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www.bidgeyayinlari.com.tr - bidgeyayinlari@gmail.com
Krc Bilişim Ticaret ve Organizasyon Ltd. Şti.
Güzeltepe Mahallesi Abidin Daver Sokak Sefer Apartmanı No: 7/9 Çankaya / Ankara

İÇİNDEKİLER

BÖLÜM 1

THE ROLE AND IMPACT OF NATURE-BASED SOLUTIONS IN THE CREATION OF SPONGE CITIES

1. ŞEYDANUR KARACA[1]
2. BARIŞ KAHVECİ[2]
3. NURİYE EBRU YILDIZ[3]

Introduction

The continuously growing population, rapid industrialisation, unplanned urbanisation, and excessive use of natural water resources have led to the deterioration of water quality in many parts of the world (Gupta & Ali, 2012; Bostancı, 2022). The development of urban infrastructure alongside increasing urbanisation has resulted in the excessive use of many natural resources, primarily water resources. The intensification of urban infrastructure construction increases impervious surfaces and disrupts the natural water cycle, leading to water scarcity, pollution,

[1]Yükseklisans Öğrencisi, Niğde Ömer Halisdemir Üniversitesi, Fen Bilimleri Enstitüsü, Peyzaj Mimarlığı Anabilim Dalı, Orcid: 0009-0009-9463-2853
[2] Dr. Öğr. Üyesi, Niğde Ömer Halisdemir Üniversitesi, Mimarlık Fakültesi, Peyzaj Mimarlığı Bölümü, Orcid: 0000-0002-8508-1748
[3] Dr. Öğr. Üyesi, Niğde Ömer Halisdemir Üniversitesi, Mimarlık Fakültesi, Peyzaj Mimarlığı Bölümü, Orcid: 0000-0002-3508-4895

and ecosystem damage (Kırmızıbayrak et al., 2024). These pressures, especially when combined with increasing impervious surfaces and construction density, further exacerbate flooding and water ecosystem problems in urban areas.

Over time, increased rainfall on impervious surfaces, such as residential areas and industrial zones, has led to insufficient infiltration, causing flooding and inundation in urban areas. Uncontrolled surface runoff causes considerable damage to cities and their inhabitants. High-rise buildings constructed as a priority for economic development increase pressure on water ecosystems or destroy ecosystems important for maintaining balance, such as lakes and wetlands (Nguyen et al., 2019; Karşıyaka Municipality, 2024). For this reason, the concept of Sponge City has been introduced to protect water and prevent ecosystem damage. Sponge City is a new generation of urban rainwater management concept developed by China. Pilot projects for sponge cities in China have optimised urban land use structures and developed a new approach to urban planning through the construction and development of sponge cities (Ji & Bai, 2021; Bostancı, 2022).

This study will investigate how the sponge city approach can be applied in urban water management through nature-based solutions and how its ecological and functional contributions emerge at the scale of city parks. The study aims to examine the opportunities offered by the sponge city model in terms of rainwater management, flood control and ecological balance.

Method

In the study, the national and international literature on sponge cities and nature-based solutions was comprehensively reviewed. In this context, the definition of the sponge city concept, its fundamental principles, components, and the ecological and functional contributions it provides at the city scale were examined in detail. Academic articles, scientific reports, international case studies, and official municipal documents were used as primary data sources during the literature review process.

In the second phase of the research, concrete examples were evaluated to reveal the practical application of the sponge city approach. In this context, both international-scale projects and applications implemented in Turkey were examined. Through the application examples, the applicability of the sponge city approach at the scale of city parks, the role of nature-based solutions within urban systems, and their effects on urban water management were analysed holistically.

Findings

The Sponge City Concept

The sponge city is a new-generation urban rainwater management concept developed by China. Pilot projects for sponge cities in China have optimised urban land use structures, and the construction and development of sponge cities have fostered a new approach to urban planning (Ji & Bai, 2021). Sponge city construction can be defined as the overall arrangement and optimisation of the city's green, grey, and blue systems to enhance the benefits of urban water ecology and water economy, the environment, resources, safety, and the system (Jia et al., 2022).

First proposed in China in 2013 as a means of coping with increasingly frequent flood disasters, the Sponge Cities concept envisages the integrated work of urban water management and landscape architecture disciplines. It encompasses the protection of urban water basins, the improvement of water quality, and water harvesting. According to the sponge city philosophy, water is not separated from cities by canals, dams, and drains but is integrated into the city and absorbed by it (Yu, 2012; Tunçay, 2022).

Sponge cities facilitate the collection, storage, and treatment of rainwater that causes flooding, preventing it from becoming a disaster. Roofs, gardens, roads, and other similar areas act as conduits for safely directing rainfall underground. Artificially created wetlands within this concept are fed by rainwater, which is stored and made available for use when needed. This ensures the safety and sustainability of groundwater (Ekici, 2019; Gürsoy & Sadioğlu, 2022).

The sponge city approach aims to store water for future use through different strategies, purify it naturally, and use it to create green spaces with high visual landscape quality that can also meet people's recreational needs, rather than removing water from cities. Instead of the traditional grey infrastructure services used throughout cities, the aim is to make water use in cities both less costly and more sustainable through nature-friendly innovative strategies. The sponge city concept requires the use of new techniques that necessitate the participation of different disciplines in solving water problems. It is a new concept related to urban rainwater and flood management. It means that cities function like sponges, exhibiting flexible adaptability to environmental changes and natural disasters caused by rainwater (Shao et al., 2019; Li, 2023; Yıldırım et al., 2023). The unique aspect of China's sponge city concept is to manage rainwater like a sponge by absorbing, storing, and purifying water in the soil, lakes, and vegetation (Han et al., 2023) (Figure 1).

According to another explanation, it aims to minimise the effects of drought and flooding by maximising water recovery and ensuring the efficient use of water resources and reserves through water recycling. Green areas created for sponge cities promote the harmonious coexistence of city dwellers and nature, reduce water pollution and local environmental management costs, and thereby integrate the city and urban landscape ecologically, ensuring balanced ecosystem protection (Konyalı Dereli, 2020).

Figure 1 Sponge city concept

Source: Shi et al., 2023.

The Sponge City concept has the following objectives:

To adopt and develop Low Impact Development (LID) principles that effectively control peak flows of urban floods, temporarily store rainwater, reuse it, and treat it;

To improve existing drainage systems and raise drainage protection standards using LID systems in order to reduce surface runoff during heavy rainfall, with more resilient infrastructure solutions (such as the construction of underground water storage tanks and tunnels);

To integrate natural water areas (e.g., wetlands and lakes) as part of the system, promote multifunctional objectives such as enhancing ecosystem services in the drainage design process, and, in addition, create artificial water surfaces and green spaces to provide higher liveability and aesthetic value in cities (Chan et al., 2018).

The benefits of sponge cities can be summarised as follows (Balamir, 2017; Hou et al. 2019; Bostancı, 2022; Avşar, 2025):

1. Provides more clean water for the city,
2. Provides cleaner groundwater,
3. Reduces flood risks,
4. Reduces the load on drainage systems,
5. Contributes to the creation of greener, healthier, more pleasant urban areas,
6. Contributes to increased biodiversity.

Nature-Based Solutions at the Urban Scale and Their Application Areas

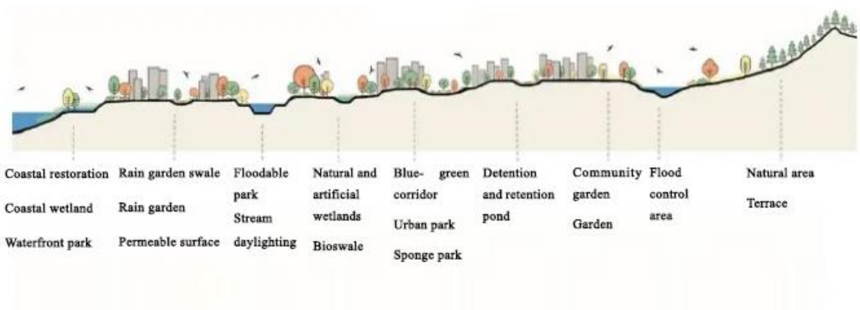
Nature-based solutions are defined as ecosystem conservation, management, and restoration interventions that can reduce the long-term impacts of climate change, manage anticipated climate risks to nature, provide mutual benefits for both humans and biodiversity, and deliver measurable positive climate adaptation and/or mitigation opportunities (World Wide Fund for Nature [WWF], 2020). Within the sponge city model, these solutions support not only sustainability but also the resilience of cities by ensuring the continuity of ecosystem services in urban areas. Nature-based solutions emulate natural processes and offer cost-effective environmental, economic and social benefits (Kaçmaz, 2021).

Natural ecosystems, although subject to degradation due to variable climate and environmental conditions, can repair themselves and survive. This resilience and flexibility are critical in urban areas in the face of climate change-driven problems. These solutions are seen as an important tool for addressing various social problems, such as increasing ecosystem resilience, protecting biodiversity, and adapting to climate change while reducing disaster risk (IUCN, 2020). These solutions can be natural (natural ecosystems), semi-natural (hybrid solutions—rainwater ditches, semi-natural stream corridors, coastal barriers, etc.), or culturally created by humans (roof gardens, green walls, etc.) (Coşkun Hepcan, 2022).

Healthy natural infrastructure in cities is effective in reducing flood risk, ensuring water conservation, retention and purification. The sponge city approach regulates water flow and ensures the replenishment of groundwater and water cycle management by recreating hydrological networks such as riverbeds, stream corridors, lakes and wetlands, and using nature-based solutions such as rain gardens, artificial wetlands and permeable surfaces. This reduces both flood and drought risk. Furthermore, urban tree cover mitigates heatwaves, improves air quality, and supports biodiversity. The balanced and widespread distribution of blue-green infrastructure plays a critical role in reducing urban risks (Coşkun Hepcan, 2022). Nature-based solutions at the city scale include blue-green solutions designed to strengthen urban systems and support disaster risk management (Figure 2).

A sponge city is defined as a city where ecological solutions are developed to reduce the collection, treatment and natural conveyance of polluted water to water sources through rainwater management. In these cities, the use of impermeable surfaces is reduced and replaced with permeable surfaces. Rainwater is directed into natural systems through structures such as rain gardens, water retention ditches, green terraces, ponds, and pools. Successful solutions and applications in sponge cities reduce the frequency and severity of floods, improve water quality, and replenish and improve underground and surface water reserves (Xu et al., 2018).

Figure 2 Nature-based solutions at the urban scale



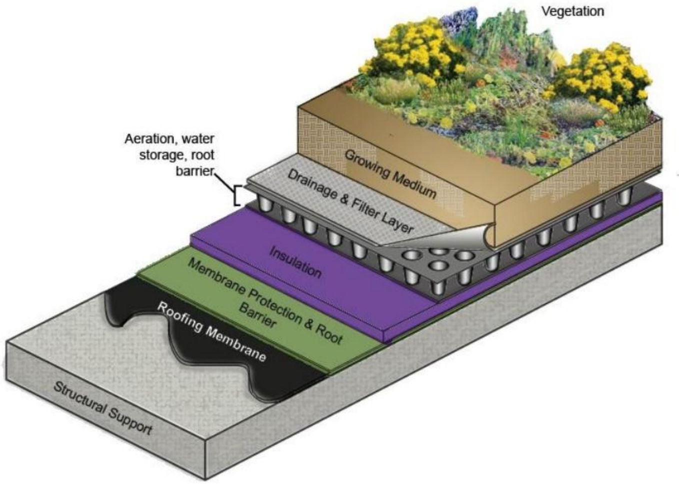
Source: Coşkun Hepcan, 2022.

Green Roofs

Green roofs are structures consisting of layers such as vegetation cover, soil, and drainage, installed on flat or slightly sloped roofs above ground level, capable of retaining a portion of rainwater and facilitating the discharge of excess rainwater. Green roofs are widely used in cities for their aesthetic appearance as well as their benefits in rainwater management and energy savings (Green Infrastructure Guide, 2015; Sutton, 2015; Aras, 2018).

Green roofs are a layer of vegetation formed by covering flat or sloped roofs with various insulation and waterproofing systems, using a growing medium, and planting trees, shrubs, and ground-cover plants on top. Generally, a green roof consists of vegetation, growing medium, filter membrane, drainage layer, waterproof or root protection layer, and waterproofing (insulation) layer (Dinçer, 2022) (Figure 3).

Figure 3 Green Roof Layers

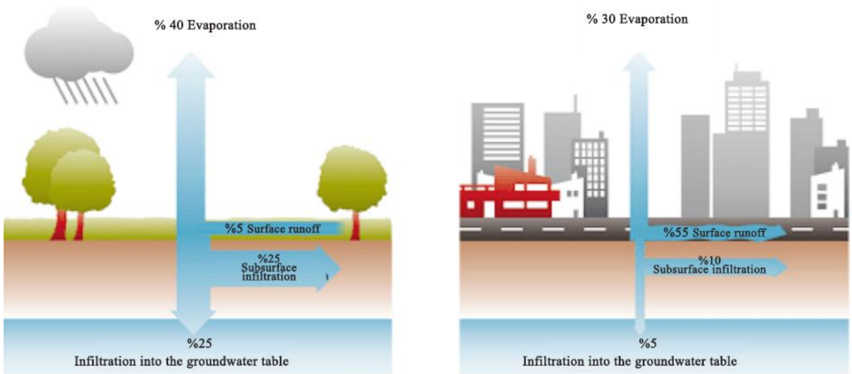


Source: The City of Lancaster, 2011

Permeable surfaces

Permeable pavements are sustainable urban drainage systems that reduce flow volume by allowing rainwater to percolate from the surface to lower layers, thereby preventing surface runoff (Dinçer, 2022). Used to reduce the amount of impervious surfaces in urban areas, permeable pavements not only reduce surface runoff and discharge but also temporarily store rainwater and direct excess water to underground sources. They also perform various functions such as removing pollutants from water sources (Levi, 2007; Aydın, 2023). Figure 4 illustrates the effect of permeable versus impermeable surfaces on the city.

Figure 4. Permeable and impermeable surface difference in the sponge city scope



Source: Anonymous, 2025.

Rain gardens

Shallow landscape areas that can collect, slow down, absorb, filter, and delay the rapid discharge of surface runoff into stormwater collection systems. Rain gardens can be of any size or shape and are typically implemented in parking areas, along street fronts, and in landscape areas at road intersections. Additionally, they can be designed with a flat base without longitudinal slope to maximise rainwater storage potential (İnan, 2020).

Rain gardens prevent surface runoff by capturing rainwater and may also allow infiltration depending on the capacity of the natural soil. Although rain gardens resemble vegetated swales and infiltration planting pads in some respects (they can be designed with vertical borders or side slopes), their primary function is not to convey rainwater but to maximise its storage (Sert, 2013; İnan, 2020). The plant species selected for rain gardens should be compatible with the area's natural vegetation. In rain gardens with three zones, care should be taken to select plant species for the first zone that are water-resistant, have strong roots, can withstand sudden floods, are resistant to both excessive water and drought, and have a wide range of adaptability. When selecting plants for the second zone, semi-arid-tolerant plants should be preferred due to its transitional nature. On the other hand, when selecting plants for the third zone, the buffer zone of the rain garden, care should be taken to choose drought-tolerant plant species (Müftüoğlu & Perçin, 2015).

Biological ditches

Rainwater drainage channels are vegetated, gently sloping linear ditches typically located near roads in urban areas to reduce the risk of flooding during or after heavy rainfall. These ditches are shallow waterways equipped with various plant species such as grass, shrubs or trees, which allow surface runoff water from impervious surfaces such as roofs, streets and car parks to slowly filter through (Demirören Civan, 2022). An important component of landscape features used in recent years for stormwater management in urban areas, biological swales are designed to mitigate surface runoff and reduce runoff-related pollution. Biological swales consist of a drainage channel filled with vegetation, compost and/or riprap. The flow path is designed to maximise the time the water spends in the trench. This helps to trap pollutants (U.S. Environmental Protection Agency [EPA], 1999).

Urban tree planting and green corridors

Urban road networks also determine the quality of the corridors they create. In this sense, applications that enrich urban corridors in terms of function and aesthetics are gaining importance. Urban road networks supported by plant material play roles such as connecting and integrating open and green spaces, such as squares and parks, which are other elements of urban corridors. Thus, the green fabric spreads throughout the city via corridors (Yerli & Kesim, 2009).

In recent years, given water shortages and drought caused by climate change, the rational use of water and the selection and application of drought-resistant plants have gained importance (Atik & Karagüzel, 2007; Tırnakçı & Aklıbaşında, 2023).

Street tree planting in cities offers numerous benefits in terms of sustainable rainwater management, water retention and surface runoff control, as well as enhancing the sustainability and quality of life in urban areas. Among the many benefits that roadside trees provide to cities are surface runoff control, adding aesthetic value, balancing the climate and reducing energy needs, purifying the air and reducing noise. Trees collect runoff by drawing water from the soil through transpiration. The amount of water reaching the soil and the volume of runoff are reduced thanks to the leaves, branches, and trunk. Trees purify the water they draw from the soil of harmful chemicals (Konyalı Dereli, 2020).

Vertical gardens

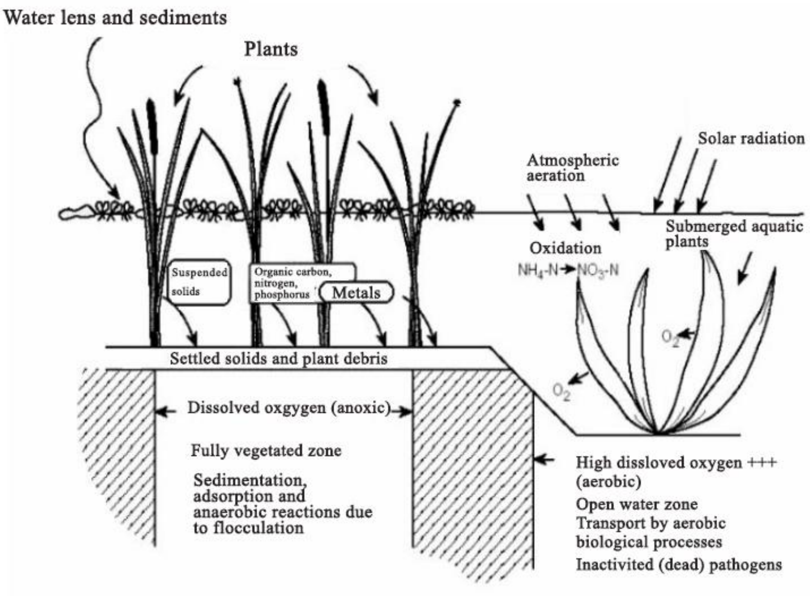
Vertical Gardens: due to the increase in urban population and the rise in environmental factors, resulting in a decrease in green spaces and the need to prevent and balance the rise in urban heat, vertical gardens are created within specific systems using plants suitable for the regional climate. (Özdemir Taş & Yerli, 2019; Anonymous, 2024). The structure is covered with plant elements growing on facades, in soil, directly on walls, or in pots. The basic elements of this system consist of plants, growing medium, root-retaining layer, carrier layer, filter layer, waterproofing, thermal insulation, vapour barrier, and wall support system. Additional elements can be incorporated into the system depending on the type of material used, the placement of materials within the system, and the area of application (Erdoğdu & Çetiner, 2014). Vertical gardens contribute to the creation of habitats for wildlife in urban areas and to the enhancement of biological diversity. Through their biological activities, plants reduce carbon dioxide levels, absorb dust and particles, increase oxygen levels, and improve air quality. They also purify rainwater from contaminants such as chemicals, heavy metals, and organic matter, and protect from the adverse effects of UV rays and extreme temperature changes. They help reduce the heat island effect in cities and control surface runoff (İpekçi & Yüksel, 2012; Kiper et al., 2017).

Artificial wetlands

Artificial wetlands are man-made wetland systems that utilise natural potential and ecological functions to enable various natural or cultural functions in wetland basins, much like the principle of green infrastructure systems (Güneş Gölbey & Kaylı, 2022). Wetlands support biological diversity and have aesthetic value. They can also be designed to increase their storage capacity against floods. The plants and algae used in these areas filter the water, improving its quality. Therefore, wetlands can serve not only in small urban sewage areas with drainage channels or pipe systems, but also as a solution to sedimentation management problems and can act as sediment traps (Figure 5) (Poleto & Tassi, 2012; Konyalı Dereli, 2020).

The working principle of artificial wetlands is based on phytoremediation. In this waste,—unwanted organic or inorganic substances—is removed by plants, thanks to their ability to clean, renew, and stabilise polluted environments. (Gülgün et al., 2010).

Figure 5 Treatment Cycles and Components in Constructed Wetlands



Source: Çiftçi et al., 2007.

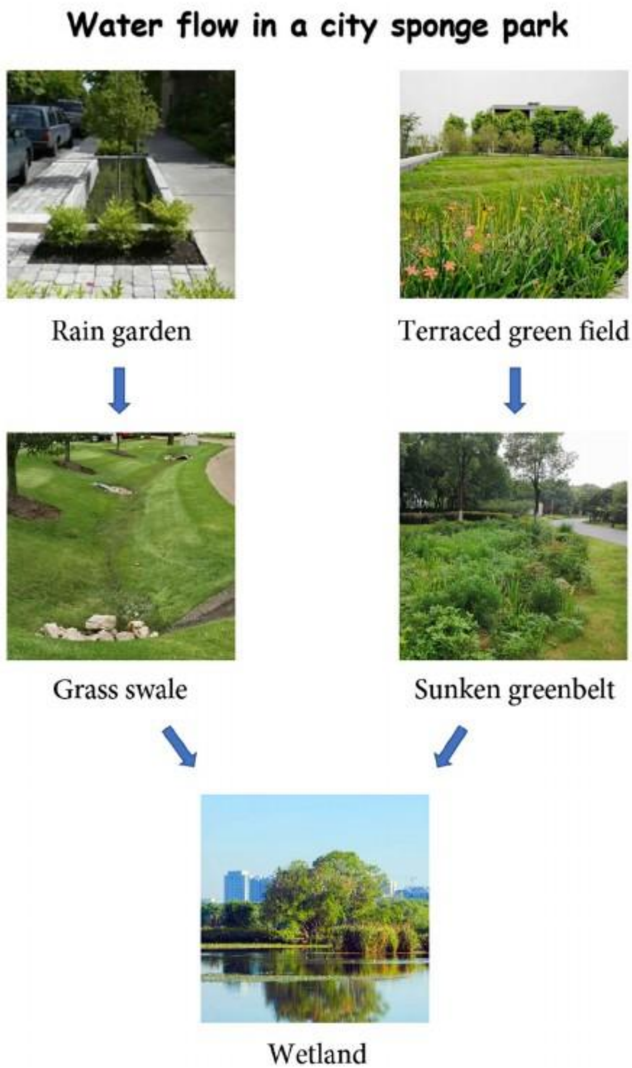
Exemplary Applications within the Sponge City Model

The European Commission has implemented the Horizon 2020 programme to promote the adoption of nature-based solutions in urban areas and to make Europe a world leader in nature-based solutions (Yaman & Yenigül, 2022; Pauleit et al., 2017). Through these programmes, sponge city design has been introduced in Europe and adopted by the Berlin City Council in line with its vision to make the city heat- and flood-resilient through initiatives such as afforestation, green roof applications, and increasing the number of artificial wetlands (DW, 2016). Nature-based solutions, increasingly used in international and regional projects, offer multifaceted opportunities to manage and adapt to the adverse effects of climate change in cities (Yaman & Yenigül, 2022; Hobbie & Grimm, 2020). A similar transformation process has also begun in Turkey. In Turkey, the Regulation Amending the Planned Areas Zoning Regulation issued by the Ministry of Environment and Urbanisation stipulates that "mechanical installation projects for buildings to be constructed on large plots of land exceeding 2000 m² or larger plots must include a mechanical installation project; a rainwater harvesting system project must also be added to collect rainwater from the roof surface in a rainwater harvesting tank installed below the natural ground level, to be filtered and reused if necessary" (Republic of Turkey Ministry of Environment and Urbanisation, 2021).

Qingshan District (Wuhan, China)

Qingshan District is one of Wuhan City's older urban areas. Prior to the sponge city transformation, the district faced chronic problems, including high groundwater levels due to ageing infrastructure, hard ground coverings, insufficient green spaces, and waterlogged roads. In 2015, this district was included in a pilot programme for ‘sponge city’ transformation, which involved the transformation of an urban area facing old infrastructure problems. Under this transformation, a public-private partnership model was used to carry out work covering a total area of 3,840,000 m², benefiting approximately 100,000 people. The objectives included controlling at least 70% of the annual rainfall volume, reducing suspended solids (TSS) pollution from surface runoff by at least 50%, and establishing a drainage and storage system that minimises flood risk even during severe storms and rainfall events that occur once every 50 years. In addition, it is envisaged that at least 25% of the collected rainwater will be reused for landscape irrigation, road washing and recreational purposes.

Figure 6 Rainwater flow process in an urban sponge park. Translated by the author.



Source: Han et al., 2023.

Nature-based infrastructure elements such as permeable pavements, rain gardens, grass swales and ecological floating barrier structures were used in the project implementation; in addition, landscaping, water-view terraces, gazebos and sports-recreation areas were also designed. Jujube trees, aquatic plants, and other ornamental plants were planted in the landscape area. Furthermore, water-view viewing terraces, gazebos, sand pits for children, and sports equipment were installed to create a suitable environment for recreational use (Han et al., 2023).

In the South Trunk Canal Park and recreation area located in the Qingshan District, significant changes have been made to rainwater management before and after the sponge city transformation project. Rainwater from outside the park, for example, from pavements, first passes through rain gardens, then collects in grass swales and is directed to the ecological wetland, i.e., the water retention basin. Within the park, rainwater flows through terraced green fields to lower-level sponge infrastructure elements, namely sunken greenbelts that capture and retain rainwater. These areas absorb and store rainwater while directing overflow to the ecological wetland, thereby reducing flood risk and supporting the natural water cycle (Figure 6) (Han et al., 2023).

Sanya Mangrove Park (Sanya, China)

The increasing recognition of the city of Sanya has been accompanied by rapid population growth, which has led to the expansion of new urban development areas and placed significant pressure on mangrove ecosystems (Maharjan et al., 2017; Ouyang et al., 2018; Arfaeinia et al., 2019). In addition to the degradation of natural waterways caused by rapid and unplanned urbanization, the intensifying impacts of climate change in recent years have further increased the risk of flooding in the city (Anonim, 2020).

To address these challenges, restoration efforts were initiated in 2015 for an approximately 10-hectare area along the Sanya River that hosts mangrove habitats—ecosystems formed by tree and shrub species that develop dense forests in saline wetlands and muddy coastal zones. Within this framework, a new park area was proposed using a nature-friendly, ecologically sensitive approach (Figure 7a) (Turenscape, 2019).

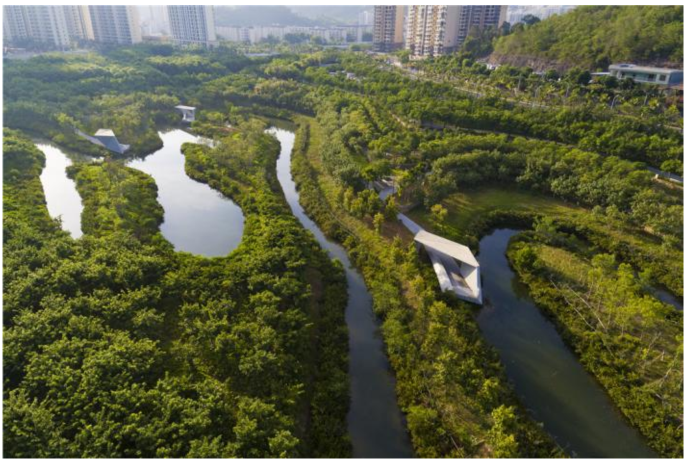
The project, led by chief designer Kongjian Yu and a team of landscape architects, aimed to rehabilitate degraded mangrove ecosystems, support urban regeneration, and transform the area into a publicly accessible, exemplary park that contributes to ecological restoration. To achieve these objectives, an innovative design approach was developed in which natural processes such as water and wind actively support the ecological recovery process (Figure 8).

Within the project site, four significant challenges were identified and addressed (Turenscape, 2019):

- **Wind:** Strong tropical monsoon storms;
- **Water:** Stream flooding caused by monsoon rainfall;
- **Pollution:** Urban pollution pressures;
- **Accessibility:** Ensuring public access without compromising the natural restoration process.

In the park, the 9-meter elevation difference between the water level and the urban area was resolved through terraced landscaping, and a pedestrian circulation network was established for users (Figure 7b). Bioswale areas facilitate the collection and management of stormwater. At the same time, pathways designed in harmony with the site's topography are integrated with scenic ramps that provide visitors with an immersive walking experience through the mangrove vegetation. Concrete shelters were constructed to withstand tropical storms, serving both protective and shading functions. Within three years following project implementation, mangrove habitats showed significant ecological recovery, ecotones were formed, fish and bird populations increased, and the site became an attractive destination for both ecological conservation and urban recreation. As a successful example of the sponge city concept, the project received several prestigious awards, including the AZ Best Landscape Architecture Awards in 2019, the ASLA Professional Awards in 2020, and recognition as a category winner at the World Architecture Festival (WAF) Landscape Awards in 2021 (Turenscape, 2019).

Figure 7a Current view of Sanya Mangrove Park and its pedestrian walkway network I

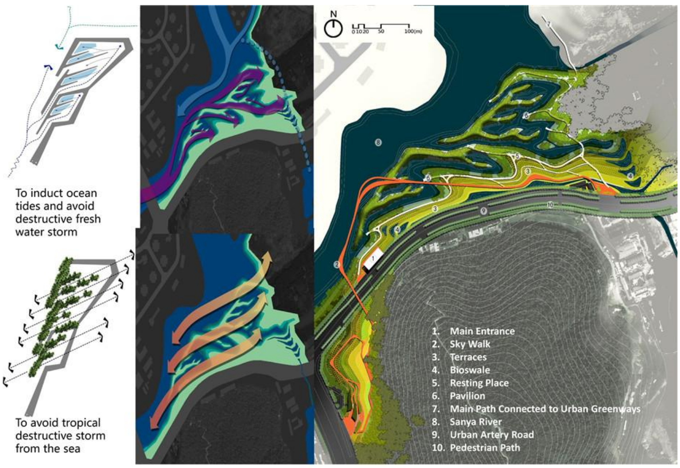


Source: Turenscape, 2019.

Figure 7b Current view of Sanya Mangrove Park and its pedestrian walkway network II

Source: Turenscape, 2019.

Figure 8 Design process form and site plan of Sanya Mangrove Park



01 Site plan: form follow processes. The designed ecotones of inter-locked fingers help to induct ocean tides, avoid the fresh water flush and destructive tropical storm

Source: Turenscape, 2019.

Copenhagen City (Denmark)

The severe storm that occurred in 2011 resulted in more than 13 cm of rainfall in certain parts of Copenhagen, the capital of Denmark. This extreme precipitation event placed significant pressure on the city's infrastructure; critical units of the largest hospital, major transportation routes, and workplaces were inundated. The disaster revealed the vulnerability of Copenhagen's existing infrastructure to climate-induced extreme weather events. It prompted city authorities to develop adaptation and resilience strategies to reduce similar risks in the future (Hockenos, 2025).

In response, the Skybrudsplan (Cloudburst Management Plan) was initiated in 2011 under the leadership of engineer Jan Rasmussen and his team. This plan not only positioned Copenhagen as a role model for climate-adaptive urban planning but also incorporated key applications of the sponge city model. The plan was designed to protect the city from intense rainfall events over the next 100 years (Petter, 2023).

The main components of the plan are as follows (BAU, 2024):

1. The creation and utilization of green spaces and parks that function as natural water retention and infiltration areas (Figure 9).
2. The redesign of streets and public squares to accommodate stormwater management.
3. The use of permeable surfaces and the integration of rainwater harvesting systems, enabling water to infiltrate on-site rather than being rapidly discharged (Figure 8).
4. The renewal of urban infrastructure and the development of new green and blue recreational areas.

5. The implementation of green roofs and green façade systems capable of absorbing water and releasing it gradually over time.

Figure 9 Sponge city applications in Copenhagen

Source: Hockenos, 2025.

Sponge City Practices of İzmir Metropolitan Municipality

The Sponge City İzmir Project is a water-oriented circular green transformation initiative based on an innovative stormwater management approach, incorporating a wide range of applications across both urban and rural areas. The project aims to improve the effective management of rainwater within the İzmir metropolitan area by emphasizing processes such as rainwater collection, storage, purification, infiltration, and reuse.

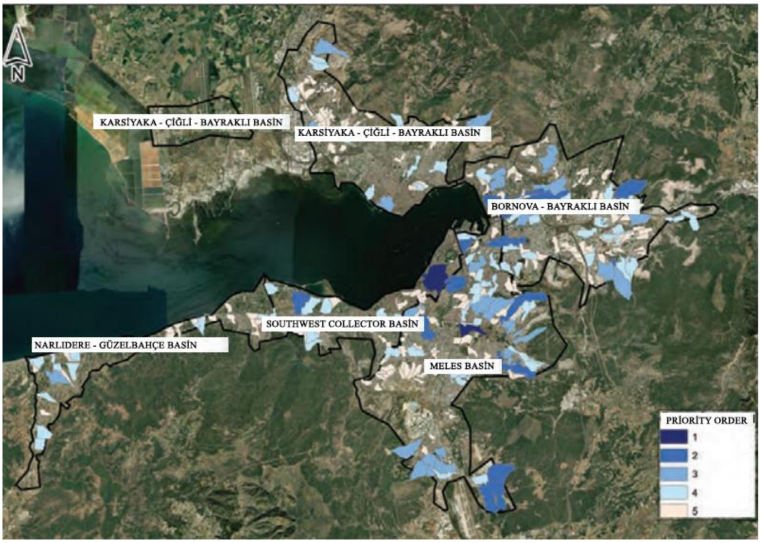
Within the scope of the Sponge City İzmir Project, solutions have been implemented at multiple scales in both urban and rural contexts. In urban areas, rainwater harvesting, storage, and reuse have been promoted through building-scale applications, including the installation of 5,000 rainwater storage tanks and 10,000 rain gardens. Public spaces such as parks, squares, and parking areas have been equipped with bioswales, permeable surfaces, and flood drainage wells, enabling controlled stormwater management while simultaneously increasing green space availability. Notable pilot projects include the Buca Bahçekapı Sponge Park and the Gaziemir Sakarya Sponge Parking Area, which stand out as exemplary sites for on-site stormwater control and management (Figure 11) (Figure 12). At the Buca Bahçekapı Sponge Park, infiltration trenches and surface runoff collection systems have also been implemented (Figure 13).

In rural areas, groundwater recharge is supported through infiltration ponds and recharge wells in the Küçük Menderes Plain. At the same time, household-scale rainwater storage systems in Karaburun Sarpıncık Village facilitate efficient water use. These practices contribute to the sustainable management of water resources in both agricultural production areas and rural settlements.

Another significant dimension of the project involves initiatives to enhance public awareness. Rain stops, collaborations with sports clubs, and ecological corridor projects help raise awareness among citizens regarding water management and climate change, thereby strengthening the social dimension of the sponge city approach. Additionally, GIS-based analyses are used to identify flood-prone areas within the city and prioritize these locations for the implementation of green infrastructure techniques (Figure 10).

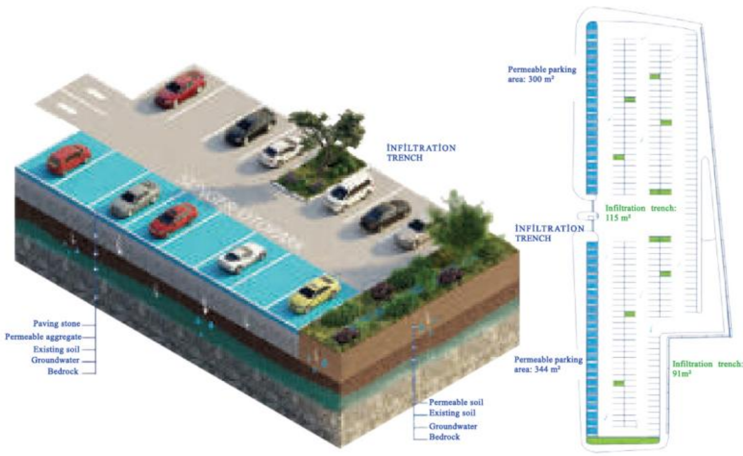
In conclusion, the Sponge City İzmir Project integrates a water-centered circular green transformation approach into the urban fabric in a holistic manner. By enabling effective stormwater management, minimizing environmental impacts, and enhancing urban resilience to climate change, the project represents a significant model for sustainable and climate-adaptive urban development (Republic of Türkiye Ministry of Environment, Urbanization and Climate Change, 2023).

Figure 10 Project prioritization study



Source: İzmir Metropolitan Municipality, 2024.

Figure 11 Green infrastructure techniques used in the sponge parking area



Source: İzmir Metropolitan Municipality, 2024.

Figure 12 Sponge parking area, İzmir

Source: İzmir Metropolitan Municipality, 2023.

Figure 13 Infiltration trench of the Buca Atatürk Neighborhood Sponge Park and surface runoff to be collected within the project area

Source: İzmir Metropolitan Municipality, 2024.

Sponge City Antalya

On 13 February 2024, a severe flood event occurred in the central districts of Antalya, with 330 kg/m² of rainfall recorded over 12 hours. The concentration of precipitation equivalent to the expected rainfall over three months within such a short time frame once again highlighted the significance of climate change impacts on urban areas. In order to prevent the recurrence of extreme rainfall and flooding events in the city center, new strategies have been developed and implementation processes have been initiated. In this context, the Antalya Metropolitan Municipality, in collaboration with the Antalya Branch of the Chamber of Landscape Architects, organized the "Sponge City Antalya" Symposium on 1–2 November 2024 (Figure 14).Within the scope of the event, theoretical knowledge and practical case studies on sponge city design were presented, focusing on urban flood mitigation, improved urban water management, and the conservation of green spaces. On 2 November 2024, the technical team prepared project drafts within the framework of the Sponge City Principle – Stockholm System at the Antalya Pilot Project Area and conducted a pilot field implementation (Antalya Metropolitan Municipality, 2024).

Figure 14 Sponge City Antalya Symposium

Source: Antalya Metropolitan Municipality, 2024.

Conclusion

In this book chapter, the role of the sponge city approach and nature-based solutions (NBS) in urban water management, climate change adaptation, and the enhancement of urban resilience has been examined through both a theoretical framework and practical case studies. In recent decades, rapid urbanization, the increasing extent of impervious surfaces, and climate change–induced extreme precipitation events have clearly revealed the limitations of conventional grey infrastructure systems. In this context, the sponge city approach has emerged as an ecosystem-based planning model that seeks to restore the natural water cycle, rather than relying solely on engineering-driven solutions that rapidly convey water away from urban areas.

The sponge city approach is founded on principles such as on-site rainwater retention, infiltration into the soil, natural filtration, storage, and reuse. Accordingly, it aims not only to reduce flood risks but also to improve water quality, support groundwater recharge, and enhance ecosystem services. Unlike traditional grey infrastructure systems, the sponge city model's provision of flexible, nature-compatible solutions positions it as a key component of climate change adaptation strategies.

The case studies discussed in this chapter—including Sanya Mangrove Park, Copenhagen, İzmir, and Antalya—demonstrate that sponge city principles can be successfully implemented across diverse geographical, climatic, and governance contexts. In these examples, urban parks, public open spaces, and infrastructure systems have been re-envisioned through nature-based solutions such as permeable surfaces, rain gardens, bioswales, constructed wetlands, ponds, and green roofs. As a result of these interventions, surface runoff has been effectively controlled, the frequency and intensity of flooding events have been reduced, and interactions between water and natural systems have been strengthened.

The ecological benefits of sponge city applications extend well beyond water management alone. These systems contribute to increased biodiversity, enhanced carbon storage capacity, and improved urban microclimatic conditions. At the same time, urban parks and green spaces designed in harmony with natural processes provide opportunities for recreation, education, and social interaction for urban residents, thereby improving overall quality of life. This highlights that the sponge city approach delivers significant gains not only in environmental terms but also in social and spatial sustainability.

In conclusion, the sponge city approach reframes urban water management from a purely technical infrastructure issue into a multidimensional planning paradigm that integrates landscape architecture, urban design, ecology, engineering, and governance. The broader adoption of this approach depends on its integration into higher-level planning frameworks, the strengthening of institutional capacity within local governments, and the promotion of public participation. The cases evaluated in this book chapter clearly demonstrate that the sponge city approach represents a powerful tool for creating climate-resilient, ecologically sensitive, and livable cities.

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BÖLÜM 2

PLANTING TECHNIQUES AND COMPARATIVE ANALYSIS OF TURFGRASS AREAS

1. Mehmet Kıvanç AK[1]
2. Ahmet BENLİAY[2]

Introduction

Turfgrass areas are among the most important components of modern urban ecosystems, both environmentally and socially. Recent studies on sustainable landscape management reveal that turfgrass surfaces serve not only aesthetic purposes but also significantly contribute to reducing flood risk by increasing rainwater infiltration, filtering water, and preventing soil erosion in sloping areas. These areas are a vital component of urban landscaping, used in and around many areas such as home gardens, sports fields, roadsides, buildings, schools, and parks. However, there is a misconception that lawn systems have limited benefits and can lead to negative environmental impacts due to mismanagement. (Lindsey et al., 2025:1). The dense and fibrous root system of grass strengthens the soil structure and helps trap pollutants, thereby

[1] Prof. Dr., Düzce University, Landscape Architecture Department, Orcid: 0000-0003-2671-1575
[2] Assoc. Prof. Dr., Akdeniz University, Landscape Architecture Department, Orcid: 0000-0002-0902-2658

improving environmental quality. (National Park Service, 2021). In addition, turfgrass areas reduce environmental temperatures through evaporation, thereby mitigating the urban heat island effect; this plays a critical role in microclimate regulation, especially in large and densely populated cities. (Bowler et al., 2010:147-155).

In addition, turfgrass areas have indirect but powerful effects on community and especially athlete health by creating safe, soft, and flexible surfaces for recreation and sports activities. Current research shows that grass surfaces encourage physical activity, improve psychological well-being, and enhance individuals' use of outdoor spaces. (Lopez & Friedman, 2024). Today, these areas, which have different functions such as ecological, social and aesthetic, have become not just a landscape element, but an integral part of sustainable urban life. Turfgrass areas, used for many different purposes, are an important representative of the group of walkable ground cover plants with different shades of green. (Avcıoğlu, 1997). In the field of Landscape Architecture in particular, the concept of a turfgrass area consists of herbaceous plants that have no agricultural benefit or primary purpose, and fulfill many ecological and functional roles in the environment through the green surface it creates. (Yazgan et al., 2003). Besides their aesthetic beauty, turfgrass areas also provide opportunities for sports, games, and recreational activities. With these features, they create more comfortable, livable, and healthy spaces, especially for people who are physically and psychologically stressed by urban life. Improving neglected areas with turfgrass areas also ensures the creation of safe and livable environments with high visual impact. (Ak et al., 2016, Kaya et al., 2016).

Examining the historical development of turfgrass, it is seen that its use became widespread in the 13th century with outdoor sports such as bowling and cricket. In later periods, its development accelerated even further with sports such as football and golf.

(Avcıoğlu, 1997). The development of turfgrass maintenance as a scientific discipline occurred after 1946. In the 1950s, new grass varieties were developed, and pesticide and herbicide technologies were improved to combat weeds, diseases, and pests. Furthermore, modern methods were developed for fertilization techniques, mowing, maintenance, and irrigation, significantly contributing to the creation of sustainable turfgrass areas. (Yazgan et al., 2003).

The functional properties of turfgrass include absorbing sunlight over large areas, reducing dust formation, preventing erosion on sloping surfaces along roadsides, and providing a suitable environment for play and recreation in urban areas. (Avcıoğlu, 1997). Its aesthetic qualities include providing a spacious and pleasing appearance, harmonizing with other landscape elements in terms of color and form, adding visual value alongside its technical function, and providing a backdrop for other plants. (Yazgan et al., 2003). In this context, Ak et al. (2014) drew attention to the visual importance of large lawn areas in park designs in urban spaces.

When the morphological structure of grass is examined, it is seen that it consists of roots and root collar, stem, leaves, inflorescence, spikelet, and seed. Grasses typically have two types of root systems: primary and secondary roots. Primary roots, which form after germination, meet the plant's needs until secondary roots develop and then disappear. (Avcıoğlu, 1997). Their roots are able to firmly hold soil particles. While some species renew their living root structure every year, others maintain it for a longer period. Root development, which increases in autumn and winter, declines in summer, and the root renewal process can vary between 0.5 and 2 years depending on the species. (Yazgan et al., 2003).

Grasses are divided into three forms based on their life cycle: clump form, stolon form, and rhizomatous form. In clump form, the plant develops into upright clumps with numerous tillers starting from the nodes closest to the ground. In stolon form, prostrate shoots emerging from the lower nodes of the main stem spread across the soil, forming roots downwards and shoots upwards at the points where they come into contact with the soil. In rhizomatous form, roots develop downwards and new shoots upwards from each node of the stems that grow horizontally underground. (Avcıoğlu, 1997).

The sustainability of urban ecosystems and the infrastructure requirements of the sports industry have led to the continuous development and updating of turfgrass field construction techniques. Beyond being merely an aesthetic landscape element, turfgrass fields also possess critical biomechanical functions in terms of erosion control, carbon sequestration, and athlete health. (Ak et al., 2018). In academic literature, plantation of turfgrass is fundamentally based on two main biological principles: generative reproduction and vegetative reproduction. (Alkın et al., 2020:16). Today, these basic methods have been supplemented with "Hydroseeding", "Seeded Biodegradable Blanket" and "Hybrid Grass System" through the integration of biotechnology and materials engineering.

This section details these five fundamental techniques and lists their advantages and disadvantages in relation to each other, developing recommendations for their application areas.

Seeding

Planting turfgrass areas by seeding is a widely used method due to its ability to preserve genetic diversity and provide cost-effectiveness over large areas. However, its success depends on the correct infrastructure design and the selection of species suitable to plant physiology. The ideal soil is one where water does not pool on the surface, is well-drained, but sufficient moisture is maintained in the root zone. The drainage principle known in the literature as "Perched Water Table" is frequently used, especially in high-level sports fields. (Schlea et all., 2014).

- **Drainage Channels:** Drainage channels should be excavated to a depth of 30-40 cm, depending on the climatic conditions of the region, and directed to the drainage areas using a herringbone pattern. Due to the fragility of the drainage pipes used in these channels, maximum attention should be paid to the cross-sections during installation.

- **Ground Slope:** Providing a slope of between 0.6% and 0.8% to the soil surface is critical for ensuring surface water runoff and gravity drainage.

- **Rootzone Mixture:** To create an ideal turfgrass area, the infrastructure of the application area should consist of a layered structure. A rough leveling process should be carried out by spreading 10-15 cm of gravel over the drainage line, followed by 5-10 cm of sand. The vegetation layer should then be laid on top of this permeable layer. Sand, peat, topsoil, and zeolite are suitable for this. The proportions of these materials in the mixture can vary depending on the grass type and climate. As a general ratio, 60% sand, 20% peat, 15% topsoil, and 5% zeolite can be used.

The choice of grass type depends on the region's climate and the plants' photoperiodic responses (whether they are short-day or long-day plants). For example, cool-climate grasses are generally long-day plants and thrive optimally between 16-24°C, while warm-climate grasses generally thrive between 27-35°C. (Kazemi et al., 2024:721).

For turfgrass planting, using 50-70 grams of seed per square meter is ideal to create a competitive texture. Before planting, the ground should be compacted with rollers not exceeding 500 kg, and the seeds should be distributed homogeneously using special machines. After planting, a "covering mixture" (sand, peat, soil) is applied to retain seed moisture. The thickness of this mixture varies depending on the climate; it is beneficial to apply it thinly (0.5-1.0 cm) in hot periods or regions, and thicker (1.5-2.0 cm) in cooler periods or regions.

Turfgrass Sod

Turfgrass sod is a process where mature grass, grown under controlled conditions using the "Generative Method" in production farms, is cut along with its root system and transplanted. This method is the most effective solution for projects where "time is of the essence".

In rolled turfgrass production, the strength of the plant's stolon and rhizome (above-ground and above-ground stem) structure is essential for the turf rolls to be transported without disintegrating. Turf with a strong texture can be cut more finely. Maintaining turgor pressure (sufficient moisture) during harvesting accelerates rooting, but overwatering increases the weight of the rolls, leading to logistical problems and potentially causing root suffocation.

Rolled turf is a living material and continues its metabolic activity after harvesting. Especially in hot weather, the temperature inside the roll can rise rapidly, leading to fermentation known as "heating." Therefore, cool-climate turf should not be laid in dry summer weather, and harvested turf should not be left standing for more than 60 hours.

The most critical aspect to consider during application is "soil-root contact". After the rolls are laid, rolling should be done to eliminate air pockets. However, rolling while the ground is muddy will disrupt the soil structure and cause compaction.

Hydroseeding

This method is a modern turf establishment technique based on spraying a homogeneous mixture of grass seed, water, fibrous organic mulch, fertilizer, and binding agents onto the application surface using specialized tank machines. This method is particularly used to create a rapid and balanced vegetation cover in large areas, on sloping slopes, and in areas with a high risk of erosion. (Reddy et al., 2025:97).

In hydroseeding, fibrous mulch helps seeds adhere to the soil surface, reducing surface transport caused by rain and wind. It also creates a microclimate on the surface, contributing to more stable temperature and humidity conditions necessary for seed germination. Studies show that germination rates in hydroseeding applications are more homogeneous and faster compared to conventional broadcast seeding. (Brown et al., 2020).

Another important advantage of this method is that the seed and fertilizer are distributed across the surface without decomposing during application. This allows for more controlled seed quantity per m^2, resulting in a competitive and balanced turf texture. The fibrous layer formed on the surface after application biodegrades and mixes with the soil within approximately 2-4 weeks, providing an organic matter contribution. (USDA, 2022).

Hydroseeding is considered an effective solution, both economically and ecologically, for highway embankments, dam fill areas, sports field surroundings, and large-scale urban green space projects. However, the success of the method depends on correctly determining the mixing ratios, applying the seed in windless weather conditions, and meticulously executing the irrigation program for the first three weeks.

Seeded Biodegradable Blanket

Developed for erosion control and water conservation, this method is based on the principle of embedding seeds into a cellulose-based organic matrix. Academic studies have observed that such textile materials increase soil aggregate stability (the adhesion of particles to each other) and promote microbial activity. (Parsakhoo et al., 2018:158).

The material used is 100% organic fiber that homogeneously incorporates seeds, fertilizer, and fungicide. The system's greatest advantage is its high water retention capacity (hygroscopic properties), which significantly saves irrigation water.

After the covering is laid, the seeds germinate within the fibrous tissue. This tissue protects the seeds from pests such as birds and ants, and also absorbs the kinetic energy of raindrops, preventing the seeds from moving. Within 3-4 months, the covering material is broken down (biodegraded) by soil microorganisms and mixed into the soil, acting as organic fertilizer.

Hybrid Grass System

Hybrid grass system is a technology that combines the biological advantages of natural grass with the mechanical strength of synthetic fibers. In the literature, hybrid systems are basically of two types:

- **Injection (Stitched) Systems:** To ensure surface runoff, a slope of 0.6% to 0.8% on the soil surface is a critical threshold for gravity drainage of water.
- **Carpet Systems:** This involves laying a base fabric (geotextile) woven from synthetic fibers on the ground and then filling it with sand/soil before sowing seeds. In this system, roots gain strength by anchoring to the synthetic fibers and the base fabric.

The most important agronomic advantage of hybrid grass is that the synthetic fibers increase the penetration resistance in the root zone. This prevents divot formation (ground tearing) during sudden turns and accelerations by players. Studies show that hybrid surfaces reduce muscle injuries and increase ground stability. In addition, synthetic fibers prevent excessive soil compaction, preserving drainage capacity. However, due to the heat retention of synthetic components, evaporation (evapotranspiration) is higher on these surfaces, requiring more frequent watering compared to natural grass. (Thanheiser et al., 2018)

In conclusion, the choice of method for establishing a turf field should be made according to parameters such as budget, time interval, and usage intensity. Success depends not only on the selection of the method but also on the construction of all infrastructure systems, from drainage to irrigation, in accordance with engineering standards. In light of this data, a comparative analysis table (Table 1) showing the advantages and disadvantages of turf field establishment techniques is given below.

Table 1 Comparative Analysis Table

Method	Advantages	Disadvantages
Seeding	•Low application cost •Economical in large areas •High flexibility in type and mixture	•Long germination and readiness time •Susceptible to erosion •Requires intensive care and irrigation in the initial period •High risk of weeds
Turfgrass Sod	• Instant green and aesthetic appearance • High erosion resistance • Homogeneous texture • Quick usability	• High cost • Transportation and storage risks • Requirement for root-soil compatibility • Limited variety options

Method	Advantages	Disadvantages
Hydroseeding	•Fast application in large and sloping areas •Homogeneous seed distribution •High erosion control •Seed, fertilizer and mulch can be applied simultaneously •Faster germination compared to generative methods	• Special equipment required • Difficulty in application in windy weather • Requires regular watering for the first 2-3 weeks • Limited visual impact in the short term
Seeded Biodegradable Blanket	•Very high erosion control •High water retention capacity •Minimum seed loss	• Material costs are higher compared to the generative method. • Precise application workmanship. • Not economical in large and flat areas.
Hybrid Grass System	• Very high durability • Suitable for heavy use • High ground stability • Professional sports performance	• Very high construction costs • Requirement for expert team and special machinery • High need for heat retention and irrigation

Considering all this data, 5 different turf laying techniques have advantages and disadvantages compared to each other. Which method will be chosen for the application area varies depending on factors such as the size of the area, accessibility, cost, slope, lifespan, maintenance possibilities, etc. Recommended application areas according to the method used can be listed as follows (Table 2).

Table 2 Suggested Suitable Use Cases

Method	Suitable Applications
Seeding	Parks, large green spaces, gently sloping terrain.
Turfgrass Sod	Prestigious areas, urgent projects, small and medium-sized areas
Hydroseeding	Slopes, highway edges, dam fill areas, large-scale landscapes and restoration areas.
Seeded Biodegradable Blanket	Small, steep slopes, areas at high risk of erosion, rehabilitation sites.
Hybrid Grass System	Professional sports fields

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BÖLÜM 3

EVALUATION OF XERISCAPE AT OSMANBEY CAMPUS AFFILIATED WITH HARRAN UNIVERSITY

1. HÜLYA ÖZTÜRK TEL[1]

Introduction

Climate change around the world and in our country can cause sudden heavy rainfall, floods, and droughts associated with high temperatures. Among the problems Turkey is expected to face during climate change, the foremost are the reduction in water resources and the resulting drought (Demirbaş & Aydın, 2020). Drought is one of the most dangerous natural disasters due to the damage it causes (Turan, 2018). Due to its geographical location, our country is among those most affected by climate change. Therefore, the efficient use of water is among the most important measures against the drought problem that will be experienced in our country due to climate change. One of the new approaches that can ensure water conservation is the "Xeriscape" approach, which involves the more efficient use of water by preferring natural species (Atik & Karagüzel, 2007). One of the most important criteria of xeriscape is

[1] Assoc. Prof., Harran University, Faculty of Fine Arts, Dept. of Architecture, hulyaozturktel@harran.edu.tr, ORCID: 0000-0001-9277-9119

the selection of species that are naturally distributed in the region where it is applied and are resistant to drought, and the significant reduction of lawn areas. This is because the more natural the plant is, the more adaptable it is and the less additional maintenance it requires. The basic principle of landscapes based on optimal water use in xeriscaping is to provide the required irrigation water using a minimum amount of water compared to other landscaping practices. The main goal is to provide plants with the amount of water they need when they need it. In areas where xeriscape landscaping is implemented, annual maintenance costs can be reduced by 54.91%, highlighting the importance of this approach (Çetin & ark., 2018).

The main goal in xeriscaping is to minimize water usage, and there are certain principles for this. These can be categorized as planning and design, soil preparation and improvement, selection of drought-resistant species, reduction of lawn areas, efficient irrigation, mulch use, and proper maintenance.

Work carried out according to xeriscape landscaping is more sustainable because it does not require regular maintenance. Minimizing water usage also prevents the depletion of water resources (Çetin, 2016). Using less water eliminates potential future drought problems and reduces the need for water. The drought resistance of the plants used is very important for drought-tolerant landscaping. The maintenance costs of gardens designed according to drought-tolerant landscaping are lower than other landscaping designs. Large lawn areas are not included in the designed areas, and they are not ostentatious. These designs are generally used for many years and are sustainable. Xeriscape landscaping is easier to implement and saves time. Respect for nature, reduced water usage, and longevity are among the most important characteristics of xeriscape (Aksoy & ark., 2022).

Şanlıurfa is one of our provinces that is clearly experiencing the effects of global climate change and, when rainfall data from many years is evaluated, shows an increasing trend and severity of drought (İrcan & Duman, 2021). According to the Aydeniz drought method, the city is classified as *very arid*. Climate data from 1929 to 2022 show that average air temperatures reached 36.4 °C, especially between May and September, with 44.1 °C recorded on June 27, 2019, one of the highest values in recent years. The average precipitation amount during the same period remained at very low levels, approximately 3.6 mm, increasing the pressure on water resources and highlighting the need for drought-tolerant landscape design approaches. In this context, the Osmanbey Campus of Harran University in Şanlıurfa, which has very arid climatic conditions, was selected as the study area. The landscape areas recently organized on the campus were evaluated in terms of the reduction of grass areas and the use of climate-appropriate plant species, with the aim of developing recommendations for sustainable landscape design.

Material and Method

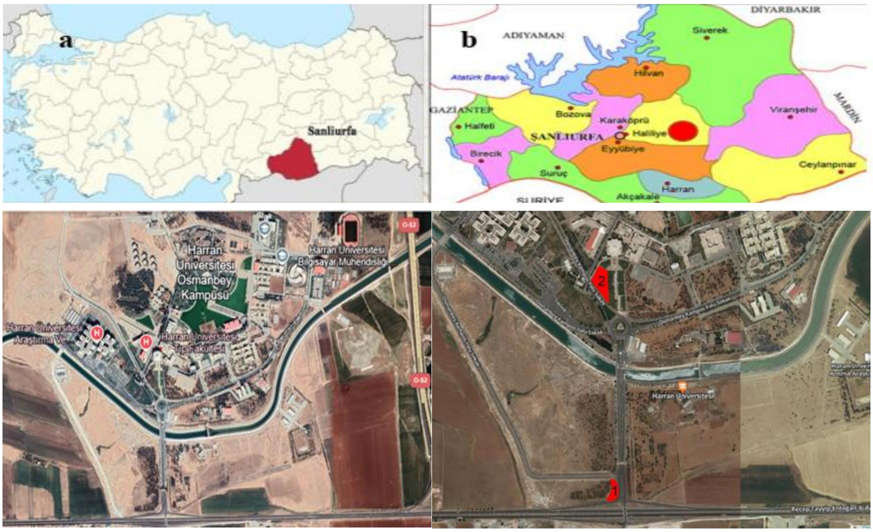
Material

The material for this study consists of green areas located at the Osmanbey Campus, which were completed in 2024.

Harran University's Osmanbey Campus is located in the east of the city, north of the Şanlıurfa-Mardin highway. It covers an area of 27,930 decares and is 540 meters above sea level. The study area has an advantageous location in terms of topography and its effect on climatic conditions. The elevation difference, aspect, and slope conditions within the campus area have created a largely homogeneous environment in terms of meteorological variables (Yayğın & Akan, 2020).

The city of Şanlıurfa is located in the C7 square according to Davis' grid system (Davis, 1965) and in the Middle Euphrates section according to Güner & ark., (2012). The location map of Harran University's Osmanbey Campus and the areas to be evaluated in terms of arid landscapes are shown in Figure 1.

Figure 1 Location of Harran University Osmanbey Campus (a, b, c) and areas to be evaluated in terms of arid landscapes (d 1-2)



Method

The method of this study consists of evaluating the green areas completed at the Osmanbey Campus in 2024 in terms of arid landscape, designing a landscape project in line with the proposed arid landscape approach, creating 3D visuals, and comparing the construction and annual maintenance costs of the existing project with those of the proposed project.

Findings and Discussion

Şanlıurfa is a province that is significantly affected by global climate change and shows a tendency toward drought. When rainfall distribution over many years is examined, the severity of drought increases from north to south at the provincial level (İrcan & Duman, 2021). Climate plays the most effective role in determining the plant species to be used in landscape areas in Şanlıurfa.

The landscape design of the settlement entrance, completed in 2024, was evaluated at the Osmanbey Settlement. The area is located at the entrance of the Osmanbey settlement and on the side of the Şanlıurfa-Mardin highway. It is located on the side of the road, where pedestrians do not pass and there is no human interaction. The majority of the area has been planted with grass, *Nerium* oleander has been planted, and the word "HARRAN" has been written to complete the design (Figures 2-3).

Figure 2 The empty state of the area and the current landscape design plan

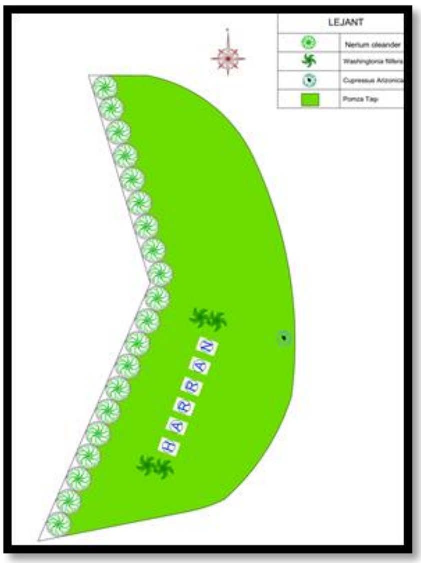


Figure 3 The implemented design

The use of *Nerium oleander* (Zakkum), a plant species with low water requirements, albeit in small quantities, was considered positive. However, the application of the "Harran" inscription is difficult for people to notice because the slope and angle are not correct. If this inscription is to be made, it should be made with ecological materials such as Urfa stone or plant material, and the angle should be correct. The use of a sprinkler irrigation system with sprinkler heads in the irrigation system was found to be appropriate.

In area 2, located north of the entrance, grass has been planted across the entire 4353 m² area between the dense *Pinus nigra* trees (Figure 4). Providing a large grass area was not considered sustainable, economical, or ecological due to high water consumption, the difficulty of maintaining greenery in an arid region such as Şanlıurfa, and the high maintenance costs. The acidic needles shed by the pines damage the grass, while watering and fertilizing the grass area can also damage the pines.

Figure 4 Extensive lawn areas in Area 2

Conclusion and Recommendations

In a period where water resources are globally significant and water scarcity is emphasized, drought-tolerant landscaping is among the topics that deserve particular attention. The landscape arrangements recently made at Harran University's Osmanbey Campus have been evaluated in terms of arid landscapes. As a result of this evaluation, it was concluded that the large grass areas in these newly arranged areas are not suitable for the landscape. On the other hand, it was determined that the irrigation systems are suitable for arid landscapes.

Recommendations have been developed to make the applications at Harran University's Osmanbey Campus more suitable for arid landscapes (Figures 5-6). A landscape design has been created for this purpose. In this design, species with low water requirements, such as *Nerium oleander* (Oleander), *Pyracantha* *coccinea nana* (Dwarf Firethorn), *Berberis thunbergii* var. atropurpurea (Lady's Saltwort), which have low water requirements and are resistant to highway landscaping, have been preferred, while the Cupressus *arizonica* and *Washingtonia filifera* species currently found in the area have been preserved. Another important principle for saving water is the use of mulch (Karagüzel and Atik, 2007). Small pebbles, pumice stone, and dolomite stone used in landscaping areas serve both aesthetic and functional purposes, as well as mulching. Therefore, pumice stone and dolomite stone are used for mulching in the area, and a palmette motif has been carved into these stones to enhance their aesthetic appeal.

Figure 5 Plan of the proposed project

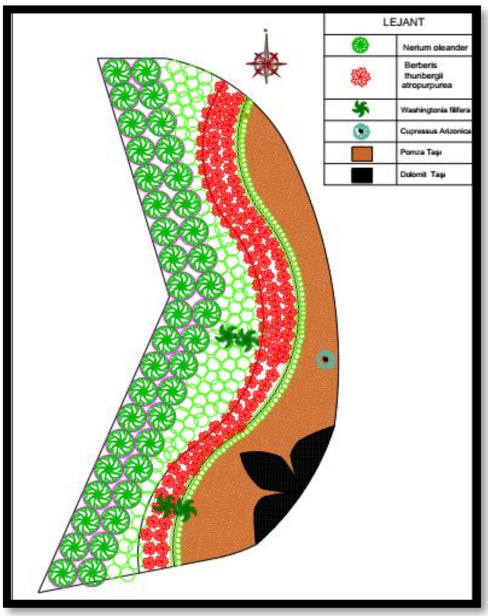
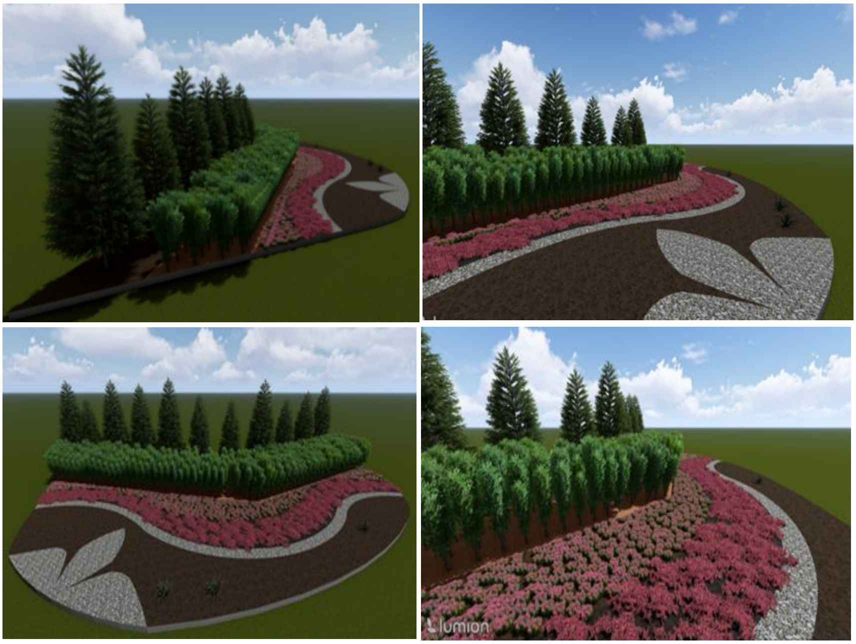


Figure 6. Visuals of the proposed project



With this project;

- Drought-tolerant species, one of the most important principles of xeriscape landscaping, have been preferred.
- Lawn areas are minimized or even eliminated,
- Drip irrigation systems are preferred over other irrigation systems,
- Mulching is done using pumice stone and dolomite stone,and requires very little maintenance, it can be said that the proposed project meets all the principles of xeriscape. The construction costs of the current project and the proposed project are compared in Table 1.

Table 1 Comparison of construction costs between the implemented current project and the proposed Project

Implemented Current Project	Quantity	Cost
Nerium oleander (60-80 cm height, 20 cm diameter) (Number)	20	6,000 TL
Grass seed (50 g per m²)	1,820 m²	13,500 TL
Fertilizer (35 g per m²)	1,820 m²	6,000 TL
Galvanized sheet metal 3 mm (for round metal letters) + painting	162 kg	7,000 TL
Tile ridge cap	360 pieces	19,800 TL
White dolomite stone (25 kg per 1 m²)	12 sq m	6,000 TL
Synthetic turf		6,000 TL
Total		**64,300** TL
Recommended Project		
Nerium oleander (Piece)	40 units	12,000 TL
Pyracantha coccinea	102 units	12,240 TL
Berberis thunbergii atropurpurea	104 pieces	10,400 TL
White dolomite stone	40 m²	20,000 TL
Pumice stone	400 m²	currently available.
Jute floor covering	440 m²	8,000 TL
Total		**62,640 TL**

The construction cost of the current project is 64,300 TL, while the proposed project costs 62,640 TL, showing that the average costs are the same. The maintenance costs of the current project and the proposed project are compared in Table 2.

Table 2 Comparison of maintenance costs for the current project and the proposed project

Maintenance Operations (Annual)	Current Project		Proposed Project	
Irrigation	May-October, 7 months, morning and evening = 420 waterings, 1420 m3 water and 31,950 Kw electricity consumption = 63,900 TL	63,950 TL	May-October, 7 months of irrigation / twice a week = 56 irrigations	8,520 TL
Lawn Mowing (Machine mowing of lawns and meadows)	May–September 27 mowings per year	12,250 TL		
Weed Removal	May–November, 7 times	1,798 TL	May-November 1 time per month = 7 times * 1,235 = 160 * 7	1,120 TL
Pruning	Shape pruning on suitable shrubs		Shape pruning on suitable shrubs	
Fertilization	Twice a year Before winter and before summer NPK (Nitrogen-Phosphorus-Potassium) 10 g per m² = 1835*10 = 18.35 kg*2 = 36.7 kg	1,225 TL	Twice a year 1235*10=12.35 kg*2=24.7 kg*33 TL=	815 TL
Pesticide application Trevistar 22 EC 0.5 L (weed killer for lawns)	Twice a year 200 ml/1000 m² 734 ml	1,000 TL		
Total		80,223 TL		10,455 TL

Since the current project allocates a significant amount of space to lawns, the annual maintenance cost, consisting of watering, mowing, weed removal, fertilization, and pesticide application, amounts to 80,223 TL, while the annual maintenance cost of the design, which complies with drought-tolerant landscaping criteria, is 10,455 TL.

In the proposed project, since there is no grass planting and instead of large grass areas, species with very low water requirements, such as Nerium oleander (Oleander), Pyracantha coccinea nana (Dwarf Firethorn), and Berberis thunbergii var. atropurpurea (Barberry) are used. According to arid landscape designs, the proposed project is more sustainable as it does not require regular maintenance. Minimizing water usage also prevents the depletion of water resources (Çetin, 2016). Using less water eliminates potential drought problems in the future and reduces the need for water.

The fact that water consumption reaches significant levels, especially in open green areas, has necessitated the development of new methods that use as little water as possible in landscaping projects. Looking at the water consumption of the current project, 1420 m3 of water is needed, while looking at the water consumption of the proposed project, it has a low water consumption of 189.3 m3 per year. Although the water needs are met by the canal passing through the Osmanbey Campus, the effective use of water should be among the most important measures against the drought problems that will be experienced in our country due to climate change, yet water resources cannot be used effectively.

It has been observed that it is quite economical to abandon classic landscaping created by planting grass and instead implement drought-tolerant landscaping practices. Although the construction costs of both projects are similar, it has been observed that drought-tolerant landscaping provides savings of 87% in annual maintenance costs. Xeriscape design principles should be taken into account in new landscaping projects within the Harran University Osmanbey Campus. For designs suitable for xeriscaping, natural plant species should be preferred, taking into account the water requirements of plant species. Instead of lawns, which are quite difficult to maintain, ground cover or shrub species should be used, and mulching should be employed to prevent evaporation.

Drought is a significant consequence of global climate change, further increasing the importance of arid landscape applications that use water efficiently. University campuses should pioneer and set an example for arid landscape applications.

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BÖLÜM 4

IMPACTS OF PERIPHERAL URBANIZATION ON LAND SURFACE TEMPERATURE DURING THE COVID-19 PERIOD

1. SELİN YILMAZ[1]
2. RİFAT OLGUN[2]

Introduction

Nowadays, the rapid growth of the population has become one of the main factors transforming urbanization processes on a global scale (Olgun, et al., 2025). The development of construction, which has grown in parallel with population growth, has led to extremely high population densities in cities. This situation has given rise to new urban problems in spatial and socio-economic contexts (Erdoğan, Olgun, Tülek, & Zaimoğlu, 2016; Arpacıoğlu, Kasap, & Durukan, 2017; Lu, Shang, Ruan, & Jiang, 2023). World Bank data shows that more than half of the world's population now lives in urban areas and that projections for 2050 indicate that the global urbanization rate will reach 68% (Gilman & Wu, 2024; Durukan,

[1] Master Student, Akdeniz University, Graduate School of Natural and Applied Sciences, Department of Remote Sensing and Geographic Information Systems, Orcid: 0009-0002-2293-1490
[2] Associate Professor, Akdeniz University, Vocational School of Serik G-S. Süral, Orcid: 0000-0002-5396-057X

Erdoğan, & Olgun, 2025). Urbanization is not merely a shift of population from rural to urban areas; it is a complex process involving multidimensional transformations such as diversification of economic activities, changes in settlement patterns, and reshaping of spatial structures (OECD, 2018; Ertaş Beşir, Bekar, & Durukan, 2020). However, rapid urbanization, especially when combined with planning deficiencies and inadequate housing policies, leads to the uncontrolled spread of urban areas, a phenomenon defined in the literature as "urban sprawl" (Karataş & Ünverdi, 2024). Characterized by low population density, fragmented land use, dispersed settlement patterns, and irregular growth towards the periphery, urban sprawl results in land fragmentation and increased spatial heterogeneity as a consequence of unplanned development in rapidly urbanizing regions (OECD, 2018; Sarif, Rimal, & Stork, 2020; Gomez-Martinez, de Beurs, Koch, & Widener, 2021). This situation raises issues in terms of human health, social cohesion, and ecological sustainability.

Pandemics around the world have significant impacts not only on social, economic, and political structures but also on the planning, development, and spread of cities (Yılmazsoy, Kırkık Aydemir, & Akdemir, 2021). The Coronavirus (COVID-19) pandemic, considered one of the most serious global health crises of the last century, has led to multifaceted transformations worldwide. First emerging in December 2019 in the city of Wuhan, China (Jones, 2020), this disease was declared a pandemic by the World Health Organization (WHO) on March 11, 2020 (Cucinotta & Vanelli, 2020; Sülkü, Coşar, & Tokatlıoğlu, 2021). With the rapid spread of COVID-19 worldwide, the first case in Türkiye was detected on March 10, 2020. This global pandemic has caused fundamental changes in the customary practices of societies (Zhao, 2020), and countries have implemented various measures to control the outbreak. In this context, schools, universities, and many public spaces with a high risk of transmission were temporarily closed (Doghonadze, Aliyev, Halawachy, Knodel, & Adedoyi, 2020; Gupta & Goplani, 2020).

The spread of COVID-19 has not been limited to social behavior patterns and health policies; the spatial structure and urban morphology of cities have also directly determined the dynamics of the spread of the pandemic. Indeed, the physical characteristics of the urban space, population density, the type of housing fabric, and settlement patterns play a critical role in the speed of the outbreak's spread (Tutuk & Salihoğlu, 2023). In particular, neighborhoods with high housing density, large households, and dense development have been areas where COVID-19 cases have been frequently observed (Sahasranaman & Jensen, 2021). Various empirical studies conducted in this regard have revealed that urban density, residential quality, spatial inequalities, and urban mobility are directly related to the spread and effects of the pandemic (Hamidi, Sabouri, & Ewing, 2020; Sahasranaman & Jensen, 2021). This situation has made the risks of high-density urban living more visible, increasing the trend toward settlement in urban peripheries and rural areas. As a result, construction has increased in low-density settlement areas, and urban sprawl processes have accelerated significantly (Yılmazsoy, Kırkık Aydemir, & Akdemir, 2021; Balçık, Kılınç, Karaoğlu, & Yamaçlı, 2021).

Peripheral urbanization trends observed during the pandemic have led to an increase in construction and impervious surfaces (Yılmazsoy, Kırkık Aydemir, & Akdemir, 2021). The increase in the proportion of impervious surfaces has resulted in a decrease in green spaces and their spatial fragmentation, and these changes have caused an increase in land surface temperature in these areas (Şenlik & Yilmaz, 2024; Karakuş & Kahraman, 2025). Remote sensing techniques and Geographic Information Systems (GIS) have been widely used to monitor and comprehensively evaluate these transformations occurring at the urban scale (Min, Zhao, & Miao, 2018; Selim, Eyileten, & Karakuş, 2023). These technologies have significantly facilitated the monitoring and analysis of the spatial and temporal components of dynamic urban processes.

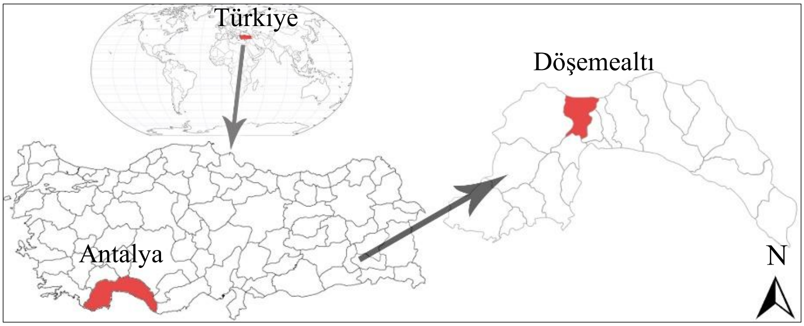
This study aims to reveal the effects of urban sprawl in peripheral areas on green spaces and to determine the changes in land surface temperature associated with this process during the COVID-19 pandemic. In this context, the Döşemealtı district, located north of Antalya, close to the city center, and under pressure from intensive construction during the pandemic, was selected as the study area.

Materials and Methods

Study Area

The Döşemealtı district, located in the north of Antalya province, has been identified as the study area. Döşemealtı district is a peripheral settlement area that has attracted attention due to its proximity to Antalya city center, its large surface area, and its rapid urban development in recent years (Güçlü, 2021; Can, 2022). The district borders Burdur province to the north, Konyaaltı to the south, Kepez to the east, and Korkuteli to the west, and has an area of about 673.1 km^2 (Antalya Metropolitan Municipality, 2014). With an average altitude of 300 m, the district is located in the northern part of the Antalya Plain and is surrounded by the extensions of the Western Taurus Mountains (Güçlü, 2021; Döşemealtı District Governorship, 2025).

Figure 1 Map of the study area boundary of Döşemealtı, Antalya.



Located under a Mediterranean climate, the Döşemealtı district exhibits significant microclimate differences at the local level due to its higher altitude compared to the city center. In terms of land cover and land use, agricultural areas and forested areas constitute a significant portion of the district, directly affecting the region's ecological structure and environmental dynamics (Döşemealtı District Governorship, 2025). In recent years, with the increase in detached housing developments, Döşemealtı has come under intense development pressure on the northern growth axis of the city of Antalya (Güçlü, 2021). Additionally, Döşemealtı district has shown a steady increase in population. The district's population was 65,794 in 2019, rising to 69,300 in 2020; 73,809 in 2021, 79,495 in 2022, and 86,109 as of 2023. These data reveal that population density in the district is gradually increasing in parallel with the growing settlement and migration movements around the city center of Antalya (Population Data, 2024). In this context, it was considered that the Döşemealtı district is a suitable and highly representative study area for examining the effects of peripheral urbanization dynamics, which accelerated during the COVID-19 pandemic, on green spaces and land surface temperature.

Methods

This study consists of three main stages: data collection, analysis, and evaluation of results. The first stage involved a comprehensive literature review and examination of open-access data sources. The boundaries of the study area were determined based on data obtained from the Directorate General for Mapping. Then, Landsat 8 OLI/TIRS satellite images from the summer periods of 2019 and 2023 were downloaded free of charge via the Earth Explorer platform provided by the United States Geological Survey (USGS) in order to calculate land surface temperature (LST) and Normalized Difference Vegetation Index (NDVI) values (USGS, 2025). The data from bands 4 (Red), 5 (Near Infrared–NIR), and 10 (Thermal Infrared–TIR) of the acquired satellite images were clipped based on the study area boundaries, and a dataset to be used in the analyses was created.

The LST map for Döşemealtı district was generated using a six-step method based on the Red, NIR, and TIR bands of Landsat 8 OLI/TIRS satellite imagery. Initially, the brightness values of the thermal band in the Landsat 8 OLI/TIRS satellite image were converted to radiance values. Then, surface temperature values were calculated using the obtained radiance values. Next, NDVI was calculated to determine the presence of vegetation cover in the study area; the Red and NIR bands of the satellite images were used during this process. The vegetation cover ratio was determined using the calculated NDVI values, and emissivity values were calculated based on these ratios. In the final stage, the LST map for Döşemealtı district was created by evaluating the temperature and emissivity data together (Karakuş & Kahraman, 2025; Olgun, et al., 2025). The equations used to calculate LST are as follows (Kafy, et al., 2020; Dadashpoor, Khaleghinia, & Shabrang, 2024):

$$L_\lambda = M_L * Q\text{cal} + A_L \quad (1)$$

where L_λ is the spectral radiance, Qcal is the quantized calibrated pixel value, M_L is the specific multiplicative factor of the band, and A_L is the additive rescaling factor specific to the TIRS bands.

$$Tb = \left(\frac{K_2}{ln(\frac{K_1}{L_\lambda} + 1)}\right) - 273.15 \quad (2)$$

where Tb is the brightness temperature of the sensor in Celsius, K_1 and K_2 are the calibration constant values given in the metadata, and L_λ is the TOA spectral radiance.

$$NDVI = \left(\frac{(NIR - RED)}{(NIR + RED)}\right) \quad (3)$$

where NIR is band 5 in and RED is band 4 in Landsat 9.

$$Pv = \left(\frac{NDVI \; - \; NDVI_{min}}{NDVI_{max} \; - \; NDVI_{min}}\right)^2 \quad (4)$$

where NDVImin and NDVImax are the minimum and maximum NDVI calculated.

$$\epsilon = \; 0.004 * P_V + 0.986 \quad (5)$$

where ε is the corrected land surface emissivity and Pv is the proportion of vegetation.

$$LST = \frac{Tb}{(1 + (\lambda * \frac{Tb}{\rho}) * ln(\varepsilon))} \quad (6)$$

where Tb is Landsat 8 brightness temperature, λ is the wavelength of emitted radiance, $\rho = h \times c / \sigma$ (h is Planck's constant, c is velocity of light, σ is Boltzmann constant).

Lastly, the values of the LST and NDVI indices for 2019 and 2023 were calculated at the neighborhood scale, the differences between the values for these years were revealed, and the statistical relationship between the values of these indices was calculated using Pearson correlation analysis.

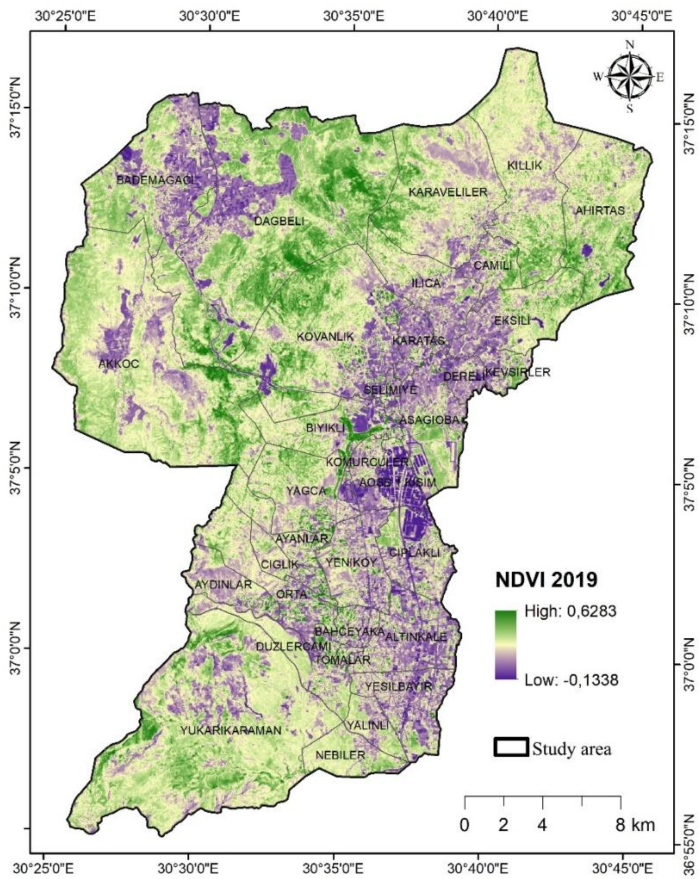
Results

According to the results of the 2019 NDVI analysis conducted to determine the spatial and proportional impact of urbanization on green areas in Döşemealtı district pre-pandemic, the vegetation cover density in the study area shows a heterogeneous distribution between -0.1338 and 0.6283 values. High NDVI values generally indicate forested areas, agricultural lands, and vegetation areas with dense green cover, while low NDVI values represent urban fabrics dominated by impervious surfaces such as asphalt and concrete.

Ahırtaş, located in the northeast of the study area, and Dağbeli, Akkoç, and Bademağacı, located in the mountainous region to the northwest, have high NDVI values. In these areas, the vegetation cover is denser, healthier, and more ecologically effective (Figure 2). NDVI values were found to be lower in areas close to the district center and in areas where the Organized Industrial Site is located. This indicates that vegetation cover density is limited in these areas.

At the neighborhood scale, the average NDVI values of the neighborhoods in the Döşemealtı district range from 0.14 to 0.31, indicating that the district consists of areas with different ecological characteristics and urban dynamics. When analyzing the average NDVI values for the neighborhoods, the highest value was observed in Dağbeli Neighborhood (0.31), followed by Ahirtaş (0.30), Karaman (0.29), Akkoç (0.29), Kovanlık (0.28), and Killik (0.28) neighborhoods. The high NDVI values in these neighborhoods indicate that the presence and density of vegetation cover are higher than in other neighborhoods. These neighborhoods are located in areas with dense forest cover and where agricultural activities are carried out. The neighborhood with the lowest average NDVI values at the neighborhood scale was found to be Antalya Organized Industrial Site (0.14). The low NDVI values observed in this area are due to the limited vegetation cover and intense construction.

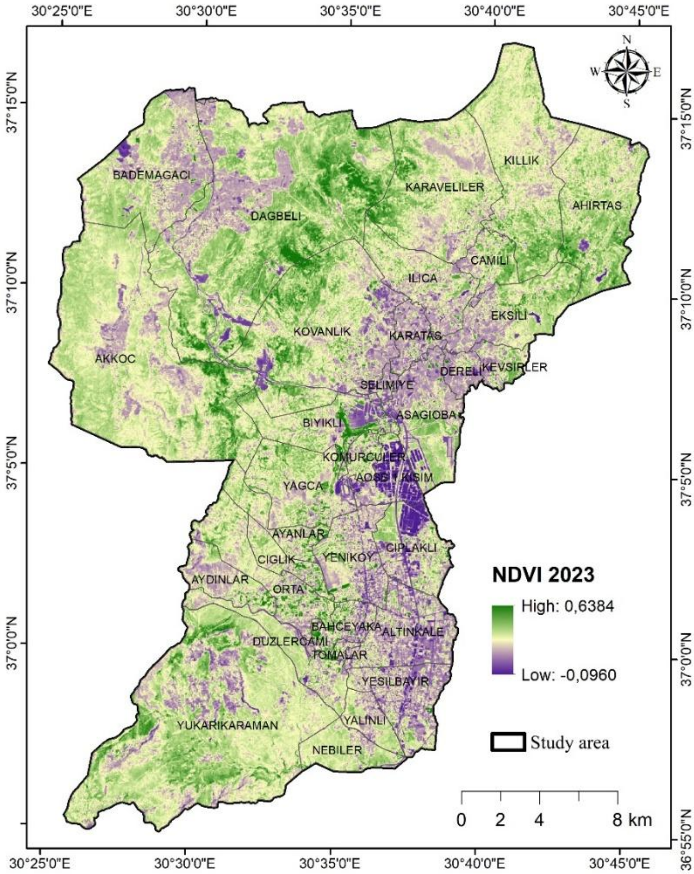
Figure 2 NDVI map for 2019.



The findings of the NDVI analysis for 2023 indicate that the vegetation cover density in the Döşemealtı district has spatially changed compared to 2019. According to the 2023 NDVI map, NDVI values are high in the northern part and southwestern regions of the study area. This is because the natural structure of these regions has been preserved, and agricultural activities are carried out in some areas. NDVI values were found to be low in settlement areas close to the district center (Figure 3).

The average NDVI values for neighborhoods within the study area in 2023 range from 0.15 to 0.30. The neighborhoods with the highest average NDVI values in the study area were observed to be Ahırtaş (0.30), Dağbeli (0.30), Killik (0.28), and Karaman (0.28). These neighborhoods maintain high vegetation cover density and are areas with both agricultural fields and forest cover. Moreover, Antalya Organized Industrial Site (0.15), Yeşilbayır (0.19), and Altınkale (0.20) neighborhoods were determined to have the lowest average NDVI values (Figure 3). The low NDVI values seen in these neighborhoods stem from urbanization density, the presence of industrial areas, their status as new settlement development areas, and an increase in impervious surfaces.

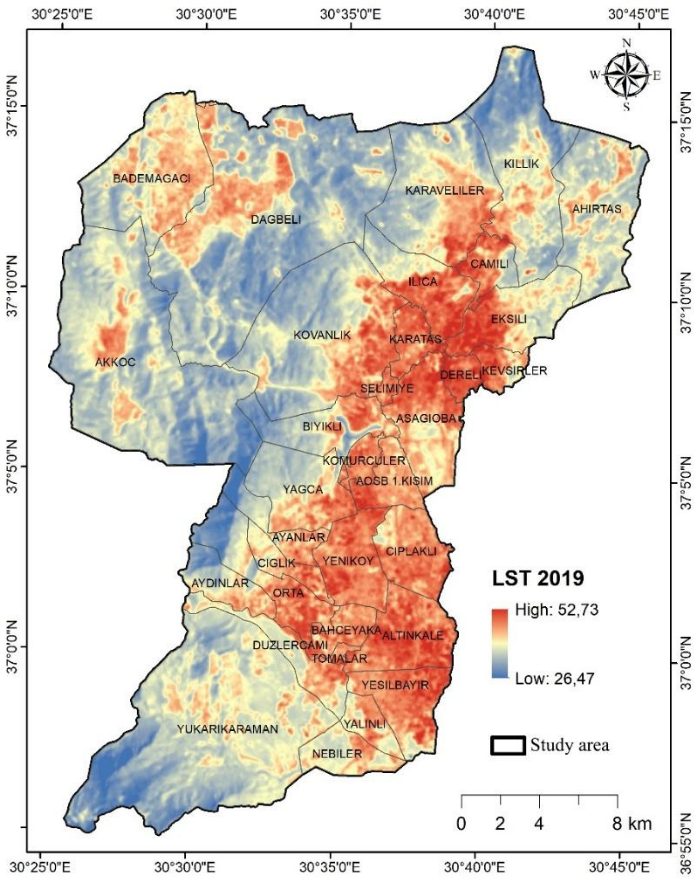
Figure 3 NDVI map for 2023.



The 2019 LST map reveals that land surface temperature values in the Döşemealtı district show spatial variations. According to the analysis findings, it was determined that the LST values in the study area ranged between 26.47–52.73 °C, with an average LST value of 39.6 °C. The highest LST values were observed to be concentrated along the settlement and development corridor extending north and south of the district center. In particular, it was determined that the land surface temperature values in the Dereli, Camili Aşağıoba, and Yeşilbayır neighborhoods were above 52 °C. However, it was seen that the lowest land surface temperature was below 27 °C in the Karaman and Akkoç neighborhoods located in the west of the study area (Figure 4).

When evaluating the average LST values for 2019 at the neighborhood level, the highest average land surface temperatures were observed in the neighborhoods of Dereli (48.28 °C), Altınkale (46.94 °C), Karataş (46.61 °C), and Yeniköy (46.25 °C). The average lowest land surface temperatures were found in the neighborhoods of Akkoç (36.35 °C), Dağbeli (36.57 °C), and Killik (36.65 °C) (Figure 4).

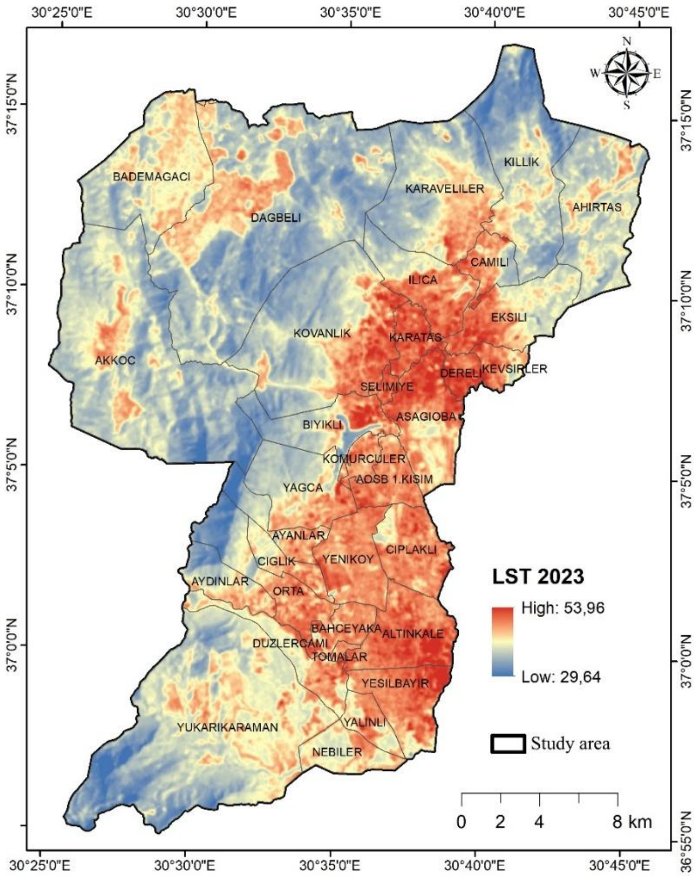
Figure 4 LST map for 2019.



The LST values for 2023 reveal that the land surface temperature values in the study area exhibit spatial variations. According to the analysis results, it was determined that the LST values of the study area ranged between 29.64–53.96 °C, with an average LST value of 41.8 °C. It was observed that the highest LST values were concentrated along the settlement and development corridor extending to the north and south of the district center, similar to the 2019 data. In particular, it was determined that the LST values in the neighborhoods of Aşağıoba, Yağca, Kovanlık, Karataş, Camili, and Altınkale were above 53 °C. However, it was observed that the lowest LST (29.64 °C) was in the Karaman neighborhood, located in the southwest of the study area.

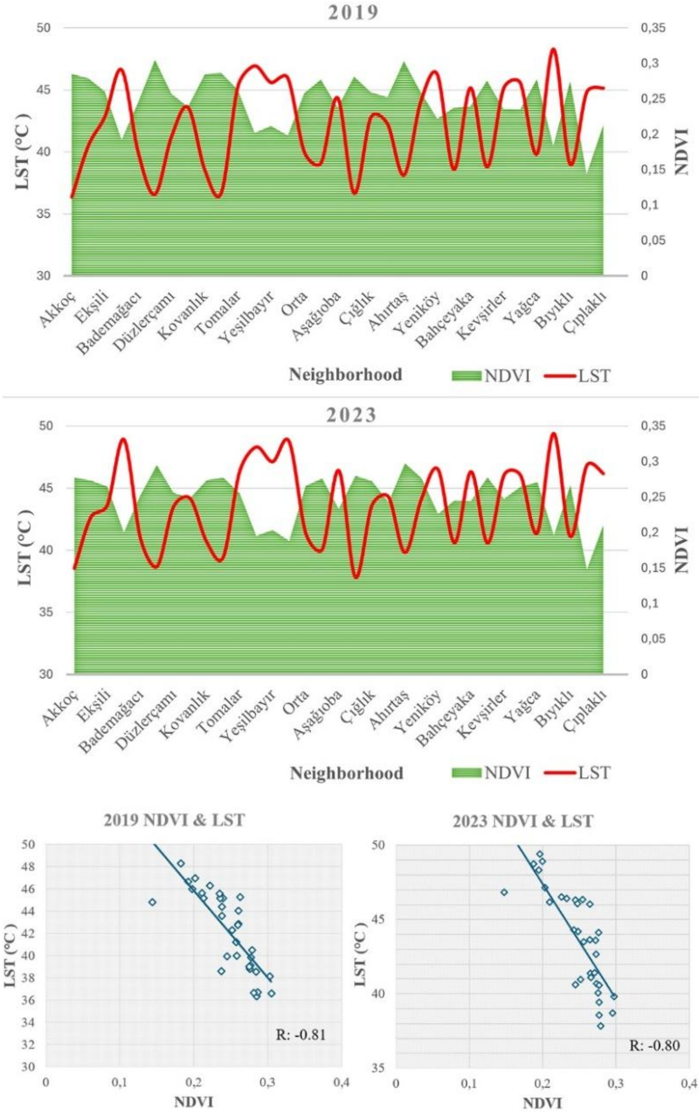
When evaluating the average LST values for 2023 at the neighborhood level, the highest average land surface temperatures were observed in the neighborhoods of Dereli (49.40 °C), Karataş (48.92 °C), Selimiye (48.74 °C), and Altınkale (48.32 °C). The average lowest land surface temperatures were found in the neighborhoods of Killik (37.83 °C), Akkoç (38.55 °C), and Dağbeli (38.69 °C) (Figure 5).

Figure 5 LST map for 2023.



A correlation analysis was performed to evaluate the relationship between LST and NDVI values for the pre- and post-pandemic periods (Graph 1). The analysis results reveal a strong and consistent negative relationship between vegetation cover density and land surface temperature in the study area. The correlation coefficient between NDVI and LST, calculated as -0.81 in the 2019 analysis, indicates that the decrease in vegetation cover density is associated with a significant increase in land surface temperatures. Similarly, the correlation coefficient for the 2023 data was −0.80, indicating that this relationship also persisted in the post-pandemic period.

Graph 1 The relationship between average NDVI and LST values at the neighborhood level between 2019 and 2023.



When comparing the distribution patterns of the graphs showing the relationship between NDVI and LST for 2019 and 2023, it is observed that LST values in 2023 are generally higher than those in 2019 within the same NDVI ranges. This situation can be attributed to the increase in impervious surface ratio and the decrease in green areas in the study area during the pandemic. Specifically, while NDVI values in 2019 were concentrated in the 0.20–0.30 range, LST values in this range were mostly observed in the 36–44 °C band. In contrast, in 2023, LST values corresponding to similar NDVI values were seen to be concentrated more in the 40–48 °C range.

Discussion and Conclusion

Assessing the effects of changes in land cover and land use on land surface temperature, examining the relationship between LST and NDVI stands out as one of the most commonly used approaches in the literature. Numerous empirical studies have shown that the presence and density of vegetation have a cooling effect on surface temperatures and, therefore, there is generally a negative and statistically significant relationship between NDVI and LST (Buyantuyev & Wu, 2010; Oğuz & Ersoy Tonyaloğlu, 2024; Olgun, et al., 2025). In this study, the statistical relationship between NDVI and LST data from the pre- and post-pandemic periods also showed an inverse correlation in both years. This inverse correlation is based on biophysical characteristics such as the shade and evapotranspiration provided by vegetation and the lower albedo effect of vegetation compared to impervious surfaces.

During the COVID-19 pandemic, the increased risk of infection in high-density urban areas, the widespread adoption of remote working practices, and changes in housing preferences have significantly increased the trend of settlement moving from city centers to peripheral areas. In this context, a low-density but expansive urban development process has emerged in the study area. The increasing demand for building has resulted in the conversion of agricultural areas and open and green spaces into building sites and their coverage with impervious surfaces. This process has led to a decrease in green space density, an increase in the proportion of impervious surfaces, and, consequently, an increase in land surface temperature values and significant changes in spatial patterns.

When evaluated from the perspective of landscape architecture and urban planning, the peripheral urbanization process that gained momentum during the COVID-19 period should not be considered solely as a phenomenon of spatial expansion. Rather, this process should be regarded as a structural transformation that produces multidimensional environmental impacts, such as loss of green infrastructure, deterioration of ecosystem services, and disruption of urban thermal comfort. In this context, the relationship between NDVI and LST provides a powerful and comprehensive analytical framework for analyzing the environmental and thermal impacts of the sprawling development trends observed in post-pandemic periods, particularly in urban peripheries. Indeed, studies have shown that not only the quantitative size of green spaces but also their spatial continuity, integrity, and fragmentation level play a critical role in determining surface temperatures (Buyantuyev & Wu, 2010; Zhou, et al., 2019; Oğuz & Ersoy Tonyaloğlu, 2024). Therefore, preserving the continuity of green spaces in peripheral areas and limiting the increase in impervious surfaces is of critical importance in terms of ecological sustainability, controlling the urban heat island effect, and developing climate change adaptation strategies.

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BÖLÜM 5

FROM DATA TO DESIGN: A COMPREHENSIVE REVIEW OF GEOSPATIAL ANALYSIS TOOLS IN ARCGIS PRO

1. HAKAN OĞUZ[1]

Introduction

The practice of Landscape Architecture is fundamentally rooted in the understanding of place.

People's perception and interpretation of place are shaped by their interactions with the surrounding environment, reflecting the dynamic relationship between individuals and their spatial context (Kordon, 2024a). A wide range of environmental factors influence this human–place relationship, and rapid population growth, migration, intensified urbanization, environmental pollution, degradation of natural ecosystems, and the prevalence of lifestyles disconnected from nature have collectively contributed to ecological, economic, and social deterioration in contemporary cities Moreover, interrelated challenges such as climate change, food insecurity, and excessive resource consumption further erode the integrity of this relationship (Özcan & Tuğluer, 2025).. Urban

[1] Prof. Dr., Kahramanmaras Sutcu Imam University, Landscape Architecture Department, Orcid: 0000-0002-0855-2032

sustainability is therefore closely linked to how people perceive and experience the spaces within cities. Two studies conducted in urban green areas demonstrated that environmental conditions can significantly alter individuals' perceptions of place and their engagement with on-site activities, either positively or negatively (Kordon & Miller, 2023; Kordon et al., 2022). In this context, the decline of natural areas, the deterioration of living conditions, the increase in food demand, and the inefficient use of water highlight the necessity of integrating green infrastructure systems into urban landscapes and selecting plant species based on accurate ecological tolerance criteria to ensure more effective and sustainable design outcomes (Ekren et al., 2024). The sustainability of cities, however, depends not only on urban green spaces. Studies have shown that environmental, economic, and sociological problems emerge when agricultural lands adjacent to or within urban boundaries are not planned in a sustainable manner (Kordon, 2024b). This underscores the need for planning and design approaches that operate in harmony with natural systems (Çakır et al., 2022).

Since Ian McHarg published Design with Nature in 1969, the profession has relied on the "layer cake" method of analysis by superimposing biophysical and cultural data to reveal land suitability (McHarg, 1969).

Building on this analytical tradition, contemporary research suggests that emerging environmental challenges—particularly climate change—necessitate the integration of spatial decision-making processes with broader policy frameworks. This transformation aligns with recent studies emphasizing that climate-oriented spatial decisions must be integrated with landscape planning frameworks, especially within the context of emerging national climate policies (Ekren & Kordon, 2025).

Yet traditional urban planning approaches often fall short in addressing these multifaceted and multidimensional issues in a holistic manner. In this regard, GIS-based mapping and layered planning methodologies have emerged as powerful tools capable of effectively handling complex and intertwined urban problems (Oğuz & Tuğluer, 2022).

While the conceptual framework of landscape planning has remained consistent for decades, the technological instruments used to execute it have undergone a radical transformation. We have moved from analog distinct overlays on mylar to the early digital cartography of ArcView and ArcMap, and now, to the high-performance computing environment of ArcGIS Pro.

However, despite the ubiquity of Geographic Information Systems (GIS) in the modern design studio, a significant "utilization gap" persists. In many academic and professional settings, GIS remains relegated to the role of a data repository or a presentation tool used primarily to generate static "Inventory and Analysis" maps at the beginning of a project. Once the base map is printed, the design process often retreats to CAD or analog sketching, severing the link between the analytical data and the creative proposal. This chapter argues that this separation is obsolete. With the advent of ArcGIS Pro, a native 64-bit multi-threaded application, GIS has evolved from a tool for representation into a robust engine for simulation and iterative design.

This shift aligns with the framework of Geodesign, defined by Carl Steinitz as a design process that changes geography by design, tightly coupling the creation of a proposal with impact simulations (Steinitz, 2012). To practice Geodesign effectively, landscape architects must move beyond simple attribute querying. They must harness advanced computational workflows that allow them to digitize with topological precision, model terrain dynamics in three dimensions, and analyze human movement through complex networks.

The transition to ArcGIS Pro offers distinct advantages for this workflow. Unlike its predecessor, ArcMap, which separated 2D mapping (ArcMap) from 3D analysis (ArcScene/ArcGlobe), ArcGIS Pro integrates 2D and 3D visualization into a single interface. This integration allows landscape architects to visualize the vertical implications of a slope analysis or a viewshed instantly, without data conversion. Furthermore, the integration of Python (ArcPy) and the visual programming environment of ModelBuilder allows for the automation of repetitive tasks, freeing the designer to focus on spatial synthesis rather than manual data entry (Law & Collins, 2022).

This chapter provides a critical review of the specific toolsets within ArcGIS Pro that are most consequential for the landscape architectural workflow.

From Analog to Digital: Data Acquisition and Interoperability

Landscape architecture rarely begins with pristine, ready-made geospatial data. The initial phases of a project are often characterized by a heterogeneous mix of file formats: surveyor's DWG files, architectural Revit models, historical paper maps, and loose conceptual sketches. The efficacy of the subsequent design phases depends entirely on the designer's ability to unify these disparate sources into a single, spatially accurate coordinate system. This section examines the critical workflows in ArcGIS Pro for bridging the analog-digital divide.

Integrating CAD and BIM: The Foundation of Site Design

For decades, the exchange of data between Computer-Aided Design (CAD) and GIS was a friction point in the industry, often resulting in loss of attribute data or geometric corruption. ArcGIS Pro has fundamentally restructured this interoperability through direct-read capabilities.

The Import CAD toolset allows landscape architects to view .dwg or .dgn files as native GIS layers without the destructive process of file conversion. However, the critical challenge remains the Coordinate System. Engineering surveys are frequently drawn in a local coordinate system, whereas GIS relies on projected coordinate systems (e.g., UTM or State Plane). To resolve this, the Georeference tab that is traditionally reserved for raster images, can now be applied to vector CAD data. This allows the designer to "move" a CAD drawing to its correct geospatial location using a 2-point transformation, ensuring that the engineering constraints align perfectly with broader environmental datasets like floodplains or soil types (Gorr & Kurland, 2020).

Furthermore, the integration of Building Information Modeling (BIM) via the Read BIM tool marks a significant leap forward. ArcGIS Pro can directly ingest Autodesk Revit (.rvt) files, preserving the semantic structure of the model. For a landscape architect, this means that a building model is not just a 3D visual; it carries attributes such as finished floor elevations (FFE) and material types. This allows for immediate analysis, such as calculating the visual impact of a proposed building height on adjacent parkland using the exact architectural specifications rather than rough massing estimates.

Georeferencing Techniques for Design Sketches

While CAD represents precision, the early conceptual phase of landscape architecture is often analog. Hand-drawn diagrams and bubble sketches allow for rapid iteration but lack spatial reference. Georeferencing is the process of assigning real-world coordinates to a raster image and is also the bridge that allows these sketches to be tested against site metrics.

The success of georeferencing relies on the selection of the appropriate Transformation method. A common error among practitioners is the indiscriminate use of the default settings. A critical distinction must be made between Affine and Spline transformations:

1. Affine / Similarity Transformation: This method maintains the geometric integrity of the source image. It scales, rotates, and shifts the image but preserves parallel lines and relative aspect ratios. This is the required method for scanned engineering plans, surveys where the internal scale is accurate.
2. Spline Transformation: Also known as "rubber-sheeting," this method optimizes local accuracy by warping the image to match the control points exactly. This is the preferred method for hand-drawn sketches or distorted historical maps.

For example, when digitizing a "loose" concept plan sketched over a printed base map, the paper may have warped, or the hand-drawing may be imprecise. A Spline transformation allows the designer to force the sketch to fit the actual site boundaries, enabling reasonably accurate area take-offs from a conceptual drawing.

Remote Sensing for Site Inventory (NDVI)

Data acquisition is no longer limited to what is provided by the client; it now includes what can be derived from satellite sensors. The Image Analyst extension in ArcGIS Pro provides access to remote sensing data, allowing landscape architects to perform rapid biological inventories before setting foot on site.

The most valuable index for this profession is the Normalized Difference Vegetation Index (NDVI). By utilizing the multispectral bands (specifically Near-Infrared and Red) from open-source imagery such as Sentinel-2 or Landsat 8/9, designers can assess vegetation health and density. In practice, this tool allows for the "historical forensic" analysis of a site. By comparing NDVI calculations from summer imagery over the past decade, a landscape architect can identify areas of chronic vegetation stress, potential soil contamination, or undocumented wetland boundaries. This moves the site inventory from a static observation to a temporal analysis of landscape performance.

Precision Digitization: Creating the Design Geometry

Once the site data has been acquired and georeferenced, the landscape architect moves into the generative phase of design. In a traditional CAD workflow, drafting is primarily an exercise in coordinate geometry—drawing lines, arcs, and circles to represent physical features. However, in the GIS environment, drafting is an exercise in topology. Topology refers to the spatial relationships between features: how polygons share edges, how lines connect at nodes, and how connectivity is maintained.

For a landscape architect, ignoring topology leads to the creation of "dirty data" such as planting plans with overlapping beds, unclosed zones that cannot calculate area, and "sliver polygons" (microscopic gaps between features) that corrupt planting schedules. ArcGIS Pro's editing suite provides specific tools designed to enforce topological integrity during the creation process, ensuring that the visual map is underpinned by a mathematically rigorous database.

The Importance of Topology in Design

In AutoCAD, a planting plan might consist of a series of closed polylines. If two planting beds are adjacent, the boundary line is often drawn twice, once for Bed A and once for Bed B. In GIS, this redundancy is a source of error. If the line for Bed B deviates even by a millimeter from Bed A, the resulting gap creates a calculation error in the total site area.

ArcGIS Pro operates on the principle of shared geometry. A single edge should define the boundary of both the lawn and the adjacent sidewalk. Utilizing topological editing tools ensures that when a designer modifies a curb line, the adjacent grass polygon updates automatically to match it. This dynamic relationship is essential for accurate Quantity Take-offs (QTO) and cost estimation (Law & Collins, 2022).

Essential Editing Tools for Landscape Architects

Three specific tools within the ArcGIS Pro Modify Features pane are indispensable for the efficient creation of landscape geometry: Auto-Complete Polygon, Trace, and Split.

The Auto-Complete Polygon: Solving the "Shared Edge" Problem The most frequent task in landscape documentation is defining adjacent land uses such as turf, shrub beds, paving, and mulch. The Auto-Complete Polygon tool is the primary mechanism for this workflow. Instead of tracing a new polygon from scratch, the designer draws only the new boundary of the proposed shape. The tool relies on the existing geometry of adjacent polygons to close the loop. For instance, when adding a shrub bed next to an existing sidewalk polygon, the designer sketches only the outer edge of the shrubs. When the sketch is finished, ArcGIS Pro automatically uses the sidewalk's edge to complete the shrub polygon. This guarantees a coincident boundary with zero gaps and zero overlaps, a level of precision that is tedious to achieve in standard CAD drafting.

Trace: Managing Curvilinear Forms Landscape architecture frequently involves organic, curvilinear forms by meandering paths, naturalized edges, and free-form water bodies. Digitizing these shapes manually by clicking hundreds of vertices is inefficient and often results in segmented, "jagged" curves.

The Trace tool automates this process by allowing the cursor to follow existing linear features. If a designer needs to create a vegetation buffer along a winding river, they simply activate the Trace tool and hover over the riverbank line. The digitizer follows the complex geometry of the river exactly. This is particularly valuable for creating hardscapes, such as generating a sidewalk polygon that perfectly parallels a road centerline. By setting an offset value during the trace, the designer can generate parallel geometry that maintains a consistent width, ensuring constructible dimensions.

Clip and Split: Phasing and Subdivision Large-scale master plans are rarely built in a single mobilization. They are often broken into phases or distinct management zones. The Split tool allows a landscape architect to take a unitary site polygon and "slice" it into constituent parts without losing the underlying attribute data.

For example, a master plan polygon for a 50-hectare park can be split by a sketched line representing the Phase 1 boundary. Unlike the "Trim" command in CAD, which simply breaks geometric lines, the Split tool in ArcGIS Pro divides the database record. It automatically recalculates the Shape_Area attribute for both new polygons. This instantaneous updating of area metrics allows the designer to test different phasing strategies in real-time by sliding the phase line back and forth to balance the construction area against a specific budget or square-meter target.

Surface and Terrain Analysis: Understanding the Physical Site

If digitization is the process of describing form, surface analysis is the process of understanding performance. A landscape is not a static 2D plane; it is a dynamic 3D surface governed by gravity, hydrology, and solar exposure. For the landscape architect, the ability to model these forces is critical for sustainable site engineering.

ArcGIS Pro separates these functions primarily into the Spatial Analyst and 3D Analyst extensions. These tools operate on raster data with grids of cells where each cell holds a value (elevation) allowing for continuous surface modeling. This section reviews the consequential analytical workflows for site planning: slope/aspect derivation, hydrological modeling, earthwork calculation, map algebra, and interpolation.

Slope and Aspect: Microclimate and Constructability

The most fundamental derivative of a Digital Elevation Model (DEM) is the Slope tool. While often used simply to generate "pretty maps" for reports, in a Geodesign workflow, slope is a hard constraint.

In ArcGIS Pro, the Slope tool calculates the maximum rate of change between each cell and its neighbors. The critical application here is Reclassification. A raw slope map with a continuous color ramp is analytically useless. Instead, landscape architects must use the Reclassify tool to bin slope data into actionable "constructability classes":

- 0–5% (Flat): Suitable for building pads, sports fields, and ADA-compliant pathways.
- 5–10% (Moderate): Suitable for standard walking paths and general planting.
- 10–20% (Steep): Requires terracing or retaining walls; higher cost of construction.
- 20% (Critical): Exclusion zones; high erosion risk and preservation priority.

By converting the continuous DEM into these discrete polygons, the designer can instantly calculate the "buildable area" of a site (Steinitz, 2012).

Complementary to slope is Aspect, which identifies the downslope direction of the maximum rate of change where essentially, the compass direction a slope faces. Aspect is the primary driver of microclimate analysis.

- Solar Gain: In the Northern Hemisphere, south-facing slopes receive the highest solar radiation, making them ideal for passive solar building orientation and heat-tolerant vegetation.
- Soil Moisture: North-facing slopes retain moisture longer and remain cooler, suitable for shade-tolerant communities.

By overlaying Aspect and Slope, a landscape architect can generate a "Habitat Suitability" map, predicting where specific plant communities will thrive without irrigation, thus driving the planting plan based on ecological logic rather than aesthetic pattern-making.

Hydrological Modeling: Designing Blue-Green Infrastructure

One of the most powerful capabilities of ArcGIS Pro is its ability to simulate water flow across a terrain without complex hydraulic engineering software. The Hydrology toolset allows landscape architects to identify natural drainage patterns before assigning land use, a principle central to Low Impact Development (LID).

The workflow follows a strict geoprocessing chain: (1) Fill, to remove data artifacts (sinks); (2) Flow Direction, to determine which of the 8 surrounding cells water will flow into; and (3) Flow Accumulation, to calculate the total number of cells draining into a specific cell.

The Flow Accumulation output is particularly valuable for siting Blue-Green Infrastructure. High accumulation values effectively draw a "network" of ephemeral streams and collection points on the site. Instead of fighting topography by piping water underground, the designer can use this layer to precisely locate bioswales, rain gardens, and retention ponds exactly where water naturally concentrates. This aligns the stormwater management strategy with the site's intrinsic hydrology, reducing infrastructure costs and improving resilience.

Cut/Fill and Grading: Earthwork Balancing

The manipulation of terrain or grading which is often the most expensive component of landscape construction. The Cut Fill tool in ArcGIS Pro provides a method for "Earthwork Balancing," ensuring that the amount of soil removed (cut) matches the amount of soil added (fill), negating the need for expensive hauling.

The output is a thematic map showing the spatial distribution of earthwork, accompanied by an attribute table quantifying the exact volume (cubic meters/yards) of change. This allows the landscape architect to audit their grading plan in real-time. If the model shows a massive surplus of Cut, the designer can raise the proposed finished floor elevations of the buildings to balance the site, optimizing the design for economic efficiency before the project reaches the engineering phase (Gorr & Kurland, 2020).

Advanced Map Algebra: The Raster Calculator

While standard geoprocessing tools offer "push-button" solutions for common tasks, landscape architecture often requires Custom-built analytical framework that falls outside standard algorithms. The Raster Calculator allows the designer to execute complex mathematical operations on raster datasets using the syntax of Map Algebra (Tomlin, 2012).

The most critical application of this tool for site inventory is the creation of a Normalized Digital Surface Model (nDSM). Lidar data providers typically deliver two distinct products: a Digital

Elevation Model (DEM), representing the "bare earth," and a Digital Surface Model (DSM), representing the "first return" of all features including tree canopies and building roofs. ArcGIS Pro does not possess a native "Tree Height" tool. However, by using the Raster Calculator, the landscape architect can derive this data through simple subtraction: nDSM = DSM - DEM.

The resulting raster shows the height of every object above ground level. This allows the designer to perform Canopy Height Analysis by instantly identifying all trees on a 50-hectare site that exceed 15 meters in height. Furthermore, the Raster Calculator is essential for Conditional (Con) Statements. Instead of running three separate tools to find a site, a designer can write a single algebraic expression to mask out unsuitable land (e.g., Con(("Slope" < 15) & ("Aspect" > 135), 1, 0)), streamlining the suitability workflow significantly.

Creating Surfaces from Discrete Data: Interpolation

Landscape architects frequently work with discrete point data such as surveyed spot elevations, soil sample pH readings, or noise decibel measurements. To analyze these isolated data points across a continuous site, they must be converted into a continuous raster surface through Interpolation. ArcGIS Pro offers a suite of interpolation algorithms, but for site planning, the choice typically falls between Inverse Distance Weighted (IDW) and Kriging.

Inverse Distance Weighted (IDW) operates on Tobler's First Law of Geography: "Everything is related to everything else, but near things are more related than distant things." This method is best for survey spot elevations. It assumes that the value of an unsampled location is a distance-weighted average of the surrounding sample points. It is computationally fast and respects local peaks and valleys, making it ideal for generating a Digital Elevation Model (DEM) from a CAD survey file containing 3D points.

Kriging (available via the Geostatistical Analyst) is a more advanced, stochastic method that accounts for both the distance and the degree of variation (spatial autocorrelation) between points. This is the industry standard for Soil and Environmental Analysis. If a landscape architect collects 50 soil samples to test for contamination or nutrient levels, Kriging can predict the values in the spaces between samples with a higher degree of statistical certainty than IDW.

For complex datasets, ArcGIS Pro provides the Geostatistical Wizard, an interactive environment that guides the user through the interpolation process. It allows the designer to visualize the "semivariogram" (a graph of spatial correlation) and optimize the search neighborhood, ensuring that the resulting topography or heat map is mathematically defensible rather than an artistic approximation (Sipes, 2014).

Visual Exposure and Impact Assessment

While slope and hydrology define the physical performance of a site, landscape architecture is uniquely concerned with the perceptual performance, specifically, the visual relationship between the observer and the environment. Visual Impact Assessment (VIA) is a standard requirement for large-scale infrastructure projects, wind farms, and scenic corridor planning. Historically, VIA relied on cross-sections or manual "sight-line" diagrams drawn on topographic maps. ArcGIS Pro automates this through the Viewshed toolset (part of the 3D Analyst or Spatial Analyst extensions), which calculates visibility based on line-of-sight algorithms across a raster DEM.

The Mechanics of Visibility: Observer and Target

The Viewshed tool operates on a simple binary principle: for every cell in the elevation model, the software determines if a direct line of sight exists to a specified "Observer Point." However, the accuracy of this analysis depends entirely on the correct parameterization of Offsets.

A common error in student work is running a viewshed on "bare earth" (Offset = 0). This assumes the observer is lying flat on the ground. To model human experience accurately, the landscape architect must define:

- OFFSETA (Observer Height): Typically set to 1.6 - 1.7 meters to simulate the average human eye level.
- OFFSETB (Target Height): The height of the object being viewed. For example, if testing the visibility of a proposed 50-meter wind turbine, this parameter is critical.

By manipulating these variables, the designer can perform "Reverse Viewshed" analysis. Instead of asking "What can I see from this park bench?", the designer asks "From which locations in the city is this proposed 20-story hotel visible?" This output, a Visual Zone of Influence (ZVI) is essential for determining if a new development will break a protected historic skyline or intrude upon a scenic view corridor.

Cumulative Viewshed and Screening

For linear projects, such as a scenic highway or a hiking trail, a single observer point is insufficient. The Geodesic Viewshed tool allows for the analysis of visibility along a dynamic path. By inputting a line feature (vertices representing the trail) as the observer, ArcGIS Pro calculates a Cumulative Viewshed.

The resulting raster does not just show simple visibility (Seen/Not Seen); it displays frequency. A value of '0' means the object is never seen; a value of '100' means the object is visible from 100% of the trail. This allows the landscape architect to quantify "Visual Magnitude."

Furthermore, this toolset is vital for Screening Analysis. By incorporating a Digital Surface Model (DSM) that includes existing trees and buildings rather than just a bare-earth DEM, the designer can test the efficacy of proposed mitigation strategies. For instance, "If we plant a 10-meter-tall row of Populus nigra along the berm, does it successfully screen the view of the industrial substation from the residential neighborhood?" The software provides a definitive, defensible answer, transforming visual aesthetics into a quantifiable metric.

Network Analysis: Measuring Movement and Accessibility

While surface analysis deals with the physical environment, Network Analysis deals with the human experience of that environment. A fundamental goal of urban landscape architecture is to ensure equitable access to public amenities like parks, plazas, and transit hubs.

Historically, planners measured access using the "Euclidean Buffer", a simple circle drawn around a point. If a neighborhood fell within a 400-meter radius of a park, it was deemed "served." This method is fundamentally flawed. It ignores physical barriers such as highways, rivers, and fences, and it assumes humans can fly. In reality, a playground might be 50 meters away "as the crow flies," but if it is separated by a six-lane arterial road with no crosswalk, it is effectively inaccessible.

ArcGIS Pro’s Network Analyst extension replaces these abstract circles with "Network Datasets", intelligent vector meshes that understand connectivity, direction, and speed.

Moving Beyond the Buffer: Service Areas (Walksheds)

The most impactful tool for verifying site accessibility is the Service Area solver. Unlike a buffer, a Service Area calculates the accessible zone based on travel capability along a specific network (sidewalks, trails, or roads).

For a landscape architect designing a neighborhood park, the Service Area tool generates "Walksheds", polygons representing everywhere a person can walk within 5, 10, or 15 minutes. This process requires configuring a Network Dataset with specific "Impedance" attributes, such as Time (based on walking speeds) and Distance. Critically, the network allows for the definition of Restrictions. A steep trail with a >8% slope can be tagged as a restriction for wheelchair users. By running the Service Area solver with this restriction active, the designer can generate a true "ADA Accessibility Map," highlighting exactly which portions of the park are exclusive to able-bodied users and identifying gaps in universal design (Law & Collins, 2022).

Location-Allocation: Optimizing Facility Placement

While Service Areas measure existing access, Location-Allocation is a prescriptive tool for planning new access. It answers the question: "Given a limited budget, where should we place new facilities to serve the most people?"

This tool is indispensable for large-scale master planning or municipal strategies (e.g., siting 10 new community gardens across a city). The solver uses a mathematical algorithm to minimize the total travel cost between "Demand Points" (population centers) and "Facilities" (candidate sites). For example, when siting emergency muster points in a large public park, a landscape architect can use Location-Allocation to scientifically prove that three specific locations will allow 95% of park visitors to reach safety within 3 minutes. This transforms site furniture placement from an aesthetic choice into a data-driven safety strategy (Gorr & Kurland, 2020).

Route Analysis and OD Cost Matrix

At a finer grain, Route analysis allows for the design of efficient circulation systems. In trail design, "Least Cost Path" analysis can determine the optimal route for a hiking trail that minimizes grade changes while maximizing scenic value (using viewshed rasters as a cost surface). Similarly, the Origin-Destination (OD) Cost Matrix is vital for analyzing flow. It calculates the travel time from multiple origins to multiple destinations simultaneously. This is often used in campus planning to analyze class-change dynamics determining if the proposed pathway width is sufficient for the volume of students moving between two specific faculty buildings during a 10-minute break.

Suitability Modeling and Geodesign

The ultimate objective of geospatial analysis in landscape architecture is Synthesis: the integration of diverse ecological, cultural, and physical factors to identify the optimal location for a specific land use. Historically, this was achieved through the "Layer Cake" method popularized by Ian McHarg (1969), where transparent acetate maps were physically overlaid to find areas of composite darkness (suitability).

In the digital era, this logic was translated into the Weighted Overlay geoprocessing tool. However, this traditional digital method remained static; if a designer wanted to test a different scenario (e.g., "What if we prioritize conservation over development?"), they had to re-run the entire tool chain, creating a proliferation of intermediate raster files.

ArcGIS Pro has revolutionized this workflow with the Suitability Modeler, a dynamic, interactive environment that operationalizes the principles of Geodesign. It transforms suitability analysis from a linear calculation into an iterative feedback loop, allowing the designer to tune criteria in real-time and immediately visualize the spatial consequences (Steinitz, 2012).

The Suitability Modeler Environment

The Suitability Modeler differs from standard geoprocessing tools because it is non-destructive and exploratory. It allows the landscape architect to combine multiple raster layers, Slope, Aspect, Distance to Roads, Land Use, into a single model without permanently altering the source data. The interface provides a Transformation Pane, which replaces the rigid "Reclassify" tool. Instead of manually typing in bin values (e.g., "0-10 degrees = Score 1"), the designer can use continuous transformation functions (such as Gaussian or Linear decay) to map raw data values to a common suitability scale (usually 1 to 10). This nuance is critical. For example, in a habitat model, suitability might not drop off internally at a hard "500-meter" buffer edge; it might decay gradually as distance increases. The Suitability Modeler allows this continuous ecological reality to be represented mathematically.

The Analytical Workflow: Weight, Evaluate, Locate

The workflow within the Modeler follows a structured decision-making process. First is Weighting (Scenario Testing). Once the layers are transformed to a common scale, the designer must assign relative importance (percentage weights). A landscape architect can create multiple scenarios within the same project, such as an "Economic" scenario prioritizing proximity to roads versus an "Ecological" scenario prioritizing wetland. By toggling between these, the designer can visualize conflict areas that require design mediation (Uy & Nakagoshi, 2008).

The final step is to Locate Regions. The Locate tab moves from pixel-based analysis to vector-based site selection. It allows the designer to specify spatial constraints (e.g., "Find the top 3 best sites, each with at least 5 hectares of contiguous area"). The software then scans the suitability surface to identify spatially contiguous regions that meet these geometric criteria. This connects the abstract analysis back to the physical reality of land development, providing the landscape architect with defensible, data-driven site boundaries (Gorr & Kurland, 2020).

Conclusion

The transition from ArcMap to ArcGIS Pro represents more than a mere software upgrade; it signifies a fundamental shift in the epistemological framework of Landscape Architecture. For too long, Geographic Information Systems were treated as a post-production tool—a mechanism for generating static inventory maps or justifying decisions already made. This review has demonstrated that the contemporary toolset within ArcGIS Pro allows GIS to function as a generative design engine, capable of driving the creative process from the initial sketch to the final site selection.

We have examined the critical necessity of "clean" data acquisition, arguing that the rigorous application of georeferencing and topological digitization is the prerequisite for any meaningful analysis. We have explored how surface analysis tools transform a passive topography into a dynamic system of flows, slopes, and microclimates, allowing the designer to engineer the landscape in concert with natural forces. Furthermore, by replacing Euclidean buffers with Network Analysis and static overlays with dynamic Suitability Modeling, we have shown how landscape architects can advocate for social equity and ecological resilience with mathematical precision.

Looking forward, the boundaries of the "GIS" profession are dissolving. The integration of BIM and GIS is rapidly maturing into the concept of the Digital Twin—a living, virtual replica of the built environment that contains both the macro-scale context of the landscape and the micro-scale detail of the architecture. Simultaneously, the bridge between ArcGIS Pro and game engines (such as Unreal Engine and Unity) suggests a near future where analytical data is not just viewed, but experienced immersively.

However, the sophistication of the tool never negates the responsibility of the designer. ArcGIS Pro is, ultimately, an instrument of Geodesign. It provides the metrics, but it is the landscape architect who must provide the meaning. By mastering these computational workflows, the profession can move beyond the "art of ornamentation" to claim its rightful place as the primary architect of the built environment’s performance, sustainability, and resilience.

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GEÇİCİ KAPAK

Kapak tasarımı devam ediyor.