ARCHITECTURAL SCIENCES AND SUSTAINABLE APPROACHES: URBAN RESILIENCE

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Architectural Sciences and Sustainable Approaches: Urban Resilience

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PREFACE

Dear Professors and Colleagues,

We are pleased bring to life that Architectural Sciences and Sustainable Approaches: Urban Resilience, which was published as an e-book by IKSAD Publishing House with the editors Prof. Dr. Ömer ATABEYOĞLU and Prof. Dr. Ertan DÜZGÜNEŞ.

This book project, entitled “Architectural Sciences and Sustainable Approaches: Urban Resilience,” aims to address sustainability-oriented approaches to urban resilience from theoretical, methodological, and practical perspectives. The volume seeks to establish a multi-layered platform of discussion, ranging from the scale of individual buildings to the entirety of the urban fabric. Within this framework, it welcomes contributions from scholars and researchers working in architecture, urban design, landscape architecture, urban and regional planning, environmental engineering, and related disciplines.

With the valuable contributions of our chapter authors working in the professional disciplines of landscape architecture, architecture, city and regional planning, urban design and sustainability, we have completed Architectural Sciences and Sustainable Approaches: Urban Resilience book study has been completed with 24 book chapters. We would like to thank you, our esteemed authors, for their contributions to the preparation of the book.

We would also like to thank the editorial board and IKSAD Publishing House. We wish to continue this process we have started in the coming years.

In addition, we would like to express our sincere appreciation to Prof. Dr. Atila GÜL, the book coordinator of IKSAD Publishing House, for his guidance and support throughout the publication process.

We hope that our book '***Architectural Sciences and Sustainable Approaches: Urban Resilience'*** will be helpful to the readers.

Best regards.

15.10.2025

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1. Introduction

With its dynamic nature, evolving and advancing technology offers new opportunities compared to past periods, leading to increased migration from rural areas to cities and, consequently, to greater urbanization. The majority of the world's population resides in urban areas due to the various opportunities they offer, which in turn puts increasing pressure on urban environments. On a global scale, the concept of the modern city can be traced back most closely to the post-Industrial Revolution era, when the demand for labor was largely met by populations migrating from rural regions. This rapid urbanization, while creating comfortable and convenient living conditions and fulfilling human needs for survival, enjoyment, and development, has simultaneously led to significant disturbance and damage to the urban natural environment (Long, 2022). This necessitates a paradigm shift towards sustainable urban planning and design (Figure 1), prioritizing the integration of natural plant species cultivation to mitigate environmental degradation and enhance urban resilience (Zarei & Shahab, 2025) (Gobster, 2010).

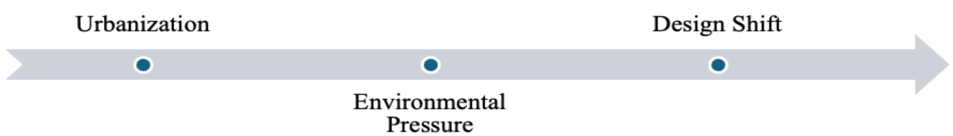

Figure 1. Emergence process of urban resilience

In this context, sustainable planning and design approaches gain importance, encompassing measures such as waste control, quality of structural materials, pollution prevention, and the balance between built and green spaces. Furthermore, the selection of plant species for urban open and green spaces is directly linked to sustainability, favoring native vegetation that requires minimal irrigation, pruning, fertilization, or pest control due to its inherent adaptation to local soil and climatic conditions. This approach not only conserves natural resources but also fosters biodiversity, thereby contributing to the ecological health and aesthetic quality of urban environments.

Urban sustainability depends greatly on ensuring urban resilience, and the concept of urban resilience includes many sub-concepts and factors. Urban sustainability is but one of the many sub-concepts of urban resilience, but is an important aspect of urban resilience. The concept of urban sustainability in turn incorporates many other concepts, and this research highlights some of the reasons and benefits of using natural vegetation and growing species in natural vegetation for the ecological sustainability of cities.

1.1.The Impact of Unplanned Urban Growth

Unplanned urban growth often leads to the loss of valuable green spaces and critical limitations on sustainable development, calling for a cross-functional urban greening approach before it is too late (Arshad & Routray, 2019). This urban growth (primarily occurring in the Global South) only adds to the environmental crisis of habitat fragmentation, extraction of additional resources and the ongoing degradation of the natural environment, meaning that adding green infrastructure as an integrated environmental scheme is key for urban growth and climate adaptation (Sahle et al., 2025). The urgency is also escalated by predictions that urban population will form two-thirds of the global population by 2050 (Figure 2), anticipated much of the concentrated load factor will continue to be due to the additional pressure of climate change and urbanization, following demographic change in populations (Applegate & Tilt, 2023). This rapid urbanization can cause significant environmental degradation, including too high heat exposure due to the urban heat island (UHI) effect, which results in temperatures that are elevated well beyond that of surrounding rural areas where the impacts of urbanization similarly stress the pre-existing ecosystems and ultimately physical health (Yılmaz et al., 2025). The compounded effect of heat health-related issues and urban air pollution, water quality degradation, loss of biodiversity, and flooding risks provides a very clear and urgent case for integrated urban green infrastructure solutions and planning for urban land (Menon & Sharma, 2021) (Teotónio et al., 2020).

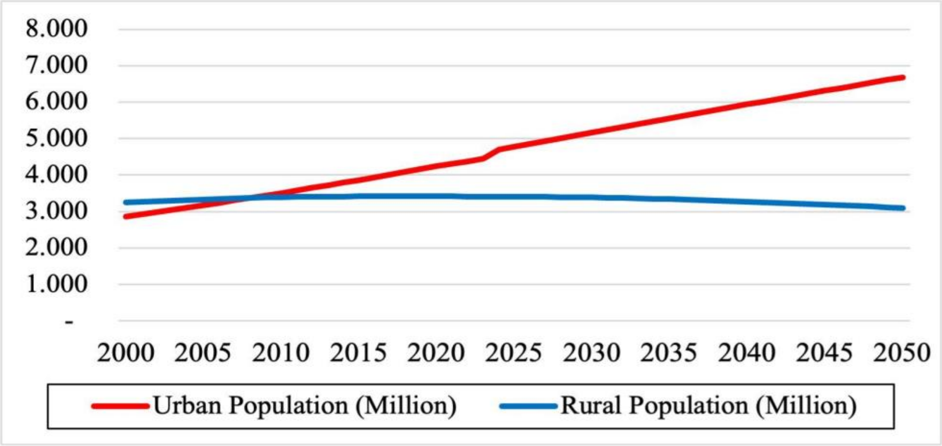

Figure 2. Indication of urban and rural growth by 2050
Source: United Nations, World Population Prospects 2022 (adapted by authors)

1.2.The Global Crisis: Resource Depletion and Pollution

Using non-native plant species that thrive outside of their local environment, especially need more water and high pest control which is a major driving force behind chemical waste that causes both soil and water pollution. The use of chemical pesticides contributes significantly to accelerating global warming, climate change, and depleting non-renewable natural. Unsustainable practices or approaches often negate any ecological benefits that are associated with urban greening and it clearly demonstrates our need to incorporate local species that provide support for local biodiversity and ecosystem services (Edeigba et al., 2024). On the other hand, smart use of native species will create a variety of ecological benefits that will lead to greater resilience to climate variability and allow for an opportunity to lessen the ecological footprint for urban care (Hensel, 2021). This means better land use planning to create and maintain urban green spaces, parks, urban gardens and roadside vegetation and demonstrate the value of mitigating airborne pollution and myriad ecosystem services (Ramaiah & Avtar, 2019). With suspected accelerating climate change and warming of urban areas under heat island effect as a result of loss of natural habitats and development sites leading to impermeable surfaces, our current urban planning process needs to include sustainable land use tools that focus on including nature-based solutions as they will have greater consequences on biodiversity loss, air quality, and overall urban ecology (Yan et al., 2024) (Ibrahim et al., 2020).

Population growth, industrialization, and urbanization have made urban morphology and energy composite notorious and have caused multiple environmental crises such as worsening air quality and an increase in average temperature within cities (Efe & Eyefia, 2014). This is a huge threat to human health and wellness and an urgent change towards green infrastructure must be made to reduce and limit the effects of urbanization on health and well-being (Liu et al., 2021). The loss of green spaces over time, because of urban expansion, is limiting biodiversity loss and urban centers should really promote integrated urban development that conserves and promotes natural habitats (Nshimiyimana et al., 2023). This also calls for more extensive usage of green infrastructure in urban planning including urban farms and urban forests to help mitigate environmental effects and promote a healthier urban ecosystem (Rallapalli et al., 2019).

1.3.Climate Change as a Consequence of Urban Expansion

Continued urban growth, primarily through sprawl, is one of the most critical factors to contribute climate change in cities. Urbanization increases impervious surfaces to increase the urban temperature, which severely impacts local hydrological cycles (Bai et al., 2017). This alteration can have multiple effects downstream, such as increased runoff, reduced groundwater recharge, UHI, and flood risk (Ajjur & Al-Ghamdi, 2022). Urbanization also raises energy consumption, as it increases cooling loads due to high urban temperatures, which also contributes to greenhouse gas emissions, resulting in further climate change (Ferrer et al., 2016). The combination of increasing energy demand due to air conditioning plus the energy to meet this need puts burdens on existing energy systems, which also increases carbon emissions, and challenges the sustainability of cities (Salamanca et al., 2013). The complex relationships between urban growth, climate change, and human health, wellbeing and livelihoods require an immediate transformation to sustainable and resilient urban planning, focused on green infrastructure and nature-based solutions for climate change adaptation and mitigation (Pandey & Ghosh, 2023) (Das et al., 2024) (Javidroozi et al., 2023). The transformation requires a reconceptualization of urban development, which relies on ecological concepts and focuses on climate resilience, to create new models of urban design to improve climate adaptation and climate change mitigation (Das et al., 2024). A resilience model incorporates urban green infrastructure as a key component of resilient socio-ecological systems, not just to improve aesthetics in the built environment, but to help society adapt to climate variability and improve urban livability (Vargas-Hernández & Zdunek-Wielgołaska, 2020) (Kabisch et al., 2021). Integrating nature-based solutions and green infrastructure into urban planning is essential to address the growing climate change pressures, promote urban resilience, and improve the quality of live for urban dwellers (Raparthi & Vedamuthu, 2022) (Choi et al., 2021).

1.4.Urban Heat Islands and the Role of Green Spaces

The urban heat island effect refers to the phenomenon where urban areas experience higher temperatures than their non-urban counterparts, primarily due to intensive energy use, reduced air quality, and associated impacts on human health (Irfeey et al., 2023) (Naserikia et al., 2019). Minimization strategies must be created, and how to achieve this is important. Green infrastructure is one important nature-based solution for addressing urban overheating and providing enhanced thermal comfort (Yuan, 2024) (Yılmaz et al., 2025). In reality, the urban heat island effect only occurs because many studies attribute component parts to it from anthropogenic heat sources and impermeable urban surface temperatures. In addition to agreements in the literature, it is known to increase temperatures of urban areas and compromise human beings, and more than ever, increasing urban planning and cities' actual response to hot conditions must be part of urban planning interventions (Nazarian et al., 2022). Urban green spaces, i.e., parks, urban forests, and green roofs, have significant potential for lessening the urban heat island effect, as green spaces provide shade, conduct evapotranspiration, and/or allow air to circulate (Kirschner et al., 2023). In particular, not only do green are partially absorb heat from urban areas, but they create a healthier urban microclimate to provide a bigger picture to urban sustainability (Song et al., 2024) (Oğuztürk et al., 2025). Specifically, green roofs can have substantial reductions of surfaces and ambient temperatures of up to 30 °C surface temperatures and thus lessen the urban heat island direct measures to mitigate and stormwater manage are superior (Zhang et al., 2024). Another method of how diverse green infrastructure is strategic is in the form of private dwelling gardens, or yards and patio, and flowerpots, which also can use some of the referred cooling effects of shading and evaporative cooling (Taleghani et al., 2019). Altogether, in addition to local effects, large urban parks and/or large green spaces are both subsequently, required to lessen urban heat island effects from a regional, agglomeration scale affecting nearby built environments (Wong et al., 2007) (Bosch et al., 2021). Because urban designers and planners must consider the high intensity, density to reduce urban heat islands (Aram et al., 2019). It understands together and the highest potential for reducing urban heat and contributing to improving urban microclimates means everything basic to improving the performance of increasing quality of urban life and so the term "urban became connected. Of all the areas of green blue grey infrastructures, registrarial, vegetation-based, water-based, and engineered green structures show a complete (overall) response to lessening overheating of urban areas and reduce energy in a positive way to be quality of the urban dweller's life is greater (Kumar et al., 2024). In the, design and development phases, integrating natural plant species in green infrastructures is crucial because natural plant species, made of existing plant species, are already suited and adapted to a more local climate. This qualitative response of species suitability and adaptation, for example, make green infrastructure systemic and sustainable systems for the city. Also, in the same dialogue, a perspective of how natural plant species provide maximum opportunity in a minimum area similar to space is precious for small urban environments.

1.5.Landscape Practices and Their Environmental Impact

Traditional landscape practices are heavily reliant on a high-input model of practice (heavy irrigation, chemicals (fertilizers and pesticides), and irrigation techniques, etc.) that causes water pollution, soil degradation, and loss of biodiversity when placed within the ecological context of urban settings. Traditional landscaping practices with little potential for ecological integrity are also increasing the heat island effect in urbanized areas by ignoring the benefits of planting native and climate/hydrology adapted plant species that require fewer resources (Mackey et al., 2011) (Virtudes, 2016). The exclusion of native species and resource-conserving plant species creates less resilient urban ecosystems that are not able to buffer against wide climatic differences or support native flora/fauna biodiversity (Shiu et al., 2022). The use of sustainable landscape practices that keep native and climate and hydrology adapted plants as part of the initial landscape design supports viable ecosystems by conserving water, reducing chemicals, and increasing urban biodiversity to create more resilient and ecologically sound urban practices. In addition to the adoption of sustainable landscape practices, policy and planning mechanisms should work together to encourage more sustainable practice adoption in urban areas and landscapes and create urban landscapes that are rich, impactful, and ecologically and economically sound (Gunawardena et al., 2017).

1.6.Principles of Sustainable Urban Design

Sustainable urban design seeks to integrate natural processes, and ecosystem functionalities into the built environment in order for our cities to become resilient, sustainable, and livable (González et al., 2023). It helps reduce its ecological impact, but encourages social equity and economic feasibility when communities achieve efficient land use, resource consumption, and benefit from green infrastructure. The intentional selection of species or vegetation that is climate- and soil-specific to the existing ecosystem is necessary to achieve sustainability because it significantly reduces maintenance requirements and embodies the most efficient resource use (Shahmoradi & Marvi, 2015). Additionally, by choosing appropriate species populations of the urban ecological character, and particularly, native plants, it provides an important opportunity to increase local biodiversity, improve ecosystem services, and re-enforce urban connection to the natural environment. Sustainable urban design promotes and prioritizes the needs of nature against the needs of humankind. Thus, an ideal sustainable urban design aims to mitigate the negative ecological impact of the built environment (in terms of water, soil, air and climate) (Thomson et al., 2022). Therefore, urban growth or development should contribute to neither the poisoning nor the degradation of ecological health. Urban cities must develop and uphold their biodiversity and be resilient enough to negotiate the actions of both human and non-human inhabitants. Sustainable urban design prescribes ways to deviate from traditional urban design models, including comprehensively adopting resistance practices (Yiu, 2025). At the heart of this paradigm is the understanding that the built environment must enhance, rather than diminish the natural environment, while planning doses must be economically sustainable and supported by a broad range of public consensus (Parra, 2002). The use of heavy agricultural equipment and other technologies, will need to be part of sustainable urban design practices that will mitigate endless, poor urban growth and truly allow to responsibly diversify and implement sustainable forms of urban design in cities. Urban agriculture is also not only praised for its contributions to urban sustainability in food procurement and maintaining landscapes (Arshad & Routray, 2019) but viewed as a vehicle for more equitable and sustainable public policy objectives addressing equitable access to good food and the environmental impact of the food chain (Saint-Gès et al., 2024). These technologies play an important role in resources optimization; trash reduction, impacts on the environment, and enhancing the resilience of urban ecosystems, directly link to sourcing natural plant species and management of green infrastructure (Shehata et al., 2022; Yuan et al., 2022).

In order for all urban dwellers to access natural resources that can be passed on to the next generations, while also keeping a proper balance between conserving and using those resources, viable planning and design approaches are gaining traction under the rubric of "combating climate change." Many actions are being implemented in the process of conserving and using the natural resource base of the earth, in areas such as inventorying and protecting existing resources, producing and utilizing renewable resources, and minimizing all waste outputs.

Sustainable design in urban public spaces is not only connected to sustainable development in diverse areas, such as using appropriate structural materials, avoiding materials that pollute, accounting for the ratio of buildings to existing open and green spaces, but also the plants under consideration in plants used/preferred plants in urban open and green spaces. Therefore, one of the main practices to provide sustainable futures and protect natural resources is if the choice/use of vegetative plants in their native ecosystems are as naturally behaving as possible and require no maintenance (eg. watering, pruning, fertilizing, and pesticides) and choose sweetly variable contextually plant species that demonstrate the highest level of adaptability to the natural soils and climates inherent to those native ecosystems.

2. Material and Method

This study was designed as a comprehensive review of literature focusing on the role of native plant species in sustainable urban design. To ensure transparency and replicability, a systematic procedure was followed in the collection, screening, and analysis of sources.

2.1. Literature Identification

Scientific publications were retrieved from major academic databases (*Web of Science, Scopus, Google Scholar*) covering the period between 2000 and 2025. Keywords such as *urban resilience, native plant species, xeriscaping, sustainable landscape design, water-efficient landscaping, climate-responsive urban planning,* and *automation in urban ecosystems* were used in various Boolean combinations. Additional relevant materials, including policy documents, municipal guidelines, and reports by international organizations, were considered to complement the academic literature.

2.2. Screening and Selection Criteria

All identified records were imported into reference management software, where duplicate entries were systematically removed. The initial screening was conducted on titles and abstracts, excluding studies that did not address sustainable urban design, native vegetation, or ecological and technological aspects of landscaping. Priority was given to peer-reviewed articles, book chapters, and conference proceedings with clear methodological contributions.

2.3. Eligibility Assessment

Full-text evaluation was applied to the remaining studies. Publications were excluded if they lacked methodological rigor, contained insufficient data on vegetation and design practices, or focused exclusively on ornamental plants without sustainability considerations.

2.4. Inclusion for Synthesis

The final set of studies was thematically categorized into clusters such as:

- Ecological benefits of native vegetation,
- Xeriscaping and water-efficient practices,
- Technological and smart system integration,
- Governance and planning frameworks for sustainable urban ecosystems.

2.5. Data Extraction and Thematic Analysis

For each included study, descriptive data (authors, year of publication, methodological approach, vegetation type, and ecological/technological contribution) were extracted. Thematic coding was used to identify recurrent strategies, design principles, and barriers in integrating native species into urban landscapes. This process allowed for comparative evaluation across different contexts without limiting the scope to a specific geographic region.

3. Findings and Discussion

Within the scope of sustainable and resilient urban landscape design, the preference and use of perennial plant species instead of annual and/or seasonal plant species, especially in urban open and green areas, ensures water-efficient landscape design while adhering to drought-tolerant landscape design principles.

The concept of xeric landscaping is based on the idea that only certain types of plants can survive during periods of drought. Accordingly, a landscaping approach appropriate to different climate characteristics must be determined. The primary objective of this approach is to minimize water consumption by using plants with low water requirements and to ensure the sustainability of natural water resources (Barış, 2007). Applications that are adapted to natural vegetation and have xeric landscaping characteristics are becoming increasingly competent today (Çorbacı et al., 2017; Çorbacı and Bayramoğlu 2021).

During the sustainable planning and design process, xeric landscaping will be implemented by selecting/using plant species found in natural vegetation, and existing water (clean water) resources will be protected.

Within the scope of water-efficient design, sustainable urban open and green spaces will be created by developing new methods and practices such as minimizing the use of clean water, increasing wastewater, and harvesting rainwater, thereby supporting the struggle with climate change.

3.2. The Importance of Native and Low-Maintenance Plant Species

The inclusion of native and low maintenance plants in urban landscapes is a core principle of sustainable urbanism, offering multiple environmental, economic and social benefits. Native plants are intrinsically suited to local climatic conditions, and require little irrigation, fertilization and pest management than plants introduced from other regions of the world. As a result, urban green spaces can significantly diminish their ecological footprint. (Russo et al., 2025). By using native plants, urban green spaces can conserve valuable resources, deepen local biodiversity, create habitats for native wildlife, and contribute to urban ecosystems that are more stable and resilient (Yiu, 2025). Native plants also contribute to the aesthetics of urban areas, demonstrating regional identity and enhancing the sociocultural value of public spaces (Al-Hagla & Al-Sulbi, 2025) (Stino, 2017). Choosing native plants also encourages stronger connections to the local ecosystem, develops community interest and interaction with ecological systems, and aids the overall sustainability goals of urban system development (Shareef & Altan, 2021). Additionally, the deep roots native plants tend to possess supports soil stabilization and permeability, supporting water management that minimizes negative urban runoff (Ulloa-Espíndola et al., 2022). In this manner, native plant establishment provides significant carbon-sequestration functions, which improves urban air and mitigates climate change through natural processes.

As a part of the landscape design process, the local characteristics of climate and soil requires consideration too. Particular attention should be paid to the use of natural plant species in the design. This is because natural plants require very little watering after the landscape application is completed, or they do not require additional watering beyond natural rainfall. In addition, they do not require additional fertilization and are more resistant to diseases and pests.

3.3. Water-Efficient and Climate-Responsive Landscaping

In particular, the large-scale consumption of water in open green spaces has necessitated the development of new landscape designs that use as little water as possible. In this regard, landscape design principles that differ from classic landscape design concepts such as "Water Efficient Landscaping," "Water-Wise," "Low Water," and "Natural Landscaping" have been developed (Barış, 2007). One of the first conceptual approaches developed with the formulation of these basic principles is "Xeriscape," which can be defined as a type of landscape design that aims to conserve water resources and the environment by using the least amount of water possible. This concept was first developed in 1981 by the Denver Water Department to promote water conservation in landscape design, combining the Greek word "xeros" (meaning 'dry') with the English word "landscape."

There are seven basic principles underlying xeric landscaping which are:

- Planning and designing that minimizes the amount of lawn space and requires the least amount of watering.
- Conducting soil analysis and improving soil conditions in accordance with the results,

- Selecting natural plant species that require minimal water and are drought-resistant,
- Designing lawn areas in a way that offers practical and economical solutions that facilitate application and maintenance work,
- Establishing an effective watering system,
- Mulching (covering the soil with materials that can create suitable temperature and moisture conditions around plant roots and preserve soil moisture, such as dry leaves, straw, etc.)
- Conducting appropriate and regular maintenance work (Barış, 2007).

According to the xeric landscaping strategy, natural and ecological factors are taken as a basis, maximum benefit is obtained from existing water resources while water consumption is minimized, and the balance of "conservation" in nature is maintained. Xeriscaping saves energy, time, and money while providing ecological benefits such as increasing the drought resistance of plants, providing habitats for fauna, contributing to the sustainability of natural resources, and creating spaces with high landscape character and quality—offering numerous ecological and economic benefits (Çorbacı and Ekren 2022).

In xeriscape applications, the use of large lawn areas and hydrophytic (aquatic) plants should be kept to a minimum, and plants with high drought tolerance should be preferred (Hersek and Korkut, 2021). This approach emphasizes the selection of drought-tolerant and climate-adapted vegetation, meticulously chosen to thrive within the specific hydroclimatic regimes of urban areas, thereby significantly reducing the demand for potable water in irrigation (Table 1). This practice, often termed xeriscaping or water-efficient landscaping, involves thoughtful plant grouping, efficient irrigation systems, and the utilization of mulches to optimize water retention and minimize evaporation. Such strategies are crucial for sustainable urban development, particularly in arid and semi-arid regions, where water scarcity is a pressing concern (Wang et al., 2020).

Furthermore, the incorporation of nature-based solutions such as green roofs, permeable pavements, and rain gardens increases retention and infiltration and transforms urban environments into more resilient "sponge cities" that can manage stormwater successfully, creating resilience against flooding (Rosenberger et al., 2021). These green infrastructure interventions address flooding, reduce urban heat by providing evapotranspiration during stormwater management, which can rehabilitate the urban heat island effect (Reinstaller et al., 2025) (Pace et al., 2025). In addition to hydrological benefits, the integrated systems described, may provide wider ecological services that deliver biodiversity services and potential aesthetic and recreational benefits for urban green space users (Sitzenfrei et al., 2020). Notably, this way of adaptive management links science and knowledge, supporting shifting to a resource-centric agenda, rather than simply considering rainwater as a risk hazard, which potential to regenerate urban ecosystems and increase the resilience of cities (Palazzo, 2018).

Table 1. Comparison of Key Characteristics of Native and Non-native Plant Species in Urban Landscapes

Criteria	Native Plants	Non-native / Imported Plants
Water Consumption	Low	High
Pest Control Need	Minimal	Frequent
Soil Compatibility	Naturally Adapted	Often incompatible
Biodiversity Contribution	High	Low
Maintenance Requirement	Low	High
Climate Adaptability	Excellent	Varies
Chemical Input (Fertilizers/Pesticides)	Low	High
Aesthetic Integration	Region-specific	Often ornamental but mismatched
Lifecycle Cost	Low	High
Carbon Sequestration Potential	High	Varies

3.4. Automation and Robotic Applications for Urban Green Spaces

The upkeep of urban green spaces requires ground maintenance activities such as pruning, irrigation, fertilization, pest control, and waste disposal, which all have significant environmental footprints with regard to energy use and greenhouse gas emissions. To identify efficiencies and reduce footprint impact is the utilization of automation and robotic technology. For example, automatic mowers are used for sustainability (Hubbard et al., 2021). Outlined designs for lawnmowers indicate the range of multi-functional and low noise alternatives for trimming bushes and grass (Liu, 2014). Water efficient cleaning devices for roadside green belts have been developed to enhance water utilization and energy efficiency (Lu et al., 2013). Urban agriculture is also emerging in cities to provide more food production in limited space (Dhakal et al., 2015), therefore, robots are being designed uniquely to monitor plants, facilitate precision-based irrigation methods, and provide economical designs for individual or urban farm level green spaces (Moraitis et al., 2022). Robotic systems are vital to improve urban farming by monitoring plants, improving resource use and sustainability (Kempelis et al., 2024).

The landscape plan that will be developed should take into account regional and microclimatic conditions, existing vegetation, topography, land use and most importantly, how to group plants where they require similar water amounts.

Watering will depend on the season, amount and length of light exposure, microclimate, type of plant, and soil. If an automatic control system is used for watering, it can be fully dependent on the season and setup based on the weather. Automatic systems must be turned off if there is rain, to save water (Deniz, 2009).

In areas with high evaporation rates, plants either go directly into dormancy or die immediately from drought by covering the upper layers of soil with their roots.

To prevent damage to plants or death due to overwatering instead of underwatering, the water requirements of existing plants should be well understood and the appropriate amount of water should be provided. When the optimum amount of water required by the plant is used, water savings will also be achieved.

3.5. Smart Systems and Sensor Technologies in Urban Greening

The advent of technologies such as the Internet of Things, computer vision, artificial intelligence, and machine learning is revolutionizing urban agricultural practices by improving efficiency, monitoring capabilities, and decision-making processes (Kempelis et al., 2024; Mahmud et al., 2023). Management systems incorporating IoT technologies are now being used to monitor and management environments, developing the logistics of supply of locally grown fresh produce, in controlled environments and indoor container farms (He et al., 2022). These systems allow for precision agriculture and incorporate sensors and automation to reduce reliance on labour while allowing for effective management in ornamental nursery crop production (Mahmud et al., 2023). The devices can provide real-time information of soil moisture, nutrient levels and plant health allowing them to manage their resources efficiently (Xing & Wang, 2024). Smart irrigation systems are also being developed to provide exacting nutrient concentrations which enable precise nutrient application which supports plants grow needs at varying stages (Sangeetha & Periyathambi, 2024). In vertical farms aeroponics systems and water recovery technologies represent some of the most advanced agronomic production systems using water very efficiently (Carotti et al., 2023).

3.6. Urban Agriculture and Controlled Cultivation Systems

In addition to nature-dominated approaches emphasizing native plants in the public realm, controlled cultivation systems (e.g., vertical farming and plant factories) provide a useful alternative system to address land constraints and rising food demand. These directed cultivation systems can be deployed at a building, block or district scale to increase production per land area and reduce supply chains within cities, enhancing food security and reducing emissions from transport in a congested urban fabric (Wang et al., 2023; Wood et al., 2020). Importantly, controlled cultivation systems are not replacing natural vegetation or non-built green space, rather they are coming in to fill certain provisioning holes while the city restores, increases, and ecologically upgrades blue-green infrastructure at the same time.

From a resource efficiency perspective, modern cultivation systems utilize recirculating hydroponics/aeroponics, close nutrient-loop delivery, and tight environmental control to minimize water losses and production inputs per kilogram of product (Erekath et al., 2024; Kabir et al., 2023; Morella et al., 2023). Sensor networks, IoT-enabled automated systems and machine-human intelligence decision support are adapting to minimize fertilization and canopy management, noting design recommendations for infiltrating built environments in a water-efficient way (He et al., 2022; Mahmud et al., 2023; Kempelis et al., 2024). Since energy demands can be considerable, it is best practice to couple these systems with on-site renewables, waste-heat recovery and demand-response operation, concurrently with design teams examining project life-cycle trade-offs on-site so that lift in water use efficiency is not be consumed by undue energy load impacts.

Controlling cultivation systems can be strategically integrated into urban plans in order to share space and resources with native plant public space to provide a more resilient multifunctional urban ecosystem. Actionable examples include: tying rooftop farms to green roofs to provide additional stormwater retention capacity, heat mitigation; selecting crops and cultivars suited to regional climate and market needs; retrieving nutrients from organic waste-sites; and, when appropriate indexing water use per kg, energy use per kg and biodiversity metrics into municipal procurements and zoning incentives (Oh & Lu, 2022). In this way, cultivation systems can be thought of as targeted solutions enabled by technology to complement nature-dominated designs in a way that cities can meet food and resource demands, while native vegetation remains the foundation for biodiversity, microclimate regulation, and cultural identity.

3.7. Toward a Resilient and Sustainable Urban Future

This section explores methods and practices of urban planning and design that recast and aim to develop a holistic approach to planning that can seamlessly integrate the cultivation of local flora with enhanced water management and climate adaptation practices (Snep et al., 2020) (Sharma et al., 2023). A holistic approach coherently implies there is a capacity for urban communities to increase resilience against the impacts of climate change, including both excessive heat and flooding, harnessing the concepts of ecology to create urban ecosystems that are self-sustaining (Avramidou & Manika, 2021). The notional resources necessitate a reversal from centralized, single-purpose infrastructure to decentralized, multi-functional green infrastructure where urban surfaces can simultaneously maximize ecological performance and deal with resource issues (Pille & Säumel 2021) (Croce, Inc. et al Ap. 2019). The success of these integrated approaches wholly depends on the continuous inventive use and universal uptake of agricultural equipment and smart technologies that will allow nature-based options to be implemented efficiently in the medium and long-term profitable methodologies (Ogwu & Kosoe, 2025). This comprehensive strategy acknowledges that, in light of the rising global urbanization levels and a certain degree of impermanence in climate, the urban water role needed to manage will require more than the traditional "grey" infrastructure alternatives, and embracing the provision of nature-based solutions will be capable of flooding controls, improved water quality and possibly climate resilience (Ahmed et al., 2022). Certainly, with extreme precipitation events likely to increase urban vulnerabilities and not wanting to experience the impacts of significant, and sometimes devastating pluvial floods, had conventional urban drainage systems provide much refuge (hyo-min et al., 2016) (Shevade et al., 2020). Naturally, we must recognize there are increasing calls for resiliant and sustainable urban drainage and what improvements can be made from green-grey infrastructure systems that aim to be flexible and adaptive to exciting climatic shifts (Fereshtehpour & Najafi, 2025; Kourtis et al., 2020). This recognizes the transformation and innovative approaches to urban water management and planning to co-consider, one urban water cycle that devotes equal treatment to the management of supply and demand, wastewater treatment for reuse and stormwater reuse, ensuring valuable human and natural elements become part of an urban water cycle as competitively valuable, securing sustainable and circular economies of water (Maftuhah et al., 2018) (Taouraout et al., 2020). This shift remains immensely important if we are to make urban environments sufficiently firm to withstand the onslaughts of environmental shocks and return to voluntary equilibrium, thus giving urban residents a deserving, healthy place to live (Beceiro et al., 2020) (Doulabian et al., 2023).

3.8. Water Efficient Landscape Design for Urban Sustainability

With increasing building density in cities, the amount of impermeable surfaces is also increasing, and the amount of open and green spaces is decreasing at the same rate. As part of the fight against climate change, one of the most important global issues, the formation of urban heat islands, air pollution, noise pollution, and similar issues caused by the increase in impervious surfaces in cities, intensive vehicle use, and the decrease in green areas, as well as the protection of existing resources, the control of resource use within the framework of a conservation-use balance, and the protection of biodiversity are among the issues included in the action plans.

Water, one of the most important resources that must be protected on a global scale, is also a key focus of water-efficient design, a method used to protect water resources and combat climate change. Water-efficient landscape design is finding its place in the design of urban open and green areas due to its features such as reducing water consumption, preserving biological diversity through the use of natural plant species, lowering facility and maintenance costs, contributing to the local economy, and enhancing visual landscape value through adaptive plant species.

4. Conclusion and Suggestions

The species in the natural vegetation of a region are those that are best suited to the natural landscape features of that region, such as climate conditions, rock structure, soil structure, slope, and wind, but there may also be species that directly require existing features. In this context, these species develop without the need for intervention or maintenance. Plants that grow, develop, branch out, leaf out, flower, and shed their leaves according to seasonal and climatic conditions offer a visual feast of different cycles throughout the year when the conditions and combinations appropriate to their location are provided. Plants that showcase the seasons and seasonal transitions through their leaves and flowers should be selected from the natural plant cover species to meet the recreational needs of people living in residential areas/urban dwellers in terms of their interaction with nature. Choosing native species for urban open and green spaces will bring many benefits. For example, creating large grassy areas in urban areas will increase water consumption and lead to maintenance requirements such as fertilization, planting, and mowing. However, natural species such as pimpernel, periwinkle, and rock samphire can be used to create extensive open and green spaces in cities without the need for pruning, watering, or fertilization. Therefore, the selection and use of natural species will provide both ecological and economic benefits.

In the planning and design processes of cities, many issues are addressed, such as land use, possible growth directions, and alternative transportation systems, through the accurate analysis of ecological data. Within this scope, studies are conducted that include the locations and quantities of urban open and green spaces. Areas such as refuges, parks, gardens, and recreational areas are defined as urban open and green spaces. In the urban design process, the basic principle of road side green belts in all planned new transportation systems and the selection of natural species for refuge plants will enable ecological gains in many areas, such as low maintenance costs, economic benefits, the non-use of clean water sources for irrigation, the prevention of groundwater pollution, and the prevention of urban heat island formation through the establishment of a permeable -impermeable surface balance, and preventing the formation of urban heat islands.

Selecting species that are naturally present in the vegetation cover as part of water-efficient landscape design or xeriscape design will reduce implementation costs, eliminate the need for additional chemical inputs as these are the most suitable and adapted species for the existing microclimate, prevent contamination of groundwater resources by eliminating the need for fertilizers and pesticides, Since these are plants with the lowest water requirements, water and energy consumption will be minimized, and maintenance will be required. The invasive characteristics of imported plants will be prevented, and the biodiversity of the existing vegetation will be preserved. During the design phase, it is essential to thoroughly analyze and evaluate the existing environmental conditions, such as climate, soil, topography, and vegetation, to the highest possible extent and ensure their protection.

Retention of existing vegetation cover and the incorporation of local, drought tolerant and water-wise plants in landscaping are crucial considerations. Lawn areas should be minimized and perennial ground-covering plants should be selected over annual flowering plants. Specific irrigation systems for the water needs of the plant, mulch for soil moisture retention, rainwater harvesting and onsite rainwater storage, and reuse of wastewater for landscaping irrigation are the key methods to effectively conserve water. It has become imperative for all sectors and professions to take precautions against increasing drought. The drought problem experienced in large cities during the dry winter season highlights the need for efficient water use and the protection of water basins and resources (Atik ve Karagüzel 2007). Agricultural engineers and landscape architects should come up with natüre-based ideas as interdisciplinary solutions within the context of urban resilience.

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Author Contribution and Conflict of Interest Declaration Information

All authors contributed equally to the article.

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