzed (Table 4), it is seen that the awareness of Atatürk University Landscape Architecture students about the role of sustainability in the education process is quite high. 74.8% of the participants stated that sustainability is an important part of landscape architecture education. In addition, 73% of them emphasized the importance of practical activities such as seminars, trips and workshops to be organized in the field of sustainability. These results show that students see sustainability not only as a theoretical concept but also as a professional and practical competence area. 74% of the participants stated that sustainable living practices would positively affect their landscape architecture careers. This finding indicates that students see sustainability awareness as valuable not only for environmental but also for professional development. Similarly, 78.3% believe that sustainable landscape planning will improve future quality of life. This indicates that students associate sustainability principles with long-term social and spatial benefits. However, another striking finding is that 58% of the students think that landscape architecture curricula in Turkey are not sufficient in terms of sustainability. This shows that the expectations of the students are not met by the current educational content and reveals the need to restructure the curriculum from a sustainability perspective. This deficiency can be addressed through practical courses, project-based learning and digital educational materials. 72.2% of the students stated that social media and digital platforms are effective in raising awareness on sustainability. This shows that supporting educational content with digital tools has the potential to create a wider awareness among students. In addition, the majority of students think that sustainability education will also develop individual values such as responsibility, resilience and environmental awareness.

Table 4. Data on Education and Awareness

Questions	Strongly Disagree	Disagree	Undecided	I agree.	Strongly Agree
Sustainability is an important part of landscape architecture education.	27	9	13	64	81
	13.9%	4.6%	6.7%	33.0%	41.8%
Sustainability principles should be incorporated into landscape planning and design processes.	25	9	13	69	78
	12.9%	4.6%	6.7%	35.6%	40.2%
I think sustainable design has a positive impact on landscape architecture practices.	21	11	15	67	80
	10.8%	5.7%	7.7%	34.5%	41.2%
Sustainable landscape planning is important for improving future quality of life	25	8	9	73	79
	12.9%	4.1%	4.6%	37.6%	40.7%
Curricula on sustainability in landscape architecture education programs in Turkey are adequate.	22	36	55	50	31
	11.3%	18.6%	28.4%	25.8%	16.0%
Lessons on sustainability should be combined with practical training for a more effective understanding	25	11	18	72	68
	12.9%	5.7%	9.3%	37.1%	35.1%
I think more projects and practices on sustainability would be beneficial for education.	23	7	14	81	69
	11.9%	3.6%	7.2%	41.8%	35.6%
I should attend more workshops and trainings to improve my knowledge on sustainability	21	10	22	80	61
	10.8%	5.2%	11.3%	41.2%	31.4%
Sustainable design should be developed in conjunction with new technologies in the field of landscape architecture.	24	8	15	77	70
	12.4%	4.1%	7.7%	39.7%	36.1%
Social media and digital platforms are effective tools for raising awareness on sustainability.	24	10	20	71	69
	12.4%	5.2%	10.3%	36.6%	35.6%
I think that environmentally friendly design approaches should be adopted in landscape architecture projects.	23	9	15	72	75
	11.9%	4.6%	7.7%	37.1%	38.7%
I think that sustainable landscape architecture trainings will be effective in finding solutions to environmental problems.	26	8	14	74	72
	13.4%	4.1%	7.2%	38.1%	37.1%

I believe that the seminars on sustainable landscape architecture will increase the success of the ongoing projects during the training period.	29	5	17	76	67
	14.9%	2.6%	8.8%	39.2%	34.5%
Sustainability education promotes values such as responsibility, accountability and resilience in students.	25	8	15	79	67
	12.9%	4.1%	7.7%	40.7%	34.5%
Adopting sustainable living practices will positively affect my career as a landscape architect.	26	8	14	69	77
	13.4%	4.1%	7.2%	35.6%	39.7%

3.3. Findings on Perception of Sustainability in Education Scores

In the statistical analysis of the questionnaires, frequency analysis Chi-Square test was performed using SPSS version 20.0. In the light of the data obtained, students' level of knowledge about the concept of sustainability, environmental protection awareness and awareness levels in education were determined. The opinions of the students about the education process were taken. When the relationship between the gender variable and the perception of sustainability is examined, it is seen that gender has significant effects on the perception of sustainability among Atatürk University Landscape Architecture students. According to the Chi- Square analysis, statistically significant ($p<0.05$) and very significant ($p<0.01$) differences were found in many questions.

In Table 5, Chi-Square analysis was applied for the gender variable. In the evaluation ($p<0,05$ significance level) was taken as a basis and evaluation was made for average levels. As a result of the evaluation, it was determined that there was a very significant ($p<0,01$) relationship between students' attitude towards afforestation activities and their gender. While the participation rate of women is 82%, it is 18% for men. Again, it is seen that there is a very significant ($p<0.01$) relationship between the issue of cleaning materials containing harmful chemicals and gender. The participation rate of women was 80%, while that of men was 20%. According to the data, it was determined that the adoption of sustainable living practices was very important ($p<0.01$) and the participation rate of women was 80% and 20% of men. This shows that the belief that sustainability will positively affect career development in landscape architecture is more common among women. Female students were also more likely to agree with the statement "Adopting sustainable living practices will positively affect my career in landscape architecture". This shows that female students embrace sustainability not only in terms of environmental awareness but also in terms of professional development. In addition, issues such as having knowledge about sustainability, following activities that support sustainability, the necessity of sanctions for the protection of biodiversity, the search for alternatives to fossil fuels and recycling also differ significantly by gender. In general, women exhibit more sensitive and conscious behaviors on these issues.

Table 5. The relationship between students' gender and their perception of sustainability

Questions	P
• I have sufficient knowledge about the concept of sustainability	0,03*
• I follow the activities carried out to raise awareness on sustainability across the country.	0,01*
• Sustainable living plays an important role in reducing environmental impacts.	0,04*
• For the protection of biodiversity, any intervention that adversely affects wildlife should be sanctioned.	0,04*
• If activities are organized for afforestation and protection of trees, I will participate (planting saplings, etc.).	0,008**
• I take care to classify garbage when I throw it away.	0,03*
• I buy cleaning materials by checking whether they contain harmful chemicals.	0,001**
• Environmentally friendly energy sources should be explored instead of fossil fuels and dependence on fossil fuels should be minimized.	0,01*
• Sustainability is an important part of landscape architecture education.	0,02*
• Sustainable landscape planning is important for improving the quality of life in the future.	0,04*
• I think more projects and practical work on sustainability issues would be beneficial for education.	0,01*
• I should attend more workshops and trainings to improve my knowledge on sustainability.	0,03*
• Sustainable design should be developed in conjunction with new technologies in the field of landscape architecture.	0,02*
• Sustainability education promotes values such as responsibility, accountability and resilience in students.	0,02*
• Adopting sustainable living practices will positively affect my career as a landscape architect.	0,007**

Significant ($p<0.05$) *, Very Significant ($p<0.01$) *

It was observed that the place of settlement significantly affected the perception of sustainability ($p<0.01$). Especially students living in the city center attach more importance to the integration of sustainability principles into the landscape planning process. In addition, it is understood that students living in the province have a higher sense of responsibility for the protection of green areas and afforestation activities. This suggests that urban areas are more exposed to sustainability awareness and that the environmental impacts of urban life increase awareness. According to Table 6, a very significant relationship was found between students' residential areas and their perception of sustainability ($p<0.01$). The majority (68%) of those who think that sustainability principles should be included in the landscape planning process live in provinces.

Table 6. The relationship between students' residential areas and their perception of sustainability

Questions	P
• In order to protect the natural environment and sustain the existence of green areas, everyone should take responsibility for afforestation and tree protection.	0,04*
• Sustainability principles should be incorporated into landscape planning and design processes.	0,002**

Significant (p<0.05) *, Very Significant (p<0.01) *

Tables 7 and 8 show that there is a significant relationship ($p<0.05$) between the educational level of the students' parents and the level of perception of sustainability. When the mother's education level and perception of sustainability were analyzed (Table 7), significant relationships were found between mother's education level and sustainable attitudes. Higher awareness was observed in students with mothers who graduated from primary school-high school, especially on issues such as using environmentally friendly products ($p=0.04$) and preferring environmentally friendly energy sources instead of fossil fuels ($p=0.01$). This finding suggests that environmental awareness is also strong in children of mothers who do not have a high level of education, perhaps because the traditional understanding of saving and respect for nature in the family may be effective. Similarly, significant relationships were found between father's education level and sustainability awareness. Students with higher levels of father's education were more aware of the impact of public transportation use on the environment (p=0.01), garbage sorting behavior (p=0.03) and the use of environmentally friendly products (p=0.01). These findings reveal that parental education has an impact on student behaviors, especially the level of education of fathers shapes environmental attitudes.

Table 7. The relationship between mother's education level and perception of sustainability

• I try to use more environmentally friendly products.	0,04*
• Environmentally friendly energy sources should be explored instead of fossil fuels and dependence on fossil fuels should be minimized.	0,01*

Significant (p<0.05) *, Very Significant (p<0.01) *

Table 8. The relationship between father's education level and perception of sustainability

• I think that increasing the use of public transportation has a positive impact on the environment.	0,01*
• I take care to classify garbage when I throw it away.	0,03*
• I try to use more environmentally friendly products.	0,01*

Significant (p<0.05) *, Very Significant (p<0.01) *

According to Table 9, a significant relationship was found between family income level and the responsibilities to be taken (p<0.05). It was observed that families with an income of 0-40.000 (65%) were more active in afforestation and environmental protection than families with high income (35%). It was determined that students in the low income group gave more importance to afforestation and protection of green areas. This result suggests that environmental awareness may decrease as income level increases; perhaps low-income individuals are in more direct contact with nature and tend to use resources more carefully.

Table 9. The relationship between family income levels and perception of sustainability

• In order to protect the natural environment and sustain the existence of green areas, everyone should take responsibility for afforestation and tree protection.	0,04*

Table 10 shows the results of the frequency analysis and Chi-Square test conducted using SPSS version 20.0 for the evaluation of students' sustainability awareness depending on the grade level. In line with these results;

It was observed that there were differences in the perception of sustainability according to grade level. In particular, while first-year students are more idealistic about sustainability issues, this rate decreases in higher grades. For example, while the rate of students who agreed that non-governmental organizations should be more active in environmental studies was 38% in the first grade, this rate decreased to 12% in the fourth grade. The relationship between the issue of sanctioning negative interventions to natural life for the protection of biodiversity and the grade level is very significant ($p<0.01$). In addition, the issues of using environmentally friendly products ($p<0.05$), reducing dependence on fossil fuels ($p<0.05$), and taking responsibility for afforestation efforts also have a significant relationship with grade level ($p<0.05$).This may indicate some loss of motivation or system criticism in students as the education process progresses. However, it was also observed that the level of knowledge and awareness on the use of environmentally friendly products, researching alternatives to fossil fuels and afforestation increased in the upper grades ($p<0.05$).

Table 10. The relationship between students' grade level and perception of sustainability

Questions	P
• The activities of governmental and non-governmental organizations working to create a sustainable environment should be increased and supported.	0,03*
• For the protection of biodiversity, any intervention that adversely affects wildlife should be sanctioned.	0,008**
• In order to protect the natural environment and sustain the existence of green areas, everyone should take responsibility for afforestation and tree protection.	0,05*
• I try to use more environmentally friendly products.	0,03*
• Environmentally friendly energy sources should be explored instead of fossil fuels and dependence on fossil fuels should be minimized.	0,02*

Significant (p<0.05) *, Very Significant (p<0.01) *

4. CONCLUSIONS AND RECOMMENDATIONS

This study examined the perception, awareness and behavior levels of landscape architecture students towards the concept of sustainability and evaluated the impact of the educational process on this awareness. The findings show that students attach a high level of importance to sustainability; however, this awareness is not fully reflected in daily life and professional practices. This situation reveals the need to restructure sustainability education not only at the theoretical level but also with an applied and holistic approach (Boarin & Molina, 2022; Park et al., 2024).

While the majority of the participants (75%) find the concept of sustainability important, the fact that they emphasize the inadequacy of current practices and sanctions (53%) points to deficiencies at the institutional level. These findings are in line with the results of similar studies conducted by Kopuz and Mülayim (2024) and show that students need stronger sustainability practices not only at the individual level but also at the system level.

It has been observed that awareness of environmental responsibility is quite widespread among students (79%) and that they are particularly sensitive to issues such as protection of green areas, afforestation and preference for environmentally friendly products. However, although students have a high level of sustainable environmental awareness, this awareness is not sufficiently reflected in some behaviors (e.g. avoiding plastic products or using second-hand goods). This finding suggests that sustainability education should not only include knowledge transfer but also behavioral transformation, as De Haan (2006) suggests. This also shows that education, infrastructure and social habits are effective in the process of transforming environmental awareness into behavior. Including more hands-on and experiential learning opportunities in education programs about why these behaviors are necessary will facilitate the transformation of this level of awareness into action. At the same time, it was emphasized that sustainability education is critical for students in understanding problems, finding solutions and making a positive contribution to their professional careers. According to a study, the majority of students (73%) think that sustainable design courses should be given more weight in the curriculum (Kopuz & Mülayim, 2024).

It shows that students' awareness of sustainability is high, but there is a lack of practice in integrating this issue into education. Students demand that the concept of sustainability should be included more effectively in the curriculum and that the courses should be strengthened with workshops, field practices and digital support. This expectation for the educational process is in line with the findings of Ramísio et al. (2019) on the structuring of sustainability strategies in higher education institutions. Furthermore, 74% of students stated that sustainability-oriented education would contribute positively to their professional careers, indicating that sustainability education is closely related to professional ethics and social responsibility (Mba et al., 2024). Improvements in this direction will enable students to fulfill their environmental and professional responsibilities more effectively by increasing their sustainable landscape design skills.

Analyses revealed that sustainability perception was significantly related to students' socio-demographic characteristics. Considering the gender variable, female students were found to be more sensitive and conscious than male students in sustainability attitudes related to environmental protection, sustainable living habits and professional development. As a result, it shows that gender is an important variable on sustainability awareness and environmental behaviors. The fact that female students are more likely to develop environmentally friendly attitudes requires gender perspective to be taken into account in sustainability education. Considering these differences, it may be recommended to develop special educational approaches that support awareness and behavior change, especially in male students.

According to the settlement factor, it was observed that students living in urban centers adopted sustainability principles more and were more inclined to integrate these principles into landscape planning processes. The level of education of the parents also significantly affects the environmental attitudes of the students; a positive correlation was found with the level of education of the mothers and fathers, especially in terms of preference for environmentally friendly products, waste management and support for renewable energy sources. Another noteworthy finding is related to income level; it is understood that students belonging to low- income groups have a higher sense of responsibility towards the environment and are more willing to engage in sustainability practices. Depending on the grade level, while an idealistic approach is observed in first year students, an increase in practical awareness is observed in upper class students. These results show that sustainability education should be structured in a participatory, applied and holistic approach that takes into account individual differences (Arezes et al., 2019). In order to increase sustainability awareness, it is of great importance to support education programs with content that not only conveys knowledge but also transforms it into behavior. It is understood that students show a high level of interest and awareness in sustainability, but systemic (lack of curriculum), individual (lack of knowledge) and social (gender, income, parental education) factors are effective in the transformation of this awareness into behavior. Taking this diversity into account, the education system needs to transform sustainability awareness into behavior through more holistic, applied and personalized methods.

In conclusion, the restructuring of landscape architecture education on the axis of sustainability should be supported by project-based learning, effective use of digital resources and social interaction-based approaches in addition to theoretical knowledge. Such an educational model will enable students to become not only knowledgeable, but also individuals who adopt sustainability principles as a way of life and professional ethics. It is vital for higher education institutions to lead this transformation in order to achieve sustainable development goals (Agirreazkuenaga, 2020; De Haan & Harenberg, 2007).

Since sustainability is a field that focuses on the challenges in the world and how these challenges should be addressed, higher education institutions have an obligation to lead this movement and contribute to a paradigm shift due to its history, mission and goals (Arezes et al., 2019).

In order to increase the impact of the perception of sustainability in the education process provided in these institutions, it should be supported by applied studies and projects to make it more prominent. Most of the respondents confirmed this idea and stated that sustainability education should be enriched with activities such as seminars, workshops and field practices. Future landscape architects play a critical role in shaping and sustaining the built environment (Mba et al., 2024). 74% of the participants stated that adopting sustainable living practices would positively impact their careers. This will make it easier for landscape architects to adopt sustainability principles during their education and to create both aesthetically and functionally effective designs throughout their lifetime.

The research shows that sustainability education is a fundamental tool for social and ecological transformation, not only in the individual context. However, in this process, it is understood that the scope of education should be expanded, course contents should be updated and sustainability presentation should be supported with more concrete practices. As a result, restructuring landscape architecture education programs with a focus on sustainability is considered as a critical step towards building environmentally sensitive and resilient cities.

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The Evolution of Cultural Landscapes: Meaning and Transformation in A Historical Context

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1- INTRODUCTION

The concept of landscape has evolved over time from merely denoting a natural scene to becoming a spatial manifestation of the multidimensional relationship between humans and their environment (Corner, 1999; Yücel & Salt, 2018; Mitchell, 1996). In particular, the concept of cultural landscape makes visible the traces of interaction between nature and culture across time, enabling the interpretation of space as a product of historical and social processes.

Cultural landscapes can be defined as areas where the modes of interaction between human communities and nature, as well as the cultural meanings arising from these interactions, are embodied (Perihan & Aşur, Karahan and Sezen, 2019; 2020; Taylor & Lennon, 2011). The inclusion of cultural landscapes in UNESCO's World Heritage List in 1992 contributed significantly to raising international awareness regarding their conservation and the need for more in-depth research (UNESCO, 2021).

Cultural landscapes should not be considered merely as physical forms or aesthetic arrangements but rather as complex structures encompassing social memory, identity formation, and struggles for spatial justice (Harvey, 2000; Cosgrove, 1984). Therefore, the study of cultural landscapes offers a broad interdisciplinary perspective that integrates fields such as geography, history, sociology, anthropology, and architecture.

The pace of transformation in cultural landscapes has accelerated with modernization, urbanization, and globalization processes (Pirli et al. 2023). These transformations sometimes lead to the disappearance or commodification of cultural landscapes, while at other times they create spaces for new forms of cultural production (Urry, 1990).

Under the influence of neoliberal policies, the reduction of space to an object of investment and consumption has led to the redefinition of cultural landscapes in terms of commercial value. In this process, the spatial attachments and cultural practices of local communities are often overlooked or marginalized (Escobar, 2001).

The meaning of cultural landscapes must be interpreted not only through their physical existence but also through the symbolic values and network of relationships they represent. Nora's (1989) concept of "sites of memory" provides a critical framework for understanding the central role of cultural landscapes in both individual and collective memory processes.

Moreover, cultural landscapes serve as powerful tools for analyzing how different identity categories such as gender, class, and ethnicity are constructed and reproduced in space (Mitchell, 1996). Questions of who produces space, how it is produced, and for whom it holds meaning are central to cultural landscape analyses.

Cultural landscapes are not merely relics of the past; they are living systems that also influence today's and tomorrow's spatial formations. Consequently, conservation strategies must go beyond a narrow focus on historical authenticity and develop flexible approaches that consider cultural continuity and change (Mitchell et al., 2009).

Faced with global environmental threats such as climate change, the preservation of cultural landscapes has taken on new urgency. In sensitive areas such as coastal regions, river basins, and agricultural lands, it is essential to evaluate both cultural and natural dynamics together (Sezen et al., 2019 ; IPCC, 2021).

The preservation of cultural landscapes should encompass not only physical structures but also the knowledge systems, life practices, and cultural values associated with them (Smith, 2011). Otherwise, conservation efforts risk creating mere empty shells, leading to inevitable losses of spatial memory and cultural identity.

In this context, the knowledge, practices, and values of local communities must be taken into account in the management of cultural landscapes. Participatory approaches are vital for both the sustainability of cultural landscapes and the achievement of spatial justice (Taylor & Lennon, 2011).

Cultural landscapes are living spaces that both bear the traces of the past and are reshaped by the dynamics of the present. This study aims to outline the theoretical framework of the concept of cultural landscape, introduce its various types, and examine the world of meanings surrounding cultural landscapes through diverse examples.

2. CONCEPTUAL EVOLUTION OF LANDSCAPE

Initially, landscape was perceived merely as a visual representation of nature or human settlements. Over time, however, the concept of landscape has evolved into an understanding that emphasizes the dynamic interaction between natural and cultural elements (Cosgrove, 1984). Emerging in the 16th century in Western Europe through art and architecture as an approach to depicting nature, landscape gradually developed into a scientific discipline (Baker, 2004).

The concept of landscape is grounded in a variety of theoretical frameworks aimed at exploring the relationship between nature and humanity. By the 18th century, landscape was increasingly seen not only as a visual representation, but also as a "space" reflecting the cultural values, identities, and socio-economic structures of societies (Mitchell, 1996). During this period, the meaning of landscape expanded beyond aesthetics to include social and cultural dimensions.

In the 19th century, the concept of landscape underwent a significant transformation due to the effects of the Industrial Revolution. Industrial landscapes, urbanization, and the expansion of agricultural areas reshaped the reciprocal relationship between nature and humanity (Harvey, 1989). Industrialization redefined landscape as a site of economic production and power struggle, initiating the commodification of nature.

By the mid-20th century, another significant phase in the conceptual development of landscape emerged with the rise of environmental movements. Increasing environmental awareness led to a broader understanding of landscape—not merely as a physical space, but as a convergence of cultural, economic, and natural processes (Cresswell, 2004). Landscape came to be recognized for its critical role in environmental sustainability and ecological balance.

The cultural dimension of landscape became particularly pronounced following UNESCO's 1992 designation of cultural landscapes. These were distinguished from natural landscapes as areas of historical and cultural significance, and thus recognized as cultural heritage requiring protection and conservation (UNESCO, 1992). This designation marked the emergence of a new paradigm in landscape conservation and management.

The recognition of cultural landscapes also deepened investigations into the interaction between landscape and social structures. This process introduced a new perspective questioning how cultural and societal identities are represented in space and how landscape influences collective memory (Tuan, 1991). Landscape came to be viewed not simply as an external visuality, but as a reflection of collective memory embedded within society.

Especially toward the end of the 20th century, the concept of landscape evolved into a more comprehensive understanding that integrated ecological and cultural perspectives. During this period, the boundaries of landscape research expanded beyond natural elements to examine the processes through which societies shape landscapes, as well as the economic, political, and cultural contexts of these processes (Swyngedouw, 2004).

A critical turning point in the conceptual development of landscape also occurred under the influence of postmodernism. Postmodern thought emphasized that landscape is not merely an objective reality but a culturally constructed phenomenon. During this era, landscape came to be understood as a product of the meaning-making processes of individuals and groups (Jameson, 1991). This perspective highlighted the plurality and dynamic nature of landscape.

The meaning of cultural landscapes should be understood not only as artifacts bearing traces of the past, but also as reflections of contemporary and future processes of meaning-making (Yazici & Gülgün, 2024). This approach acknowledges that landscape is an evolving and mutable construct. While its meanings vary across societies, they also emerge in response to social changes and environmental threats (Giddens, 1990).

Cultural landscapes are directly linked to contemporary social issues such as spatial justice and social inequality (Sezen & Yılmaz, 2006). Problems such as urbanization, displacement, and environmental degradation have necessitated a reconsideration of the landscape's impact on social structures (Harvey, 2000). At this point, the management and protection of landscapes emerge not only as matters of aesthetics but also as issues of social rights.

At its current stage of conceptual development, landscape is understood as a construct that embodies both physical and symbolic meanings. It is a dynamic structure that reflects the cultural, historical, and social processes of a society. Therefore, landscape studies must address not only the physical dimension of space but also its relationship with social structures (Lefebvre, 1991).

Finally, the conceptual evolution of landscape has brought about a significant transformation not only in academia but also in societal practices. Contemporary understandings of landscape incorporate environmental sustainability, cultural heritage preservation, and public participation, thereby promoting more inclusive and dynamic approaches to landscape management. These approaches recognize that landscape is not only a reflection of the past, but also a force that shapes the future.

As a result of this conceptual evolution, landscape today is recognized as a multi-layered, polysemic, and historically contingent concept. Therefore, landscape studies must consider not only the physical space but also the dynamics of representation, identity, memory, and power.

3. CULTURAL LANDSCAPES IN HISTORICAL CONTEXT

Cultural landscapes are spaces shaped over time by the relationship between humans and nature, imbued with meaning and carrying collective memory. These landscapes reflect how humans have used, organized, and interpreted space throughout history. The term "cultural landscape" was formally defined by UNESCO in 1992 as areas where natural and cultural elements are interwoven (UNESCO, 1992). However, the origins of the concept stretch back much further, with evidence of cultural landscapes present from the earliest periods of human history.

Historically, cultural landscapes have often served as symbols of power and authority (Yuca & Aşur, 2021). In the Roman Empire, monumental gardens, bridges, and cities symbolized imperial strength. As the empire expanded, cultural landscapes represented not only control over nature but also structures of governance and social order (Coates, 1998). Roman villas, for example, conveyed much more than aesthetic appeal—they functioned as important cultural symbols representing aristocratic lifestyles and the power of the Roman state.

In medieval Europe, landscapes took form around monasteries, churches, and the organization of feudal land systems. Feudalism played a central role in determining the social structures tied to land management and use. The cultural landscapes of this era were characterized by the organization of agricultural lands and the presence of protected natural areas (Bloch, 1961). Gardens surrounding monasteries were not only productive agricultural sites but also carried religious and cultural significance.

The Renaissance era marked a period in which cultural landscapes were redefined through a fusion of visual aesthetics and scientific thought. The relationship between humanity and nature was reinterpreted, with Renaissance landscapes emphasizing symmetry, perspective, and geometric depictions of nature. In Italy, Renaissance gardens emerged as symbols of aristocratic and ecclesiastical power. These landscapes highlighted not only natural elements but also human control and ordering of the environment (Ferguson, 1994).

From the 17th century onward, landscape design in Europe—especially the French formal garden style—embodied the ideal of human dominance over nature. The Gardens of Versailles, designed by André

Le Nôtre, represent the epitome of this ideology. Versailles functioned not merely as a royal garden but as a symbolic space of absolute monarchy. Le Nôtre’s design reflected an imposed order that demonstrated human authority over the natural world (Berger, 1985).

Following the Industrial Revolution, cultural landscapes were reshaped through the emergence of large cities and factories. The 19th century ushered in a period of rapid urbanization, leading to a significant transformation of natural landscapes. Villages gave way to cities, and human-made environments replaced natural settings (Harvey, 1989). This era saw landscapes become increasingly urbanized, commodified, and rapidly transformed. At the same time, however, awareness of the need to preserve cultural landscapes began to emerge.

In the early 20th century, particularly in Germany, the notion of protecting cultural landscapes gained traction. Emphasis shifted toward the preservation of not only natural but also historical and cultural landscapes. These landscapes were seen as spaces that did not merely reflect the past but also offered insight into the future (Mumford, 1961).

By the mid-20th century, the growing influence of ecological thought fostered a more integrated approach to landscape, recognizing the interdependence of cultural and natural elements. Landscape began to be understood not simply as a fragment of nature but as a constructed environment reflecting human ways of life. The rise of ecological landscape management further reinforced this conceptual shift (Swyngedouw, 2004).

UNESCO's 1992 designation of cultural landscapes marked a significant step forward in landscape preservation. From that point, cultural landscapes were considered not merely physical structures but as spaces shaped by the social meanings and values surrounding them. UNESCO emphasized the importance of preserving these landscapes due to their role in safeguarding historical and cultural memory (UNESCO, 1992).

Today, global phenomena such as climate change, globalization, and rapid urbanization have made the preservation of cultural landscapes even more critical. In the face of environmental and cultural threats, it is increasingly important to manage cultural landscapes in a way that is both socially and ecologically sustainable. Within this context, the role of local communities in the conservation of cultural landscapes has gained greater importance (Escobar, 2001).

Cultural landscapes have served as reflections of historical processes, cultural identities, and human–environment relationships from the past to the present. These landscapes not only possess aesthetic value but also embody collective memory, identity, and relations of power. Therefore, the conservation of cultural landscapes should be seen not only as an effort to protect heritage, but also as a step toward addressing social inequalities and injustices.

In short, cultural landscapes have carried different meanings throughout history, shaped by the cultural, social, political, and economic dynamics of their time. These landscapes are not only physical and aesthetic forms, but also expressions of societal values and cultural identities. Thus, the preservation of cultural landscapes is a multidimensional process that necessitates an understanding of the past, present, and future together.

3.1. Some Cultural Landscape Types and Features

The table below provides information on some cultural landscape types and features (Table 1).

Table 1. Some cultural landscape types and features

Type	Definition	Example	Source
Design Product Cultural Landscape	They are landscapes planned and created by human hands for aesthetic or functional purposes.	Gardens of Versailles, France	(UNESCO, 2021)
Organic Evolving Cultural Landscape	They are landscapes that evolve over time through natural processes and human intervention.	Cinque Terre, Italy	(Mitchell et al., 2009)
Relational Cultural Landscape	They are landscapes that carry spiritual, religious or cultural meaning and have symbolic value rather than physical arrangement.	Uluru-Kata Tjuta, Australia	(Lennon, 2012)

The gardens of the Palace of Versailles (Figure 1) represent one of the most exemplary instances of a deliberately designed cultural landscape. Conceived by André Le Nôtre in the seventeenth century, these gardens serve as a spatial manifestation of the power exerted by the absolute monarchy (Berger, 1985). The geometric order, application of perspective, and incorporation of water features collectively reflect a landscape design philosophy that underscores humanity's dominance over nature (Berger, 1985). This design approach, characterized by its geometric rigor, perspectival techniques, and water elements, embodies a conceptualization of landscape that accentuates human control and authority over the natural environment.

Figure 1. A view from the Versailles garden in France (Url-1, 2025).

The best example of an organically evolving cultural landscape product can be seen in Cinque Terre in the Liguria region of Italy (Figure 2). This is a landscape where five villages established on the coastline over the centuries have evolved together with nature through agricultural terraces and paths. Known for its colorful houses, terraced vineyards and steep cliffs, this region is on the UNESCO World Heritage List (UNESCO, 1997). It is also an example where both economic activities and local lifestyles are embodied in space.

Figure 2. A view of Cinque Terre on the Ligurian coast of Italy (Url-2, 2025).

The most important representation of the Relational Cultural Landscape example can be seen in Uluru-Kata Tjuta National Park located in central Australia (Figure 3). This park has spiritual importance for the Anangu Aboriginal community and is considered sacred. In addition, the landscape here gains meaning through spiritual narratives rather than physical elements. For this reason, Uluru is a strong representation of the relational cultural landscape. This park is included in the UNESCO World Heritage List with both its natural and cultural values (Lennon, 2012).

Figure 3. A view from Uluru-Kata Tjuta National Park in central Australia (Url-3, 2025).

4. LANDSCAPE TODAY

Today, landscape is no longer merely a natural and cultural area with aesthetic value, but has become a multidimensional concept shaped by environmental, social and economic dynamics. In the modern understanding of landscape, the interaction between natural elements and cultural elements has become more pronounced, and landscape has become a reflection of the complex relationships that human societies establish with their environment (Giddens, 1990). In this process, landscape design and management have adopted principles of sustainability from both aesthetic and ecological perspectives, and strategies have been developed to address environmental threats.

Following the First World War and especially the Second World War, the social and cultural importance of landscape increased. Wars led to the destruction of large cities and the loss of natural areas. This destruction reinforced the idea that landscapes needed to be rebuilt and protected (Mitchell, 1996). Cities, in particular, began to be reshaped during this period, and the relationship between humans and the natural environment was redesigned in the face of the destructive effects of war.

The protection of cultural landscapes has also become an important part of the modern understanding of landscape. In 1992, UNESCO defined cultural landscapes, stating that they are not only physical areas but also places that carry social memory and cultural identity (UNESCO, 1992). This definition created global awareness regarding the protection and management of landscapes, and it was accepted that cultural landscapes have value not only in a historical context but also in a contemporary social context.

Environmental sustainability is one of the cornerstones of today's understanding of landscape. Environmental threats such as climate change, pollution, and habitat loss have made it imperative that landscape management and design be carried out with the aim of preserving ecological balance (Swyngedouw, 2004). In this context, concepts such as green infrastructure, ecosystem services, and ecological corridors have come to the fore. Green infrastructure aims to maintain a balance between urbanisation and natural areas, while ecosystem services define nature's contributions to human life.

However, the social function of landscape has also gained increasing importance. The design and management of landscape have become a factor that directly affects the quality of life of people. Landscapes that shape social life, such as public spaces, parks, and green areas, serve not only aesthetic and ecological functions but also social ones (Cresswell, 2004). Such landscapes are shaped according to the needs of society, with concepts such as accessibility, equality, and social participation coming to the fore.

Urbanisation, rapid population growth and the challenges brought about by modern life have led to the rapid destruction of natural areas. In this context, urban landscape management has focused particularly on sustainability and environmentally friendly solutions. Solutions such as increasing urban green spaces, rainwater management and sustainable agricultural practices are important elements of modern landscape design. Making cities greener, healthier, and more sustainable is one of the fundamental goals of contemporary landscape design (Harvey, 2000).

In modern landscape design, it is emphasised that human-nature interaction and environmental factors must be taken into consideration. Landscape is no longer merely an aesthetic element but also a living space. The relationship humans establish with nature does not merely create visible beauty but also plays a critical role in the efficient use of natural resources and the preservation of environmental balances (Lefebvre, 1991). Therefore, sustainability principles are prioritised in landscape design.

The role of technology in landscape design has significantly increased, particularly with innovative tools such as digital mapping, 3D modelling, and geographic information systems (GIS). These technologies enable landscapes to be designed, managed, and protected more effectively. Geographic information systems play a major role in landscape planning and the development of ecological conservation strategies (Tuan, 1991). These digital tools are used to analyse the dynamic structure of the landscape and consider various environmental variables.

With the influence of postmodernism, it has been emphasised that the landscape is not merely a physical environment but also a social and cultural structure. Landscape is an area where individuals and communities construct their identities and imbue them with cultural meanings (Jameson, 1991). This understanding reveals that landscape represents much more than its aesthetic value and plays an important role in the social context.

The diversity of cultural landscapes is increasingly recognised and celebrated today. Different societies and cultures have created their own unique landscapes and protected them. These landscapes carry great significance in terms of social memory, identity, and historical context. Modern landscape management is showing greater sensitivity in recognising and protecting cultural diversity and local identities (Cosgrove, 1984).

In the modern understanding of landscape, the importance of social participation is increasingly emphasised. Landscape design and management are seen as a process in which local people, experts and decision-makers work together. The needs, desires and cultural values of communities are important factors that are taken into account in landscape design. This process ensures the production of more inclusive and sustainable landscape solutions.

Today's understanding of landscape does not focus solely on the physical characteristics of a space, but also on a deep understanding of the relationships between humans and their environment, cultural interactions, and social contexts. This perspective recognises the multidimensional nature of landscape, ensuring that ecological, aesthetic, and social factors are considered together. Today, landscape is a dynamic field shaped by environmental sustainability, the preservation of cultural values, social participation, and technological innovation. Modern landscape design must set aside aesthetic concerns and take into account ecological balance, social equality, and cultural heritage. This understanding aims to redefine the role of landscape in human life and create more sustainable and livable environments.

Today, cultural landscapes are affected not only by social change but also by global environmental threats. Processes such as climate change, loss of biodiversity, natural disasters and urbanisation pose serious threats to the preservation and sustainability of cultural landscapes (IPCC, 2021).

The effects of climate change can be devastating, especially for cultural landscapes in coastal areas (Sezen and Akpınar Külekçi, 2020). Rising sea levels, erosion, and extreme weather events can lead to the destruction of historic settlements (UNESCO, 2017).

Rural landscapes are also seriously affected by climate change. Changing temperature and rainfall patterns threaten traditional agricultural practices and the cultural landscape forms associated with them (FAO, 2016).

In urban areas, rapid population growth and unplanned expansion are causing the fragmentation and loss of identity of cultural landscapes. Traditional neighbourhood structures are transforming or disappearing under the pressure of modern urbanisation (Harvey, 2000).

In contrast, some cultural landscapes are considered to be systems with high ecological resilience and adaptive capacity. Agroecological systems and locally-based knowledge practices offer important models for adapting to climate change (Altieri & Nicholls, 2017).

Contemporary conservation approaches now argue that cultural landscapes should not merely be ‘frozen’ but that their dynamic characteristics and adaptive capacities should be preserved (Taylor & Lennon, 2011). This understanding is based on the idea that cultural landscapes must coexist with change.

5. CONCLUSION AND EVALUATION

Throughout history, cultural landscapes have been meaningful areas that carry social memory, where both natural elements and man-made elements coexist (Akpınar Külekçi et al., 2019). These landscapes have shaped and given meaning to people's relationship with their environment not only on a physical level but also on a cultural and social level. Throughout history, cultural landscapes have evolved in line with the social, political, economic and environmental conditions of different periods and have acquired different meanings over time (Sauer, 1925).

In ancient times, cultural landscapes were often composed of elements that reflected power, authority, and aesthetic sensibilities. The magnificent villas of the Roman Empire and the temples and gardens of ancient Greece are examples of this sensibility. These landscapes not only symbolised the lifestyle of the elite class but also the social order of the time (Cosgrove, 1984). Roman and Greek landscapes did not merely aim to create visual pleasure; they reflected humanity's dominance over nature and the power to maintain order.

In the Middle Ages, cultural landscapes were shaped more around religious and feudal structures. Monastery gardens, feudal castles, and churches symbolised the hierarchical order of the social structure, while agricultural lands were symbols of survival and power (Braudel, 1979). During this period, landscapes established the relationship with nature within a moral and religious framework, defining people's connection with their environment on a spiritual plane.

The Renaissance was an era in which the aesthetic understanding of cultural landscapes was reshaped. The relationship between humans and nature was re-examined through the combination of science and art, and landscapes were designed as symbolic spaces reflecting both the beauty of nature and human domination over it. The landscapes of this period became synonymous with visual harmony and symmetry and were an expression of the aristocratic lifestyle (Mann, 1997).

With the Industrial Revolution, rapid urbanisation and industrialisation greatly transformed cultural landscapes. Urbanisation led to landscapes becoming spaces that no longer encompassed only the natural environment but also urban culture, technology, and industrial power. With the rise of modern cities, human-made environments replaced nature, and cultural landscapes became increasingly associated with urbanisation, social class differences, and industrial development (Harvey, 2000).

In the 20th century, the shift in landscape understanding towards an ecological perspective marked an important turning point in this field. The rise of ecological awareness has reinforced the view that landscape is not only an aesthetic and cultural value but also a means of maintaining ecological balance (Çatalbaş and Kılıç, 2022; Mitchell, 1996). Environmental sustainability has become one of the fundamental principles of modern landscape design. This understanding views landscape not merely as a tool serving humans but as an effort to create a livable environment for all living beings.

Another important stage in the evolution of cultural landscapes was UNESCO's definition of cultural landscapes in 1992 (Çiftçi, 2025). This definition emphasised that landscapes do not only have aesthetic and physical value, but also historical, cultural and social significance (UNESCO, 1992). UNESCO's approach has spread the understanding that cultural landscapes must be protected and managed sustainably on a global scale. The protection of cultural landscapes is not limited to preserving the heritage of the past, but also aims to ensure that these landscapes are preserved in a sustainable manner for future generations.

Today, cultural landscapes face global threats such as globalisation, rapidly increasing population, and climate change. These threats have made the need to reshape and protect landscapes even more urgent (Giddens, 1990; Sezen and Patan, 2015). The conservation of cultural landscapes requires not only the protection of their physical structures but also the preservation of the cultural and social meanings they carry. However, for cultural landscapes to coexist harmoniously with modern life, social participation, the awareness of local communities, and the prioritisation of cultural values are essential (Cresswell, 2004).

Another important factor in the evolution of cultural landscapes today is the increasing use of technology and digital tools. Technologies such as geographic information systems (GIS), 3D modelling, and digital mapping enable landscapes to be analysed and managed more accurately. These technologies make it possible to design landscapes in a balanced manner from ecological, cultural, and social perspectives (Swyngedouw, 2004).

The conservation and management of cultural landscapes is a process aimed not only at preserving the heritage of the past but also at safeguarding future living spaces. This process can be made more effective by evaluating cultural, ecological, and social factors together. In this context, the future evolution of cultural landscapes will be shaped by human societies developing a sensitive, sustainable, and participatory approach to the environment (Harvey, 2000).

The evolution of cultural landscapes is an important concept that reflects the constantly changing dynamics of the relationship between humans and the environment, in light of social structures, cultural values, and environmental interactions. In the future, the preservation of cultural landscapes will mean not only the preservation of the past but also the sustainable preservation of the cultural heritage and social meanings carried by these landscapes (Braudel, 1979).

In conclusion, cultural landscapes have carried different meanings throughout history and have been a reflection of the relationship between societies and their environment. From ancient times to the present day, cultural landscapes have been an important part of human history, showing how people perceive, shape and value nature (Sauer, 1925). These landscapes not only carry aesthetic value but also encompass important social and environmental values such as cultural identity, social memory, and environmental sustainability (Cosgrove, 1984).

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Impacts of Carbon Sinks on Urban Microclimate and Their Role in Combating Climate Change

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1. INTRODUCTION

Climate change, whose impact is increasingly felt on a global scale, stands out as one of the most critical and urgent environmental issues of the 21st century—and likely of the centuries to come. This crisis, manifested through rising temperatures, unexpected sea level increases, extreme weather events, biodiversity loss, and freshwater scarcity, affects not only ecological systems but also a wide array of issues, ranging from human health and economic development to food security and social stability. The multifaceted and interconnected nature of climate change necessitates multidisciplinary and holistic solution strategies.

The primary drivers of climate change include the intensive use of fossil fuels for energy production, unregulated agricultural and industrial expansion, the destruction of natural habitats, and rapid urbanization (Gülgün et al., 2015; Yazici et al., 2017). Greenhouse gases released through anthropogenic activities—particularly fossil fuel combustion, deforestation, and urban sprawl—intensify the greenhouse effect and result in global temperature increases. This situation has made it essential to develop effective and sustainable strategies to combat climate change (Doğan, Doğan, Tüzer, 2021).

Within this context, concepts such as nature-based solutions and ecosystem services have come to the forefront, with carbon sinks being considered strategically vital tools in climate change mitigation. Carbon sinks are natural or managed ecosystems that absorb and store atmospheric carbon dioxide (ÇEM, 2025). In addition to forests, wetlands, marine ecosystems, and agricultural lands, urban green infrastructure elements can also serve this function (Yazici & Gülgün, 2021). Thanks to their plant diversity, biomass capacity, and soil properties, urban green spaces not only help reduce carbon emissions but also improve urban quality of life (Tuğluer & Oğuz, 2022; Nowak, 2025). Especially in densely populated and fast-growing cities, urban green areas are indispensable for sustainable urban planning due to their carbon sequestration potential and contributions to livability.

Landscape architecture plays a pivotal role in the planning, design, and management of these green spaces. Landscape architects are responsible for spatial configurations that enable green infrastructure to function as carbon sinks while making ecological and aesthetic contributions to sustainable urban development. Design strategies such as the selection of high carbon-absorbing plant species, the protection of soil structure, the enhancement of permeable surfaces, and the continuity of green corridors highlight the discipline's central role in climate action. Landscape architecture, through an interdisciplinary approach and with ecological sensitivity and aesthetic integrity, significantly contributes to the creation of environmentally and socially resilient cities.

Figure 1. Congo Basin, known as the world's largest carbon sink (Star Gazetesi, 2022).

Sustainable urban planning requires the comprehensive integration of blue and green infrastructure elements that provide ecological functionality (Pirli et al., 2023).

The functions of urban green areas such as carbon sinks should be analyzed from the perspective of landscape architecture. The potential of urban open green spaces in carbon sequestration should be evaluated; their impact on urban heat island formation and microclimate regulation should be examined; and different types of green spaces should be assessed based on their carbon emission mitigation capacity. Design strategies and implementation examples must be explored to shape a sustainable future. In doing so, the theoretical and practical dimensions of landscape architecture's role in the fight against climate change can be fully revealed.

2. MATERIALS AND METHODS

This study aims to evaluate the carbon sink capacity of urban green spaces within the framework of landscape architecture and to analyze their potential contributions to climate change mitigation. A qualitative research design was adopted, with literature review serving as the primary method. Additionally, comparative analysis and deductive reasoning techniques were employed. The research material consists of academic studies conducted at national and international levels, scientific articles related to urban planning and landscape architecture, climate policy documents, and datasets published by international organizations such as the Intergovernmental Panel on Climate Change (IPCC) and the Food and Agriculture Organization (FAO). Furthermore, in the context of Turkey, selected green areas in major metropolitan cities such as Istanbul, Izmir, and Ankara were examined as case study areas.

The methodological approach is structured around the following three main stages:

- Literature Review: To establish the theoretical framework of the study, international literature on carbon sinks, urban ecosystem services, landscape planning, and climate change was reviewed. Priority was given to peer-reviewed publications published between 2010 and 2024.
- Comparative Analysis: Data on the carbon sequestration capacities of urban green spaces in different countries and cities were comparatively analyzed. In this analysis, various types of green spaces—such as parks, urban forests, and groves—were examined, with a focus on their carbon storage potential.
- Evaluation from a Landscape Architecture Perspective: The findings were interpreted through the lens of landscape architecture. They were assessed in relation to green infrastructure planning, planting design, and sustainable urban development. This approach enabled the consideration of carbon sinks not only from an ecological standpoint but also within spatial and design-oriented contexts.

In line with this methodological framework, the extent to which the carbon sink functions of urban green spaces can be used in combating climate change and the role of landscape architecture in this process have been revealed in a multifaceted way. The evaluations obtained as a result of the study aim to provide a scientific basis for developing recommendations for urban planning and green infrastructure strategies. In addition, the study flow diagram is shown in Table 1.

Table 1. Flowchart of the study

CARBON SINKS AND ECOSYSTEM SERVICES	URBAN GREEN SPACES AND CARBON ABSORPTION CAPACITIES, DESIGN APPROACHES IN LANDSCAPE ARCHITECTURE	REINFORCING THE ROLE OF URBAN GREEN SPACES IN COMBATING CLIMATE CHANGE

2. FINDINGS

2.1. Carbon Sinks and Ecosystem Services

Climate change is one of the most complex and multidimensional environmental challenges of the 21st century. This global issue is not limited to rising atmospheric temperatures; it also entails a series of adverse consequences such as drought, the depletion of water resources, sea level rise, increased frequency of extreme weather events, ecosystem imbalances, and biodiversity loss. In this context, controlling the accumulation of greenhouse gases in the atmosphere—particularly by reducing carbon dioxide (CO_2) emissions—has become a top priority in climate change mitigation. However, it is not sufficient to merely reduce carbon emissions; it is also necessary to remove existing carbon dioxide from the atmosphere and store it safely. At this point, carbon sinks emerge as vital components of natural infrastructure, playing a strategically important role in the management of the climate crisis (Doğan, Doğan, & Tüzer, 2021).

Carbon sinks are ecological systems that capture atmospheric carbon dioxide and store it through a variety of natural processes. These systems help mitigate global warming by reducing the concentration of greenhouse gases in the atmosphere, while also generating multiple environmental, economic, and social benefits through the ecosystem services they provide. The services offered by carbon sinks include key functions such as improving air quality, regulating the water cycle, enhancing soil fertility, supporting biodiversity, and protecting natural habitats (Doğan, Doğan, & Tüzer, 2021).

In today's world—where urbanization is intensifying and the majority of the population now lives in cities, the need to plan and implement carbon sinks not only in rural areas or forest ecosystems but also within urban environments has become increasingly evident. Cities are among the primary sources of carbon emissions due to their high energy consumption and the extensive presence of impervious surfaces.Therefore, green spaces created in urban landscapes—such as urban forests, green roofs, vertical gardens, and green corridors—can function as artificial or semi-natural carbon sinks, playing a vital role in the development of climate-resilient cities (Tuğluer & Oğuz, 2022).

Viewing carbon sinks not merely as biophysical processes but also as infrastructural components that provide ecosystem services necessitates the restructuring of environmental policies. In this context, the classification of carbon sinks, the analysis of their functions, their spatial integration into the urban fabric, and their sustainable management require interdisciplinary collaboration—particularly involving the field of landscape architecture—as an essential strategy in combating climate change.

2.1.1. Classification of natural and artificial carbon sinks

Carbon sinks are functionally categorized into two main types: natural and artificial carbon sinks.

a) Natural carbon sinks refer to systems that form autonomously within ecosystem dynamics and are capable of storing carbon through biological or geochemical processes. This category includes forests, grasslands and meadows, wetlands, marine ecosystems, oceans, and particularly soil systems rich in organic matter. The defining characteristic of these systems is their ability to absorb atmospheric carbon dioxide through photosynthesis and store it long-term in plant biomass (e.g., stems, branches, leaves, roots) as well as in the organic components of the soil (Figure 2).

Forest ecosystems, in particular, are among the most significant natural sinks on Earth in terms of carbon storage capacity, playing a vital role in regulating the global climate system. Oceans, on the other hand, function as important biogeochemical sinks, capable of absorbing nearly one-quarter of atmospheric CO_2. They store carbon both biologically—via surface plankton—and chemically—through dissolved carbonate compounds.

If we briefly list forests and other natural carbon sink areas (Portillo, 2025):

- **Forests and terrestrial vegetation**: Forests and terrestrial vegetation are among the most significant natural carbon sinks, primarily through the process of photosynthesis, by which trees and plants absorb atmospheric carbon dioxide (CO_2). Tropical, boreal, and temperate forests constitute major terrestrial reservoirs in the global carbon cycle. The carbon sequestration capacity of these ecosystems is strongly influenced by their size, health, and biodiversity. In general, the larger and more ecologically intact a forest is, the greater its potential to capture and store carbon over the long term.
- **Seas and oceans:** Seas and oceans function as major biogeochemical carbon sinks, absorbing approximately 25% of the carbon dioxide (CO_2) emitted annually through anthropogenic activities. This significant capacity is facilitated by both physical and biological processes within marine systems. One of the key biological mechanisms is photosynthesis carried out by phytoplankton—microscopic marine algae that drift near the ocean's surface. Through this process,

phytoplankton capture CO_2 and contribute substantially to the biological carbon pump, which transports carbon from the atmosphere into deep ocean layers, where it can be stored for centuries.

- **Soils:** Soils act as substantial carbon reservoirs by storing organic carbon through natural biological, chemical, and physical processes. A significant portion of this carbon is retained in the form of soil organic matter (SOM), which plays a critical role in long-term carbon sequestration.
- **Wetlands and grasslands:** Ecosystems such as wetlands, peatlands, and grasslands are particularly effective soil-based carbon sinks due to their high productivity and slow decomposition rates—provided they remain undisturbed and ecologically intact. The disturbance or degradation of these ecosystems (e.g., through drainage, tilling, or land-use change) can lead to the release of stored carbon back into the atmosphere, turning them from sinks into sources.

Wetlands also serve as distinctive carbon sinks due to their high biomass productivity and low decomposition rates, allowing them to store carbon for extended periods, especially in the form of peat (Wu, Zhao, & Gan, 2023).

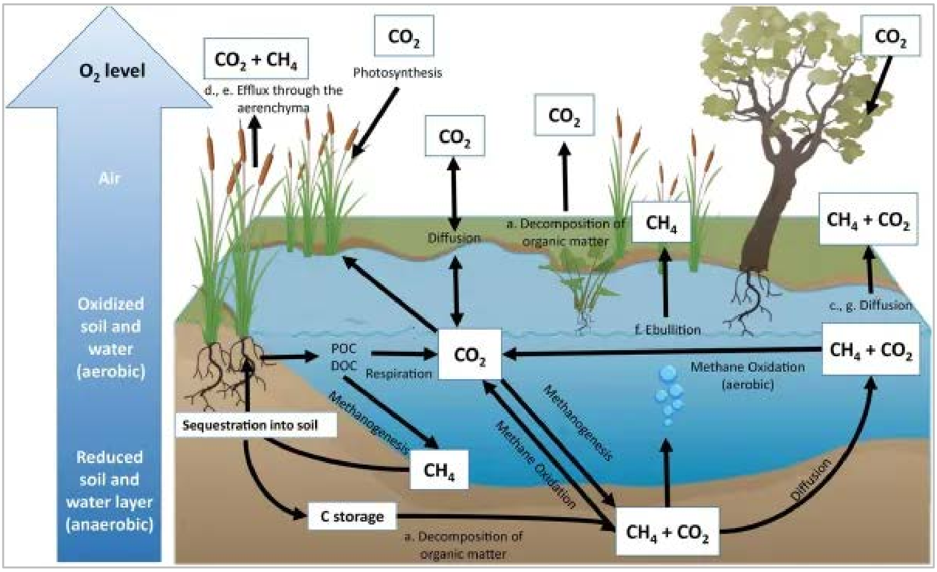

Figure 2. What is a carbon sink used for (Portillo, 2025).

b) Artificial carbon sinks refer to systems that are designed, constructed, or modified through human intervention. These sinks typically emerge in urbanized areas or regions subject to intensive human activity and play a supportive role in carbon absorption and storage where natural systems are insufficient.

Within this scope, examples of artificial carbon sinks include urban parks, green roofs, vertical gardens, urban forests, green corridors, green infrastructure implementations, and technological solutions such as biochar application. These systems store carbon either through biomass-based absorption (e.g., urban afforestation) or via physical and chemical transformation processes (e.g., carbon stabilization through biochar) (Çetinkaya & Akar, 2022).

The implementation of such systems contributes to urban carbon management strategies and enhances the resilience of cities to climate change, particularly by integrating ecological functions into the built environment. Turkey's greenhouse gas emissions from 1959 to 2020 are illustrated in Figure 3.

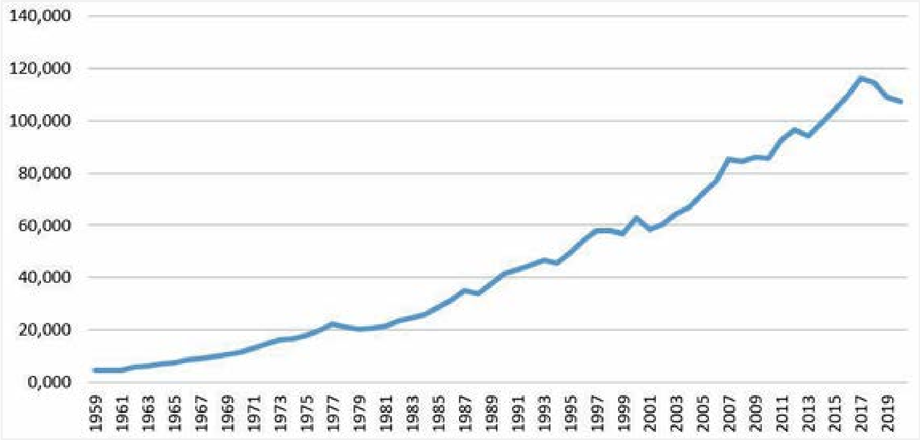

Figure 3. Greenhouse Gas Emissions in Turkey between 1959 and 2020 (Çetinkaya ve Akar, 2022).

The effectiveness of artificial carbon sinks depends not only on their physical construction but also on the integrated management of several key factors, including appropriate planning approaches, sustainable landscape design, selection of plant species suited to local climatic conditions, preservation of soil health, efficient irrigation strategies, and regular maintenance. The integration of these components enables artificial sinks to generate not only environmental benefits but also functional, aesthetic, and social value.

At this point, the discipline of landscape architecture plays a critical role both in enhancing the ecological functionality of such systems and in developing and implementing urban-scale sustainable carbon management policies. Landscape architects contribute by designing green infrastructure components informed by nature-based solutions, facilitating the integration of high carbon-sequestration systems into the urban fabric (Tuğluer & Oğuz, 2022).

This approach aims not only to offset carbon emissions but also to enhance ecological, social, and aesthetic values in urban life.

In conclusion, the complementary functions of natural and artificial carbon sinks necessitate the development of multi-layered and holistic strategies in the fight against climate change. To formulate effective strategies, carbon sinks must be regarded not merely as technical or physical structures but as ecological infrastructure components with social, environmental, and economic implications (Doğan, Doğan, & Tüzer, 2021).

This multidimensional perspective provides a sustainability-oriented roadmap for the creation of climate-resilient cities.

In this context, urban green spaces serve not only as carbon sinks but also play a vital role in regulating the urban microclimate. Vegetation contributes to localized cooling by increasing atmospheric humidity through evapotranspiration, while broad-leaved trees provide shading, thereby reducing surface temperatures and significantly mitigating the urban heat island (UHI) effect (Tuğluer & Oğuz, 2022; Kentlerin Karbon Yutakları, 2023).

Especially in city centers dominated by impermeable surfaces and dense construction, green areas can reduce ambient temperatures by several degrees in summer, thereby lowering energy consumption and reducing carbon emissions indirectly. Furthermore, green spaces with permeable soils reduce surface runoff by facilitating natural groundwater recharge, thereby preventing microclimatic disturbances such as flash flooding and sudden heat accumulation (Doğan, Doğan, & Tüzer, 2021).

In this regard, urban green spaces contribute to climate change mitigation both directly through their carbon storage capacity and indirectly by reducing UHI effects. As integral components of the urban landscape, they also enhance the resilience of urban ecosystems and positively impact public health. Therefore, the design of urban green spaces should consider not only their aesthetic and recreational functions but also their carbon sequestration potential, microclimate regulation capacity, and roles in climate adaptation. This comprehensive perspective further underscores the strategic position of landscape architecture within sustainable urban policy frameworks.

2.1.2. Ecosystem services provided by urban green spaces

Urban green spaces are among the key ecological components that support the sustainability of modern cities. Their contribution to urban life goes beyond aesthetic or recreational values; they directly enhance urban quality of life through the multifunctional ecosystem services they provide.

The concept of ecosystem services encompasses the full range of benefits that nature offers to human well-being and is typically classified into four main categories: supporting, regulating, cultural, and provisioning services. In this context, urban green spaces, by virtue of their natural characteristics and functional potentials, are capable of delivering services across all four categories to varying extents. The ecosystem services provided by urban green spaces are (Çoban & Yücel, 2018):

- From the perspective of regulating services, urban green spaces play a vital role in balancing urban microclimates, improving air quality, and reducing carbon emissions. Through photosynthesis, trees and vegetation act as carbon sinks by absorbing atmospheric CO_2. At the same time, they help filter out dust, harmful gases, and airborne pollutants, thereby contributing to urban air purification. These functions not only support climate change mitigation but also provide important public health benefits. Moreover, green spaces help manage stormwater by slowing surface runoff, reducing flood risks, and supporting groundwater recharge. Their capacity to reduce the urban heat island (UHI) effect also helps balance energy consumption by decreasing the need for artificial cooling, especially during hot seasons.

- In terms of supporting services, urban green spaces play a crucial role in maintaining biodiversity and ecological continuity within the urban matrix. They provide habitats for birds, insects, small mammals, and various plant species, thereby preserving ecological networks. Urban green corridors help prevent habitat fragmentation and safeguard migration routes for many species. In addition, fundamental ecosystem processes such as soil formation, organic matter cycling, and nutrient recycling are sustained through these areas, contributing to long-term ecological resilience.
- With respect to cultural services, urban green spaces offer environments that facilitate human-nature interaction, strengthen social connectivity, and enhance physical and mental well-being. Parks, gardens, urban groves, and urban agriculture spaces serve diverse cultural functions such as social inclusion, outdoor recreation, aesthetic experience, and environmental education. These spaces act as a counterbalance to the pace of urban life, helping reduce stress levels and fostering environmental awareness and nature stewardship among urban residents.
- Regarding provisioning services, urban green spaces particularly stand out through urban agriculture practices. Activities such as local fruit and vegetable production, beekeeping, and plant cultivation contribute to urban food security while allowing city dwellers to develop more productive and meaningful relationships with nature (Çoban & Yücel, 2018).

When all these functions are evaluated collectively, it becomes evident that urban green spaces are not merely decorative or recreational landscape elements. Rather, they are living infrastructure components that deliver a wide range of ecological services. Therefore, in the context of climate change mitigation, enhancing urban quality of life, and strengthening social cohesion, the planned and sustainable design of these spaces must be considered a strategic priority—particularly for the discipline of landscape architecture, as well as for all sectors involved in urban development.

2.1.3. Carbon storage potential through soil, vegetation, and trees

One of the key factors determining the effectiveness of carbon sinks is the nature of the biophysical environments in which carbon is directly stored. In this context, soil, vegetation, and trees play a critical role in capturing atmospheric carbon dioxide (CO_2) and storing it within ecosystems over the long term. These three components operate both independently and interdependently, forming integrated carbon storage systems that collectively define the carbon balancing capacity of ecosystems (Çetinkaya & Akar, 2022).

Soil is considered one of the largest terrestrial carbon reservoirs on Earth. The entry of organic carbon into soil is primarily facilitated by plant residues, root systems, microbial activity, and the formation of humus. These processes lead to the creation of Soil Organic Matter (SOM), which enables the long-term stabilization of carbon—sometimes for thousands of years—within the deeper soil layers.

In urban soils, despite intense structural pressures, appropriate landscape design interventions can increase organic matter content and thereby enhance the soil carbon stock. However, the compacted, impermeable, and contaminated nature of many urban soils often limits the full realization of this potential. Therefore, the carbon storage function of soils should be supported not only through natural processes but also through landscape architectural practices and ecological planning strategies (Wu, Zhao, & Gan, 2023).

Vegetation plays a crucial role in carbon sequestration by absorbing atmospheric carbon dioxide (CO_2) through the process of photosynthesis. Carbon is stored both within the plant biomass and through organic matter transferred into the soil. Despite their short life cycles, herbaceous and shrub species contribute dynamically to the carbon cycle due to their rapid growth rates. Increasing plant diversity in green spaces, incorporating evergreen species, and selecting plants with deep and extensive root systems are key strategies for enhancing carbon storage capacity. Furthermore, the continuous renewal of vegetation and the sustainable maintenance of biomass productivity help delay carbon release, thereby improving the overall efficiency and resilience of the system (Gül, Tuğluer, & Akkuş, 2021).

Trees are among the most effective vegetative elements in terms of carbon storage potential. Due to their ability to store carbon over the long term—particularly in their trunks, branches, and root systems, they are considered foundational components of terrestrial carbon sinks.Broad-leaved species, fast-growing trees, and long-lived taxa possess particularly high potential for carbon sequestration. Additionally, trees provide regulating ecosystem services by influencing the urban microclimate through shading and evapotranspiration, which indirectly contribute to reducing carbon emissions. In urban afforestation projects, factors such as species selection, planting density, maintenance strategies, and tree health management are critical planning decisions that directly impact the carbon sink capacity of green infrastructure. Soil, vegetation, and trees are not only vital biotic components of ecosystems but also serve as nature-based solutions for capturing and regulating atmospheric carbon. The synergistic and integrated functioning of these elements maximizes the carbon balancing potential of landscapes. Therefore, urban landscape planning should adopt approaches that prioritize carbon storage potential, particularly by encouraging soil restoration, the use of native plant species, and sustainable afforestation practices. These strategies form the foundation of nature-based solutions that enhance urban resilience in the face of climate change (Gül, Tuğluer, & Akkuş, 2021).

2.2. Types of Urban Green Spaces and Their Carbon Sequestration Capacities

Urban activities and industrial zones located in the peripheries of cities generate significant amounts of waste and gaseous emissions, which exacerbate the urban heat island (UHI) effect and, consequently, intensify the greenhouse effects contributing to the acceleration of the global climate crisis. On the other hand, even in limited quantities, urban green spaces play a leading role among the elements that allow cities to "breathe" by mitigating these adverse impacts. Their cooling effects, capacity to absorb pollutants, and role in enhancing urban ventilation make them indispensable in climate adaptation strategies (Figure 4).

Providing green and recreational spaces for urban residents is essential for improving the overall quality of life in cities. In this regard, urban parks play a significant role as key components that enhance urban livability, offering both physical and psychological benefits within the dense fabric of the built environment (Yazıcı & Gülgün, 2017).

Figure 4. Greenhouse gases, the intensifying greenhouse effect, and global climate change (Türkeş,2025).

Urban green spaces are classified into different types based on their physical characteristics, size, vegetation composition, and spatial location—each type exhibiting varying capacities for carbon sequestration. These spaces serve as essential components of urban infrastructure, not only in terms of environmental sustainability but also in balancing carbon emissions within the broader context of climate change mitigation.

Among these, urban parks are one of the most common green space types at the city scale. Due to the presence of diverse vegetation and multiple tree species, they possess high carbon storage potential. Large-scale urban parks, with their dense plant cover and extensive soil surface, function as effective carbon sinks. In sustainable park design, the use of native and long-lived tree species is among the primary strategies that significantly enhance the carbon sequestration capacity of these areas (Wu, Zhao, & Gan, 2023).

Urban forests are green spaces characterized by a more natural structure, dense vegetation, and semi-wild ecosystem features. Due to their extensive surface coverage and rich tree canopy, they are highly effective in storing carbon both in biomass and in the soil.In addition to their carbon storage function, urban forests play a strategic role in urban carbon management by supporting habitat connectivity, enhancing biodiversity, and improving ecosystem resilience. (Wu, Zhao, & Gan, 2023).

Green roofs and vertical gardens are artificial green systems created by planting horizontal and vertical surfaces within the built environment. These structures offer important opportunities for maximizing carbon absorption potential, even in space-constrained urban areas. Particularly, extensive green roofs not only contribute to reducing carbon emissions but also mitigate the urban heat island (UHI) effect on building surfaces—thereby indirectly lowering energy consumption. In addition to their aesthetic value, vertical gardens improve air quality and have a positive impact on the environmental microclimate surrounding built structures (Wu, Zhao, Gan vd. 2023).

Roadside tree plantings create carbon-absorbing corridors along urban transportation networks, contributing significantly to the improvement of air quality within cities. These trees serve a filtering function in areas with high exhaust gas emissions by absorbing atmospheric carbon dioxide (CO_2) and by reducing both air and noise pollution.

In addition to their environmental benefits, roadside green elements also enhance urban aesthetics and support wayfinding functions, making them a multifunctional component of urban landscape design (Gül, Tuğluer, & Akkuş, 2021).

Other forms of green infrastructure, such as urban agriculture areas, cemeteries, school gardens, university campuses, and green corridors, also hold significant potential for carbon sequestration. These spaces not only generate vital ecosystem services but also serve multiple social, cultural, and economic functions, thereby contributing to holistic sustainability goals. Each type of urban green space offers context-specific advantages in terms of carbon retention capacity. Therefore, considering this diversity in landscape planning processes constitutes a fundamental step toward making cities more resilient to the climate crisis (Wu, Zhao, Gan et al., 2023).

2.3. Strategic Design Approaches in Landscape Architecture

The discipline of landscape architecture offers a multidimensional design approach that extends beyond mere aesthetic arrangements, focusing instead on environmental sustainability, ecological balance, and climate resilience. In this context, strategic design approaches developed to strengthen the role of carbon sinks within urban settings and to support natural processes directly enhance the environmental impact of landscape architectural practices.

Nature-Based Solutions provide both economically and ecologically sustainable strategies for addressing climate change. This approach supports the design of green spaces with high carbon storage capacity by mimicking and reinforcing the functioning of natural systems. Key elements of this strategy include the expansion of water retention areas, the increase of permeable surfaces, and the conservation of biodiversity. Moreover, sustainable plant selection and the use of native species represent another critical strategy for enhancing the effectiveness of carbon sinks. Native plants, being well-adapted to local climatic and edaphic conditions, require less maintenance, are longer-lived, and possess higher potential for carbon storage. Additionally, their use contributes to reinforcing the resilience of urban ecosystems and establishing a more robust foundation for climate adaptation (Kaçmaz, 2021).

Establishing urban ecological connectivity represents another strategic approach in landscape architecture that supports carbon management. Ecological networks such as green corridors, inter-park linkages, and wildlife crossings not only facilitate species mobility but also ensure the continuity of carbon sinks by integrating fragmented green spaces into a cohesive system. Soil management and rehabilitation constitute one of the most fundamental practices for long-term carbon sequestration. In landscape design, the adoption of practices that prevent soil compaction, increase organic matter content, and support ecological vitality contribute both to improved plant health and to the stabilization of soil carbon. Within this framework, technical methods such as biofiltration systems, compost application, and water management strategies integrated with green infrastructure are gaining importance, offering multi-functional solutions that enhance ecosystem services while reinforcing carbon storage potential (Çetinkaya & Akar, 2022).

Within the scope of carbon-neutral design principles, the entire cycle—from material selection to maintenance practices—is aimed to be executed with a minimal carbon footprint. In this context, the use of recyclable materials, the preference for energy-efficient design solutions, and the integration of transportation networks with green infrastructure emerge as key strategic approaches to reducing environmental impact.

Strategic design approaches developed within the field of landscape architecture not only enhance the potential of carbon sinks but also contribute significantly to increasing urban resilience to the climate crisis. These approaches support the creation of sustainable environments by integrating ecological, functional, and climatic goals into the design process. Therefore, every landscape intervention—regardless of scale—must be addressed through a holistic framework that extends beyond aesthetics to include environmental sustainability and climate adaptation objectives.

3. DISCUSSION AND CONCLUSION

This study has comprehensively examined the carbon sink capacity of urban green spaces from a landscape architecture perspective and has revealed, based on the findings, that these spaces play a vital role in combating climate change. As emphasized in the literature, the carbon storage potential of urban green areas is influenced by multiple factors, including plant composition, site size, soil characteristics, climatic conditions, and maintenance practices. Notably, this research highlights the decisive impact of plant species diversity and landscape design on carbon sequestration capacity.

Data and results obtained from the literature review support the argument that landscape design contributes not only aesthetic and social functions but also plays a critical role in the carbon cycle. The spatial organization, biodiversity, and sustainable management of planned green areas in urban environments emerge as key parameters for enhancing carbon sink capacity. Accordingly, landscape architects are expected to develop and implement design strategies that maximize this capacity.

Additionally, the differences observed among various types of green spaces in terms of their carbon storage capacity clearly demonstrate the direct impact of design and management decisions on ecosystem services. For instance, areas dominated by broad-leaved trees significantly differ from those covered with groundcover plants in terms of carbon sequestration. This finding underscores the importance of preserving and enhancing biodiversity in green space design to increase carbon sink potential (Çetinkaya & Akar, 2022).

Enhancing the carbon sink capacity of urban green spaces is not merely an ecological necessity for mitigating the negative impacts of climate change, but also offers social and economic benefits. Beyond carbon storage, green spaces provide multiple ecosystem services, including improved air quality, reduced urban heat island effects, support for biodiversity, and public health enhancement. These multidimensional benefits highlight the importance of integrating landscape architecture and urban planning into broader climate policy frameworks.

Nevertheless, challenges and limitations related to increasing the carbon sink function of urban green areas must be addressed. Rapid urbanization, land-use changes, and inadequate maintenance can reduce the effectiveness of green spaces. Furthermore, accurate and reliable measurement of carbon storage capacity requires advanced technology and long-term field monitoring. In this context, multidisciplinary approaches and technology-assisted monitoring systems are crucial (Doğan, Doğan & Tüzer, 2021).

In conclusion, this study emphasizes the crucial role of urban green spaces in the fight against climate change and highlights the contribution of landscape architecture discipline to this process. Considering carbon sink potential in the design, management, and planning of green areas serves as an effective strategy to enhance urban environmental sustainability. Future research should focus on a more detailed assessment of the carbon storage potential of urban green spaces and the development of innovative methods to enhance it. Furthermore, it is essential for policymakers to create incentive mechanisms for the conservation and development of urban green infrastructure and to align these efforts with sustainable urbanization strategies as part of climate action plans. Landscape architects should play an active role in this process by revising their design principles to enhance carbon sink functionality. Thus, urban green spaces will not only serve as essential public environments but will also function as critical defense mechanisms against climate change.

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Green Infrastructure Approaches for Sustainable Tourism: The Case of Tortum Waterfall

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1. INTRODUCTION

Located in the Uzundere district of Erzurum province in northeastern Türkiye, Tortum Waterfall stands as one of the highest and most impressive waterfalls not only in the country but also in Europe. Cascading from a height of approximately 48 metres along a natural rock fissure, this water mass draws attention not only for its hydro geomorphological formation but also for its location within the rural landscape fabric. Situated at the southern end of Lake Tortum, the waterfall constitutes the epicenter of nature tourism in the region due to its aesthetic impact and biophysical character. However, such uniqueness simultaneously brings significant planning and conservation responsibilities. In recent years, the increasing number of tourists, associated infrastructure demands, and construction pressures have posed a growing threat to the natural landscape values of Tortum Waterfall (Irmak and Yılmaz, 2010; Yılmaz et al. 2010; Göktuğ et al. 2013; Demir et al. 2014. Sezen et al. 2015; Davardoust and Karahan, 2021; Özgeriş et al. 2024a; Özgeriş et al. 2025b)

At the global level, the rising quest for sustainability has highlighted the importance of green infrastructure approaches in managing tourism within rural landscapes. The integration of multiple objectives—such as conserving natural areas, balancing tourism impacts, and enhancing local community well-being—requires holistic and nature-based solutions beyond conventional zoning approaches (IUCN, 2020; EPRS, 2023). In this context, tourism policies to be implemented in rural-natural attractions such as Tortum Waterfall are expected to serve not only economic development but also ecological balance, disaster risk management, and the sustainability of cultural landscape values (Özgeriş et al. 2024a).

In recent years, international organizations such as UNESCO, UNWTO, and IUCN have identified the concept of green infrastructure as a key instrument for the development of sustainable tourism (IUCN, 2020; BMUV, 2024). Green infrastructure encompasses not only the conservation of natural elements but also multifaceted benefits such as maintaining ecosystem services, reducing natural disaster risks, ensuring climate adaptation, and strengthening spatial resilience. Green infrastructure networks developed in integration with landscape planning provide a framework for planning ecotourism destinations that is not only aesthetically pleasing but also functionally and environmentally sustainable (Austin, 2014; Monteiro et al. 2020; Wang et al. 2021).

The objective of this book chapter is to discuss the conceptual framework of a green infrastructure approach aligned with sustainable tourism goals, using Tortum Waterfall as a case study, and to elucidate how planning strategies can be structured within this context for rural areas. The chapter will first define the natural and cultural landscape character of Tortum Waterfall, followed by an analysis of the tourism pressures, existing infrastructural challenges, and the level of vulnerability to natural hazards in the region. Subsequently, green infrastructure strategies that can be proposed in line with nature-based solutions, resilience principles, and local development objectives will be systematically presented.

This study aims to provide a framework that can serve not only at the local level but also as a model for other rural-natural tourism destinations with similar characteristics. Increasing visitor density in rural landscapes often threatens fragile ecosystems, leading to unplanned constructions, the exceeding of carrying capacities, and the disruption of landscape integrity. In this regard, there is a need for multi-scalar, nature-based, and holistic planning approaches that take into account not only the economic but also the ecological and social dimensions of sustainable tourism.

Tortum Waterfall is considered a pilot site where such approaches can be tested and refined due to its physical thresholds and regional development potential. Therefore, in the subsequent sections of this chapter, the definition of green infrastructure, its relationship with rural landscapes, its integration with nature-based solutions, and its articulation within the framework of landscape ecology and resilience principles will be examined. Additionally, its compatibility with Türkiye's legislation, planning instruments, and institutional capacities will be assessed.

2. GREEN INFRASTRUCTURE AND SUSTAINABLE TOURISM

The concept of green infrastructure (GI) was institutionalized as a policy instrument with the European Commission's 2013 communication entitled "*Green Infrastructure – Enhancing Europe's Natural Capital*". This approach offers a planning framework that integrates nature-based solutions with multifunctional interventions that strengthen ecological connectivity (European Commission, 2013). Green infrastructure not only serves the conservation of natural assets but also generates multifaceted public benefits, including climate change adaptation, disaster risk reduction, and the enhancement of societal well-being (Sturiale and Scuderi, 2019).

In this context, the Green Infrastructure Planning Manual published under the Magic Landscapes Project provides a comprehensive guide for identifying, operationalizing, and integrating green infrastructure networks into governance processes, particularly within rural landscapes. The manual recommends a holistic evaluation of ecologically critical structures such as nature conservation areas, agricultural lands, waterways, and forests in conjunction with local community needs and sustainable development objectives (Magic Landscapes, 2019). In this way, ecosystem services provided by natural systems are integrated into spatial planning, thereby enhancing ecosystem resilience and reducing disaster risks.

Rural areas, in particular, have become implementation arenas for green infrastructure strategies due to the interplay of issues such as development pressures, climate change-induced threats, and tourism growth. In natural areas like Tortum Waterfall, which are biophysically fragile yet possess high touristic potential, a green infrastructure approach grounded in nature-based planning principles stands out as one of the most effective tools to balance conservation and utilization. Thus, a strategic framework emerges that can serve not only environmental sustainability but also the objectives of economic vitality and social cohesion.

The concept of sustainable tourism is defined as a development model that considers the needs of both the present and the future across its environmental, social, and economic dimensions. According to the United Nations World Tourism Organization (UNWTO, 2017), sustainable tourism is a holistic process that simultaneously addresses the needs of visitors, the industry, the environment, and host communities. Within this framework, three core principles emerge: environmental integrity, socio-cultural authenticity, and economic sustainability. Environmental integrity entails the long-term conservation of natural resources and the maintenance of ecosystem health; socio-cultural authenticity pertains to the preservation of local cultures, community participation in decision-making, and the promotion of cultural diversity. Economic sustainability aims to support local economies, ensure equitable income distribution, and increase employment opportunities.

These principles directly align with targets such as SDG 8.9 (supporting local culture and products through tourism) and SDG 12.b (developing sustainable tourism policies) within the United Nations 2030 Sustainable Development Goals. Tools such as the European Tourism Indicator System (ETIS), developed by the European Commission, enable the monitoring and evaluation of sustainable tourism policies based on measurable criteria. In this regard, sustainable tourism and green infrastructure strategies are not merely complementary approaches but constitute two fundamental frameworks that must be conceptualized in an integrated manner (Artmann et al. 2019).

Nature-based tourism types constitute a significant subset of sustainable tourism. Within this scope, ecotourism emerges as a form of travel that directly engages with nature, predominantly targeting protected areas, and is oriented towards education and experiential learning (Walter, 2013). Rural tourism, on the other hand, revolves around agricultural production, local lifestyles, and traditional cultural practices, offering visitors authentic experiences (Bessière, 1998). Adventure or "*soft nature*" tourism encompasses low-carbon activities such as hiking, cycling, and birdwatching (Di Ruocco et al. 2020). The applicability of these tourism types is directly related to the site's topographic structure, ecological sensitivity, visitor profile, and existing infrastructural capacity (Boers and Cottrell, 2007). Indeed, unplanned and uncontrolled tourism practices within fragile ecosystems can lead to irreversible environmental degradation by damaging natural habitats, disrupting landscape integrity, and exceeding carrying capacities (Buckley, 2000).

Therefore, in rural areas where nature-based tourism types are to be implemented, it is of critical importance to integrate spatial planning processes with green infrastructure strategies. GI systems, structured according to the area's conservation status, ecosystem services, and disaster risk profile, facilitate both the guidance of visitors and the preservation of natural processes. The Tortum Waterfall case offers an area where subtypes of nature-based tourism such as ecotourism, adventure tourism, and rural experiential tourism can be implemented collectively. However, managing this potential in a sustainable manner is only possible through an integrated, nature-based, and multifunctional green infrastructure planning approach.

3. GREEN INFRASTRUCTURE APPROACH IN THE CONTEXT OF LANDSCAPE PLANNING AND NATURAL DISASTER RISK

Within landscape planning theory, the concept of "*multifunctionality*" refers to the capacity of an area to simultaneously generate ecosystem services, socio-cultural values, and economic benefits. This holistic approach facilitates the integration of not only environmental and spatial potentials but also risk reduction and resilience objectives into landscape design processes. Recent studies have demonstrated that such functionality can play a protective role particularly against natural disaster hazards. For instance, designing components such as permeable surfaces, agricultural lands, recreational areas, and habitat corridors within the same green network not only enhances landscape quality but also mitigates flood impacts, thereby creating a resilient foundation in urban or rural risk zones (Bai et al. 2018; Zhang et al. 2019; Yacamán Ochoa et al. 2020; Far et al. 2024).

Studies conducted specifically in the Tortum Valley reveal that this multifunctional landscape structure simultaneously carries a significant potential for risk generation. Visual landscape quality analyses by Bulut et al. (2010) have shown that the region's hydro geomorphological diversity needs to be considered not only in terms of visual appeal but also in relation to disaster risk. Similarly, spatial analyses included in the Uzundere Tourism Master Plan prepared by Karahan and Çakır (2011) identified overlaps between active landslide areas and recreational use zones, recommending risk-sensitive site selection in these areas. These findings align with the disaster-sensitive settlement policies emphasized in Türkiye's Twelfth Development Plan (T.C. Cumhurbaşkanlığı Strateji ve Bütçe Başkanlığı, 2023).

At this juncture, green infrastructure mitigates disaster risks such as floods, landslides, droughts, and heatwaves through both natural and hybrid structures, while simultaneously generating ecosystem services such as recreational use and ecological integrity. According to the design guidelines of the United States Environmental Protection Agency (EPA, 2024), permeable green surfaces have the potential to suppress peak surface runoff from sudden rainfall events by up to 30%. Comparative studies conducted by Onuma and Tsuge (2018) have revealed that green and blue infrastructure applications manage flood risks and enhance resilience at lower life-cycle costs compared to conventional "*grey*" infrastructure solutions.

Within the context of Türkiye, Kopar and Çakır (2013), in their geodiversity analysis conducted around Lake Tortum, reported that the "*karstic balcony*" morphology surrounding the waterfall facilitates the gradual distribution of water through natural terraces, thereby reducing potential hazards such as rockfalls. In the Uzundere Biodiversity Strategy prepared by Karahan et al. (2017), these natural buffer zones were defined as "*risk-absorbing nodes*" within the green infrastructure network, and the strengthening of their conservation status was recommended.

To enable a more systematic management of disaster risks within tourism destinations, international organisations have also proposed strategic approaches. UN Tourism (formerly UNWTO), under its Crisis and Resilience Initiative, has developed the Risk-Sensitive Tourism Planning (RSTP) model. This model provides a planning framework that integrates hazard-focused land use decisions, early warning and evacuation systems, visitor management based on carrying capacity, and financial instruments supporting post-disaster recovery (UNWTO, 2017).

Field studies conducted around Tortum Waterfall indicate the concrete necessity of such planning frameworks. Davardoust and Karahan (2021) observed that in areas of increased visitor density around the waterfall, hydrogeological risks were inadequately communicated, and hiking trails intersected active landslide zones. In the same year, a recreational value analysis by Özgeriş and Karahan (2021) revealed that scenarios incorporating disaster risk information resulted in an 18% increase in visitor satisfaction. This finding demonstrates that risk communication plays a critical role not only in ensuring safety but also in enhancing the perceived quality of the destination.

In light of all these findings, a risk management approach based on green infrastructure should be considered an integral component of sustainable tourism policies in geologically fragile yet tourism-rich areas such as Tortum Waterfall. This integrated approach should be implemented across three key levels: (i) integrating green infrastructure elements into spatial planning to function as disaster buffers, (ii) developing carrying capacity frameworks and early warning systems in accordance with the RSTP model, and (iii) strengthening community-based participation mechanisms within local development strategies

(KUDAKA, 2011). In this way, the multifunctional potential of the landscape can be mobilized to reduce disaster risks while enriching visitor experiences in a nature-based, safe, and sustainable manner.

4. STRATEGIC UTILISATION OF GREEN INFRASTRUCTURE IN RURAL TOURISM

Natural attractions such as Tortum Waterfall offer significant opportunities for the development of rural tourism, yet they simultaneously face threats such as the exceeding of carrying capacities, damage to biodiversity, and the disruption of natural processes. Particularly in high-attraction areas where the balance between conservation and utilization must be maintained, it is imperative to plan visitor management, accessibility, and ecosystem integrity in an integrated manner. International organizations recommend the use of tools such as carrying capacity analyses, site zoning, and soft access systems to ensure sustainable governance in such areas (IUCN, 2021). Studies on Tortum Waterfall have reported that during peak tourism seasons, daily visitor densities surpass ecosystem sensitivity thresholds, with instantaneous carrying capacities at viewpoints such as observation terraces limited to 250 individuals (Göktuğ et al., 2013).

In this context, green infrastructure provides two principal solutions for managing visitor pressure. The first is modular walkway systems composed of permeable stone, wooden grids, and natural-surfaced boardwalks. These systems do not impede water flow and contribute to the preservation of natural microhabitats by reducing erosion. The second solution involves low-carbon ring-shuttle lines, such as an electric mini-bus service operated between the village centre and the waterfall. This practice can limit motor vehicle traffic while reducing noise and exhaust emissions by approximately 60% (Karahan and Özgeriş, 2022). Implementing these systems alongside risk-sensitive site zoning balances visitor distribution and enables natural areas to fulfil their tourism functions without exceeding their carrying capacities. Risk maps proposed by Kopar and Çakır (2019) also provide a guiding foundation in this regard.

The green infrastructure strategies developed for Tortum Waterfall are not confined solely to visitor management; they also aim to establish a balance between ecological connectivity and recreational aesthetics. In this regard, multifunctional corridors are designed through blue-green spines. Riparian buffer zones commencing from the waterfall (for example, at least 25 metres wide along the Tortum River) are reinforced with native species such as *Populus tremula* and *Salix alba*, thereby reducing flood and inundation risks; these areas simultaneously function as habitat passageways. In the upper elevations of the waterfall, green spines are formed through mosaics of oak-pine forests, *Pirus caucasica* orchards, and terraced agricultural fields, creating transitional corridors at the intersection of cultural and natural landscapes. Small "*pocket-meadow*" islands connected to these main axes host aromatic plants and butterfly habitats, thereby supporting both biodiversity and aesthetic landscape values. Corridor-based designs of this nature have been reported to enhance habitat integrity by 15–30% within the past five years (MaGIC Landscapes, 2019).

On the other hand, the economic and cultural functions of green infrastructure must not be overlooked. As emphasised in UN Tourism's (2023) Tourism and Rural Development action plan, nature-based solutions integrated with cultural landscape elements and local products create added value for experiential tourism. In the vicinity of Tortum, agricultural production in agro-ecological terraced gardens using traditional irrigation techniques could be supported through "*farm-to-table*" walking routes. Concurrently, the promotion of region-specific products such as honey, dried fruits, and aromatic oils could be facilitated through product markets established under the leadership of local cooperatives. Culture routes supported by digital technologies could present tangible and intangible heritage sites—such as stone arch bridges and watermills—to visitors through QR code-guided narratives, while augmented reality applications could enhance visitor loyalty (Vallerani and Visentin, 2018; Moropoulou et al. 2021).

These strategies necessitate not only physical planning but also the integration of community participation into spatial infrastructure. In this regard, the Eco-Development Committees (EDC) model, successfully implemented in the Panjabi Tiger Reserve, may serve as an exemplar. This structure, which employs local youth as nature guides or visitor centre managers, supports local development while fostering a sense of ownership in conservation processes (Gubbi et al. 2008). The existing women's cooperative infrastructure within Uzundere Municipality demonstrates that this model is scalable around Tortum as well (Özgeriş, 2020).

In conclusion, multifunctional green infrastructure design should be underpinned by a governance model that offers visitors a place-based experience while simultaneously strengthening rural identity and cultural continuity. Through such an approach, it is possible to achieve up to a 40% increase in average expenditure per visit, a 25% growth in local product sales, and an 18% rise in repeat visitation rates (Skuras et al. 2006). These figures clearly demonstrate that nature-based and locally focused infrastructure planning serves not only environmental sustainability but also economic and social sustainability objectives.

5. A CONCEPTUAL GREEN INFRASTRUCTURE MODEL FOR TORTUM WATERFALL

The landscape surrounding Tortum Waterfall presents a multifunctional structure in which natural thresholds and cultural fabric are intricately intertwined. This complex system, comprising the stepped waterfall-lake sequence, stony fords, terraced agricultural areas, and riparian forest belts, embodies both challenges and opportunities from a spatial planning perspective. The conceptual model developed within this study aims to guide these dynamics through nature-based solutions by addressing ecosystem services, disaster risks, and tourism pressures within a unified structural integrity.

The model is structured across three principal spatial layers. At the macro scale (≥ 1:25,000), the blue-green spine extending along the Tortum River plays a critical role in enhancing regional ecological connectivity and mitigating flood risks. Indicators at this level include ecological corridor continuity and reductions in peak flood discharges. At the mezzo scale (1:5,000–1:25,000), multifunctional corridors comprising terraced gardens and aromatic herb meadows simultaneously sustain both natural and cultural functions such as habitat permeability and agricultural production. Indicators at this layer may include NDVI trends and erosion rates. At the micro scale (≤ 1:5,000), low-impact recreational networks—such as natural-surfaced walking trails, panoramic terraces, and boardwalk systems—not only facilitate visitor guidance but also enhance microclimatic comfort. At this level, visitor density heat maps and surface temperature variation metrics become prominent.

This hierarchical framework has been constructed through the adaptation of the MaGIC Landscapes Project planning model (2019) and the European Green Infrastructure Strategy (EC, 2013) to the local context, rendering it implementable within the Tortum valley landscape

The spatial model in question encompasses not only static planning decisions but also dynamic scenario-based solutions for disaster risk mitigation. For instance, the clay-schist soil composition and steep slopes located in the upper elevations of the waterfall significantly increase landslide hazards. The proposed green infrastructure intervention in this area comprises bioengineering applications supported by the root systems of juniper (*Juniperus excelsa*) and *Ostyra carpinifolia* species, in combination with coconut fibre mesh consolidation techniques. This application has the capacity to reduce potential mass movement velocities by up to 35% (Karahan et al. 2017; Özgeriş and Karahan, 2021).

Similarly, the flood risk associated with intense rainfall in the entrance zone of the waterfall can be mitigated through a plaza system composed of tiered rain gardens and permeable stone surfaces. HEC-RAS modelling indicates that such a system can reduce peak flow rates during sudden water surges by up to 28% (Özgeriş et al., 2024). For drought scenarios, the recommended solution involves implementing "*sponge terrace*" systems within lake-terrace structures located in the upper catchment. These systems store water during rainy seasons and enable controlled releases in summer months, thereby ensuring the maintenance of ecological minimum flows (Orhan, 2019).

This green infrastructure-based approach is not confined solely to disaster risk reduction; it also encompasses the nature-based transformation of existing tourism infrastructure. For instance, to mitigate the heat island effect of concrete viewing terraces and enhance their integration with the landscape, wooden-steel composite canopy deck structures and green roof systems planted with sedum species are proposed. Such interventions can achieve surface cooling of up to 1–3°C, thereby improving both visual harmony and user comfort. Moreover, converting asphalt-surfaced car parks into permeable grid systems supported by rain-sensor misting technologies reduces surface runoff while enhancing visitor comfort. Additionally, transforming enclosed buffet areas into low-energy rammed-earth pavilions based on local soils and supporting them with PV solar panels not only ensures energy savings but also reduces the carbon footprint.

Replacing conventional lighting systems with directed low-lumen LEDs and bio-based glow-path applications reduces light pollution while protecting bat and bird migration corridors in the area. These transformation proposals not only improve ecological functions but also offer significant gains in terms of rural development and community participation. As Özgeriş and Karahan (2021) observed in the Uzundere context, integrating women's cooperatives into nature-based tourism activities increases local employment and supports sustainable development. Evaluating local material use alongside cooperative-based production models could provide the foundation for a long-term sustainability strategy around Tortum waterfall.

The integration of all these components can be visualised through the proposed "*Tortum Waterfall Green Infrastructure Integration Scheme*". This scheme incorporates the hydro geomorphological risk grid, green infrastructure spine, and tourism service zones, with recommended spatial data sources including the 1:10,000 scale base map, Google DEM, and TKGM datasets. The final visual outputs can be operationalised using vector graphic tools such as Adobe Illustrator or Inkscape.

6. NATIONAL AND INTERNATIONAL BEST PRACTICE EXAMPLES

Practices integrating sustainable tourism and green infrastructure contribute not only to ecological conservation objectives but also to the preservation of cultural landscapes and the support of local development. In this regard, the Spreewald Biosphere Reserve in Germany and the Wachau Valley in Austria at the international scale (Bethwell et al. 2022;

Riedl et al. 2022), alongside Turkey’s Yenice Forests at the national scale (Karataş et al. 2025), offer comprehensive models demonstrating how nature-based tourism practices can be successfully implemented in diverse contexts.

The Spreewald Biosphere Reserve, located in eastern Germany south of Berlin, is renowned for its multi-channelled swamp forests and traditional Slavic village landscapes, and it is recognised as a UNESCO-supported conservation area. Since 1990, an ecotourism model focused on green infrastructure has been developed, encompassing wooden platform-guided access systems, water-based transportation modes (canoeing, boating), organic farming-based agrotourism enterprises, and zoning-based visitor carrying capacity analyses (Karahan et al., 2011; Karahan and Özgeriş, 2022; Özgeriş, 2022; Sezen et al., 2015). Each route is equipped with digital solutions integrating QR code-based nature interpretation and sustainable production certificates. Nonetheless, challenges have arisen, such as irregular seasonal visitor distribution, conflicts between traditional structures and contemporary needs, and the surpassing of ecological thresholds in water resources. The Spreewald model is particularly exemplary for water landscape-centred planning and cooperative-based governance in areas such as Tortum Waterfall, where hydro-morphological characteristics are predominant.

Austria’s Wachau Valley, a UNESCO World Heritage cultural landscape, extends along the Danube River and is distinguished by its terraced vineyards, historic settlement fabric, and monastic structures. Within the framework of nature-based tourism policies initiated in the late 1990s, green walking trails traversing the vineyards and visual landscape carrying capacity analyses were developed. The ecological buffer zones established along the riverbanks and the culturally themed routes enhanced by digital guidance represent an integrated approach to spatial continuity and visitor experience. However, the density of cultural heritage has introduced certain challenges, including a lack of flexibility in building conservation legislation and spatial-temporal conflicts between agricultural activities and recreational uses. The Wachau model offers a strong comparative example for the integration of agricultural terraces and traditional orchards into tourism infrastructure in Tortum. Particularly in the context of visual landscape planning, the zoning practices implemented in Wachau provide instructive strategies for application in the Tortum context.

Turkey's Yenice Forests, meanwhile, represent a unique model in which nature tourism approaches based on rural development are conducted collaboratively with local communities. Located within the Karabük province, this region has hosted ecotourism projects coordinated by TEMA Foundation, ORKÖY, and the Karabük Governorship since the 2000s. Initiatives such as homestays operated through women's cooperatives, rural product markets, nature guiding, and low-impact trekking routes have diversified sustainable income sources. Nevertheless, structural limitations such as discontinuities in management plans, demand decline during off-seasons, and the inability to retain young populations in rural areas remain salient issues. The Yenice experience shares significant parallels with Tortum Waterfall's surrounding rural settlements in terms of enhancing women's employment, branding local products, and contributing to the local economy through nature guiding initiatives.

Moreover, the proposed eco-trail network planning in Uzundere aligns directly with Yenice's low-impact routes and appears strategically feasible for implementation.

In conclusion, these exemplary practices can serve as guiding frameworks in shaping nature-based tourism strategies to be developed in and around Tortum Waterfall. Planning centred on water landscapes, visual landscape management, rural development models integrated with women's cooperatives, and low-impact green infrastructure applications collectively support the principle of sustainability across both spatial and societal dimensions. The insights derived from these examples form the foundations of an applicable and holistic vision specific to the Tortum valley and waterfall context.

7. STRATEGIC RECOMMENDATIONS AND POLICY IMPLICATIONS

Rural areas constitute complex socio-ecological systems that encompass both significant opportunities and inherent vulnerabilities for the development of sustainable tourism. Evaluations conducted through the Tortum Waterfall case demonstrate that the green infrastructure (GI) approach in rural tourism planning serves not only ecological conservation objectives but also multidimensional goals such as social integration, economic diversification, and disaster resilience. The strategic recommendations developed within this framework offer a transformative perspective extending from the local level to national policy-making.

Policies supporting sustainable tourism in rural regions through GI must be approached with a multi-scalar planning framework. At the regional scale, macro-level green networks comprising ecological corridors, water catchments, and forest zones should be planned; at the watershed or district scale, semi-natural components such as recreational areas, agricultural landscape mosaics, and nature trails should be integrated. At the micro scale, site-specific solutions such as rain gardens, green roofs, and permeable surfaces should be incorporated into spatial strategies. In this manner, while the continuity of ecosystem services is ensured, sustainability indicators such as visitor management and site carrying capacity can also be effectively monitored.

The alignment of green infrastructure (GI) planning with thematic tourism types constitutes an effective strategy for ensuring the efficient use of resources. For ecotourism applications, an approach prioritising habitat connectivity and nature interpretation networks should be adopted. In agrotourism destinations, emphasis must be placed on agricultural biodiversity and the security of local food production, whereas in areas driven by cultural tourism, the restoration of landscape heritage elements and the enhancement of public access opportunities should form the core of the planning process.

To promote the implementation of GI practices, performance-based policies must be developed. Incentive instruments such as "*green tourism certifications*", tax reductions, and favourable credit facilities aimed at improving the sustainability performance of tourism enterprises not only reinforce environmental responsibility but also enhance economic capacity. Such mechanisms elevate environmental awareness in rural areas whilst accelerating the green transformation of the tourism sector.

In Turkey, the planning legislation has yet to fully integrate the multifunctional nature of green infrastructure. Nevertheless, environmental master plans and recent regulatory frameworks have created significant potential for advancement in this area. Within this process, the development of specialized planning instruments for rural tourism regions is of critical importance. GI-focused sub-regional plans should integrate ecosystem services inventories, biodiversity strategies, and disaster risk maps into statutory planning documents. Additionally, it is recommended that development implementation plans define criteria such as green connectivity networks, natural surface ratios, and ecological buffer zones, incorporating an obligation to submit a "*green infrastructure calculation report*" within planning notes. Tourism master plans must address GI components not merely from a landscape aesthetics perspective but also through the lenses of disaster prevention, biodiversity, and social inclusivity. For instance, the GI-supported disaster risk scenarios proposed for Tortum Waterfall may be regarded as an exemplary planning instrument within this framework (Figure 1).

Figure 1. Tortum Waterfall and Tortum Lake (Oğuz Gökçe)

A statement emphasizing the need for an integrated project covering accommodation, food and beverage facilities, visitor centers, and ecotourism activities between Tortum Waterfall and Tortum Lake. Such an approach is considered critical for preserving the geosites and ensuring the sustainable utilization of Turkey's highest waterfall in the medium and long term (Oğuz Gökçe, 2024).

The success of green infrastructure (GI) policies relies not only on technical regulations but also on the establishment of robust participation mechanisms. The active involvement of local stakeholders in knowledge and decision-making processes is decisive for ensuring the practical applicability of rural planning initiatives. Within this context, the institutional capacities of actors such as municipalities, village administrations, agricultural cooperatives, and women's associations should be enhanced; practical GI training programmes and pilot projects supported by organizations such as UNDP and the Ministry of Agriculture and Forestry should be expanded. Moreover, in order to elevate ecological literacy levels, nature-based learning modules, visitor centres, and digital interpretation applications should be developed. These efforts are also aligned with long-term strategies aimed at retaining the young population within rural areas.

Finally, digital participation opportunities represent innovative tools that strengthen GI-based planning in rural regions. Open data platforms and mobile applications enabling local communities and visitors to contribute real-time feedback facilitate the democratization of governance processes. For instance, the development of a mobile application for the Tortum Waterfall area allowing users to report hazardous zones would not only enhance the responsiveness of local administrations but also foster a culture of community participation.

Collectively, these recommendations increase the scalability of the spatial planning model developed for the Tortum context, offering a multifunctional, resilient, and inclusive infrastructure framework for sustainable rural tourism.

8. CONCLUSION

This study has provided a detailed examination of the critical role that green infrastructure (GI)-oriented planning approaches can play in achieving holistic sustainability objectives within rural tourism destinations, using the Tortum Waterfall case as an illustrative example. At the conceptual framework level, GI is positioned as a multifunctional instrument that enhances ecological connectivity, mitigates disaster risks, supports the continuity of cultural landscapes, and stimulates local economic vitality. In these respects, GI offers an interdisciplinary planning paradigm that enables rural tourism policies to transcend the conventional "*conservation–utilisation*" dichotomy.

Field-based analyses conducted in the Tortum basin have concretized the translatability of this conceptual framework into spatial practice. The multi-scalar GI configuration—comprising macro-scale blue-green backbones, mezzo-scale multifunctional corridors, and micro-scale low-impact recreational networks—has produced a spatial fabric congruent with the waterfall's geomorphological thresholds, hydrological regimes, and cultural landscape structure. This fabric not only maintains visitor management within carrying capacity limits but simultaneously supports habitat integrity, water quality regulation, and micro-climatic comfort. GI solutions focusing on disaster scenarios (including bioengineering-supported slope stabilisation, intra-terrace rain gardens, and sponge-terrace systems) have alleviated physical risks while also generating positive impacts on socio-economic indicators such as agricultural productivity and visitor satisfaction.

A holistic evaluation of these findings points to four fundamental conclusions:

- ***Integrated Governance Potential:*** Visitor flows, disaster mitigation, and cultural heritage preservation can be synchronously managed through the spatial integration of green infrastructure (GI), thereby minimising potential goal conflicts among planning decisions.
- ***Cross-Scale Effectiveness:*** Hierarchical GI networks, spanning from macro to micro scales, enable the development of rural tourism destinations without exceeding their carrying capacities while ensuring the continuity of ecosystem services.

• ***Nature-Based Innovation:*** GI-driven solutions reduce disaster risks at lower life-cycle costs compared to engineering-focused "*grey*" interventions, whilst simultaneously enhancing agro-ecological productivity and recreational aesthetics.

• ***Societal Ownership:*** Governance models rooted in cooperatives, alongside ecological literacy programmes, support local acceptance and the long-term sustainability of GI implementations.

The model developed for Tortum Waterfall possesses a high degree of transferability to other waterfall, canyon, and lake landscapes that exhibit similar hydrological and geomorphological fragilities coupled with strong touristic appeal. In this manner, sustainable tourism strategies will transcend a narrow focus on economic returns to embrace a multidimensional approach that equitably integrates environmental integrity, social justice, and cultural continuity.

This study not only provides an interdisciplinary framework that integrates the Green Infrastructure perspective into rural tourism planning but also stimulates new research agendas within this field:

• ***Spatial Modelling and Scenario Analysis:*** Development of GIS-based Green Infrastructure (GI) scenarios integrating indicators such as carrying capacity, erosion risk, and habitat connectivity, to be tested under multiple climate change projections.

• ***Effectiveness of Participatory Planning:*** Field monitoring and mixed-methods evaluation of the socio-ecological impacts of pilot GI implementations co-designed by local communities, women's cooperatives, and visitors.

• ***Monitoring and Evaluation Systems:*** Creation of multi-criteria indicator sets that holistically measure the ecological (biodiversity, water quality), economic (local income, employment), and social (satisfaction, sense of belonging) dimensions of GI projects.

- ***Comparative Policy Analysis:*** Examination of the scalability potential of GI policies in Tortum through comparative assessment with best practice examples such as Spreewald, Wachau, and Yenice, in terms of institutional capacity, financing mechanisms, and stakeholder participation.

These proposed research directions, when underpinned by interdisciplinary collaboration, long-term monitoring programmes, and innovative financing models (e.g. green bonds, carbon credit mechanisms), will enhance both the scientific rigour and practical effectiveness of green infrastructure-based rural tourism planning. The multifunctional vision articulated in the Tortum Waterfall case study thus offers a flexible, adaptive, and community-oriented strategic roadmap for analogous landscapes in regional and global contexts.

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