Türkiye Peyzaj Araştırmaları Dergisi
2025, 8:1, 1-20
Derleme Makalesi

Turkish Journal of Landscape Research
2025, 8:1, 1-20
Review Article

THE ROLE OF URBAN LANDSCAPE IN CREATING RESILIENT CITIES: AN EVALUATION IN THE CONTEXT OF URBAN HEAT ISLAND EFFECT

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Abstract

The urban heat island effect, which is caused by rapid population growth, uncontrolled urbanisation activities and uncontrolled use of natural resources, is one of the issues that should be addressed as a priority not only because of meteorological changes, but also because it reduces the quality of life of urban people and threatens public health. In this context, the study aims to address the importance of urban open green spaces in creating cities compatible with climate change and to reveal what kind of methods should be used to reduce the urban heat island effect. In this context, the relevant academic literature has been examined in detail, practices developed to minimise the urban heat island effect at national and international level have been evaluated and descriptive analysis method has been used. As a result, suggestions are made on which adaptation and adaptation policies can be developed to increase urban resilience.

Anahtar Kelimeler: *Urban Heat Island, Climate Change, Urban Resilience, Urban Landscape, Urban Open Green Space.*

DİRENÇLİ KENTLERİN YARATILMASINDA KENTSEL PEYZAJIN ROLÜ: KENTSEL ISI ADASI ETKİSİ BAĞLAMINDA BİR DEĞERLENDİRME

Özet

Hızlı nüfus artışı, kontrolsüz kentleşme faaliyetleri ve doğal kaynakların kontrolsüz kullanımı sonucu ortaya çıkan kentsel ısı adası etkisi, sadece meteorolojik değişimler nedeniyle değil, kent insanının yaşam kalitesini düşürmesi ve halk sağlığını tehdit etmesi nedeniyle de öncelikli olarak ele alınması gereken konulardan biridir. Bu bağlamda çalışma, iklim değişikliğine uyumlu kentler yaratmada kentsel açık yeşil alanların önemini ele almayı ve kentsel ısı adası etkisini azaltmak için ne tür yöntemler kullanılması gerektiğini ortaya koymayı amaçlamaktadır. Bu kapsamda ilgili akademik literatür detaylı olarak incelenmiş, ulusal ve uluslararası düzeyde kentsel ısı adası etkisini en aza indirmek için geliştirilen uygulamalar değerlendirilmiş ve betimsel analiz yöntemi kullanılmıştır. Sonuç olarak, kentsel dayanıklılığın artırılması için hangi uyum ve adaptasyon politikalarının geliştirilebileceğine dair önerilerde bulunulmuştur.

Anahtar Kelimeler: *Kentsel ısı adası, iklim değişikliği, kentsel direnç, kentsel peyzaj, kentsel açık yeşil alan*

Received (Geliş tarihi): 14.12.2024, **Accepted** (Kabul tarihi): 27.06.2025 *Corresponding author (İletişim yazarı: *basakyurtseven1@gmail.com*)
Citation (Atıf): Yurtseven B.., Güler U., (2025) The Role of Urban Landscape in Creating Resilient Cities: An Evaluation in The Context of Urban Heat Island Effect Turkish Journal of Landscape Research, 8 (1), 1-20, **DOI:** https://doi.org/10.51552/peyad.1601036

1. INTRODUCTION

Most cities around the world are characterized by changes in air movement, air pollution (or changes in air composition), land economy and temperature economy. In other words, the air in cities is extremely hot, polluted and stagnant (Bernatzky, 1982). Especially in large residential areas the change of atmospheric conditions and the formation of an artificial climate are clearly felt or consequences are visible (Bernatzky, 1982). The new forms created by the 20th century technology in the topography of the land through excavation-infills, the transportation and destruction of ground cover such as plants, soil, rock and water, the draining of swamps, the masses of buildings built side by side in stone and concrete molds and the increase in the number of vehicles create significant changes in the urban climate (Öztan, 1970).

Climate change, which is a global problem with severe consequences observed in the last century and even more severe consequences expected, appears as a complex problem all over the world (Adger et al., 2005; Leal Filho et al., 2021; Feliciano et al., 2022; Abbass et al., 2022). The Intergovernmental Panel on Climate Change (IPCC) has revealed that the main cause of global climate change is greenhouse gas emissions resulting from human activities and that a significant increase in these emission values has been observed (IPCC, 2013). Greenhouse gases consist of approximately 72% Carbon Dioxide (CO2), 19% Methane (CH4) and other gases. The significant increase in carbon dioxide is primarily due to the use of fossil and biomass fuels. Secondarily, it is shown as the change in land cover and land use (Orhan, 2021).

Urban areas constitute about 5% of the world's surface as a dynamic and complex ecosystem. Approximately 55% of the world population lives in cities. This rate is expected to reach 70% by 2050 (Zhan et al., 2013; Jain et al., 2017; Khan et al., 2021; UNDESA, 2023; Yılmaz & Öztürk, 2024). With the increase in urban population, cities experience continuous growth and change, land cover changes, and this affects the formation of urban heat islands (Öztürk & Yılmaz, 2023; Üstündağ et al., 2023). This climatic difference between urban and rural areas was first defined as "urban heat island" by Luke Howard for the city of London in 1820 and entered the literature and has been investigated in major cities of the world until today (Streutker, 2003; Fan, 2004; Duman Yüksel & Yılmaz, 2008). Urban heat island is the most prominent climatic indicator of urbanization.

Urban heat island is defined as the fact that the temperature inside the city is higher than the rural area around the city. Natural landscapes in the city are being replaced by impermeable surfaces such as concrete and stone. Natural landscape elements that can be defined as rural fringes are removed from the city center, while commercial, transportation and industrial areas are developed to serve the city as the city grows. Urbanization and industrialization affect the heat and water cycle in the boundary layer of the atmosphere. Extensive modification of surface and atmospheric characteristics at local scales means that cities alter almost all atmospheric variables in their vicinity. Cities thus influence locally the weather in a significant way, especially modifying, and most of the time enhancing, high-impact weather hazards. This is urban climate (Oke, 1981). Urban climate also indirectly influences air quality (which is primarily due to pollutant emissions), given a different vertical temperature structure of the atmosphere in the first 0.1–1.0 km above the Earth's surface and modified horizontal wind circulations. These can create ventilation issues leading to warm air accumulation and poor air quality, especially in dense high-rise urban areas (Masson et.al., 2014) (Figure 1).

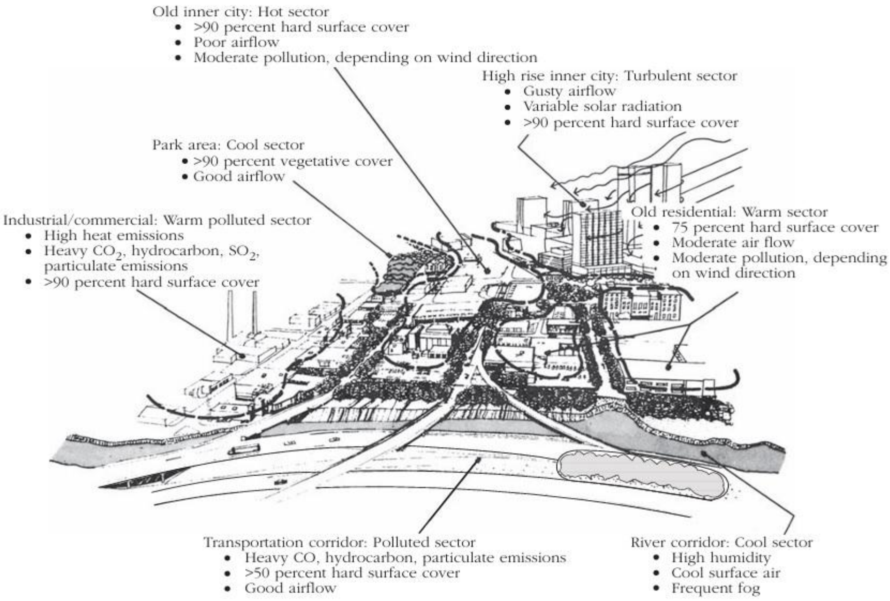

Figure 1. Climatic conditions near the ground in different sectors of a city. Conditions vary with surface cover, solar radiation, air flow, and air pollution, among other things (Marsh, 1991, p.366)

At the same time, different land use types such as land surface, water distribution, vegetation cover, spatial characteristics of cities, and longwave radiation significantly increase the temperature difference in the areas around the city, leading to the formation of urban heat islands (Stone et al, 2013; Çobanyılmaz & Duman Yüksel, 2013; Zhou et al., 2014; Wang et al., 2015; Peng et al., 2016; Li et al., 2017; Canan, 2017; Dai et al., 2018; Çilek Ünal, 2022; Yao et al., 2022; Yılmaz & Öztürk, 2023; Yin et al., 2023). In this context, against global warming and climate change which affect all cities on a global scale, cities need to be planned with the capacity to withstand natural and technological hazards, with the flexibility to adapt to extreme events or situations with minimal damage, and with the capacity to recover quickly from disaster impacts.

Many resilient system principles have been identified for planning cities in this context (Cartalis, 2014; Zhang and Li, 2018; Hurlimann et al., 2021; Zeng et al., 2022; Sanson & Masten 2023; Yılmaz & Öztürk, 2024). The concept of resilience has been defined and interpreted by different disciplines and different perspectives. The importance of urban landscape in the creation of resilient cities emerges, and in order for cities to be resilient to climate change, a holistic planning framework should be established by including mitigation and adaptation policies in urban planning. In order to address mitigation and adaptation policies together in spatial plans, it is necessary to first understand the current and future risks. In this process, it is especially important to ensure the resilience of cities, which are adversely affected in many environmental, social and economic aspects, in all areas as a whole (Martin & Sunley, 2007).

In this context, this study aims to address the functions of urban open green spaces in both mitigating the negative consequences of climate change and creating climate change compatible cities, and to reveal what kind of methods should be used to reduce the urban heat island. In this context, the relevant academic literature was analyzed in detail, practices developed to minimize the urban heat island effect at national and international level were evaluated, and descriptive analysis method was used. At the same time, urban resilience was examined by the discipline of landscape architecture through the urban heat island effect. Thus, the urban heat island effect is emphasized, and it is aimed to make suggestions on what strategies can be compatible with global climate change and which adaptation and adaptation policies can be developed to increase urban resilience.

2. LITERATUR REVIEW

2.1. The Concept of Resilient City

The number, frequency and impact areas of climatic and meteorological disasters due to climate change tend to increase. This is exemplified by stronger heat waves, longer droughts, more frequent floods, rising sea water levels and storm surges in various parts of the world. It is evident that increasing climate events and their impacts vary according to different geographical characteristics, and that they seriously challenge both the individuals living in urban areas and the decision-making mechanisms that carefully monitor the process on issues such as natural ecosystems, urban infrastructure and superstructure elements, food supply and security, and forced migration.

Disasters, especially in developing countries, significantly increase the vulnerability of highly vulnerable groups such as low-income individuals, the elderly, individuals with chronic diseases, individuals with special needs and children (Baysal, 2019). The world has a fragile structure (Baysal, 2019). Urban landscapes facing climate change are becoming weaker and more vulnerable in the face of increasing population. The urban heat island increases the impact of heat waves and threatens the health of the urban population. Urban landscapes are exposed to destructive consequences due to extreme weather events, disasters such as floods and floods caused by irregular rainfall lead to a decrease in water availability and food crisis, and coastal cities are damaged as a result of sea level rise (Baysal, 2019; Gergin, 2023).

The International Office for Disaster Risk Reduction (UNISDR) defines resilience as the ability of a system, community or society exposed to hazards to resist, absorb, adapt and recover from the effects of a hazard in a timely and effective manner, including the protection and repair of its basic structures and functions (Gerçek & Güven, 2016). In other words, urban resilience refers to the ability of an urban system (economic, social and ecological) or a city to resist and withstand a variety of sudden, adverse situations and events (Leichenko, 2011; Yılmaz & Öztürk, 2024; Galderisi, 2013; Masson et.al., 2014). At the same time, it refers to the ability of cities with complex systems to be resistant to changes and uncertainties along with their existing fragility (Levin 1993; Demir, 2022). In 1976, the United Nations Conference on Human Settlements (UN-Habitat) put on the agenda the resilience and sustainability of urban landscape against the effects of climate change. These goals are also addressed in the UN 2030 Sustainable Development Goals. Hyogo Framework Action Plan targeting the years 2005-2015 is an other global plan aiming to minimize the damages caused by disasters. In the plan, ensuring resilience in urban landscapes is mentioned as the primary goal (Gerçek & Güven, 2016).

The concept of urban resilience does not refer to a fixed feature. It includes the development of the urban system against changing and transformable conditions (Galderisi, 2013; Gergin, 2023);

- Accessibility of urban uses and transportation,
- Increased diversification of production in the local economy and consequently increased employment,
- Saving energy with renewable energy sources,
- Prolonged use of natural resources,
- Being prepared for disasters or adverse conditions and accordingly minimizing the loss of life and property,
- Ensuring adaptation to climate change,
- Preparedness against risks.

From an urban planning perspective, resilience involves ensuring the continuity of infrastructure systems, reducing disaster risks, promoting flexible land use strategies, and fostering social inclusion. Accordingly, spatial planning processes must address not only physical development but also the enhancement of community resilience. Meanwhile, urban landscape plays a critical role in providing the ecological and aesthetic dimensions of urban resilience. Nature-based solutions, green infrastructure, stormwater management, and permeable surface designs increase a city's capacity to adapt to environmental stressors, while also improving public health and overall quality of life. The integration of these two disciplines—urban planning and landscape architecture—is essential for creating urban environments that are both disaster-resilient and sustainable.

Considering all these factors, it is an important necessity to emphasize the factors that can guide landscape planning policies in order to mitigate urban heat island formation, its effects and mitigation, which is an important concern especially on a global scale in the process of combating climate change today. As stated in 2023 in the 'AR6 Synthesis Report: Climate Change 2023' prepared by the Intergovernmental Panel on Climate Change (IPCC), urban landscapes have caused 95% of the increase in average surface temperatures worldwide since the mid-20th century (IPCC, 2013). From this point of view, it would not be wrong to say that urbanization processes have become the driving force of global climate change due to many factors (increasing impervious surfaces, increasing pollutant emissions, intensive use of fossil fuels, lack of conservation-use balance, etc.). The landscape impact of resilient cities brings significant changes to the design, function and management of open and green spaces in cities. It is possible to summarize this impact under several headings. In resilient cities, landscapes are no longer just aesthetic or recreational, but take on multiple functions such as disaster risk reduction (flood control, fire resistance), climate regulation (lowering temperature, improving air quality), ecological (supporting biodiversity), social solidarity space (gathering, events). Landscape planning is integrated with systems that mimic the functioning of nature. It helps to ensure ecosystem continuity by integrating fragmented green spaces within the city, and is important both in terms of preparedness against crises and improving long-term quality of life.

2.2. Urban Heat Island (UHI) Effect

The increase in human activities in the city, the change in the morphological structure of the urban fabric and the decrease in soft surfaces and increase in hard surfaces pave the way for changes in meteorological parameters at local and regional scales and the formation of unfavorable microclimatic conditions. The urban heat island effect is one of the leading microclimatic problems in cities (Figure 2). Urban heat islands affect cities in many areas such as energy consumption, soil and water systems, especially built environments.

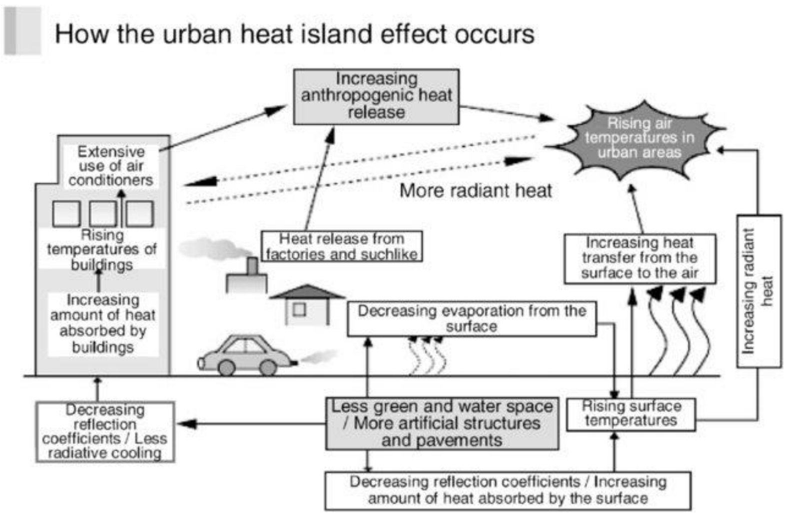

Figure 2. Impact of urban heat island on cities (Yılmaz & Öztürk, 2023)

Urban heat island is the most prominent climatic indicator of urbanization. Urban heat island is the situation where settlements have higher air temperature values than the rural areas around them. Urbanization and industrialization affect the heat and water cycle in the boundary layer of the atmosphere and differentiate the urban climate from rural areas (Yüksel, 2005). It can also be defined as the formation of high temperature differences between urban and rural areas as a result of the heat absorbed by buildings, roads and other structures in cities during the day and re-radiated after sunset (Figure 3). The urban heat island (UHI) effect causes higher temperatures in urban centers than in their surroundings, with significant negative impacts on the urban landscape. Increased temperatures accelerate water loss in plants, leading to problems such as drying and wilting, reducing soil moisture and making it difficult for especially sensitive plant species to survive. This leads to a decrease in biodiversity in urban landscapes. In addition, increased temperature increases the need for irrigation of landscapes, putting pressure on water resources. The KIA effect also affects the plant species used; landscape designs often favor heat- and drought-resistant species, which can limit natural diversity. Heat-retaining surfaces such as concrete and asphalt can also overheat surrounding landscapes. This weakens the cooling function of landscapes and reduces their capacity to maintain urban temperature balance. To mitigate these effects, it is crucial to design with nature-based solutions such as shading trees, permeable surfaces, green roofs and vertical gardens. In short, the urban heat island effect weakens the ecological functions of landscapes and is a problem that needs to be carefully managed for sustainable urban living.

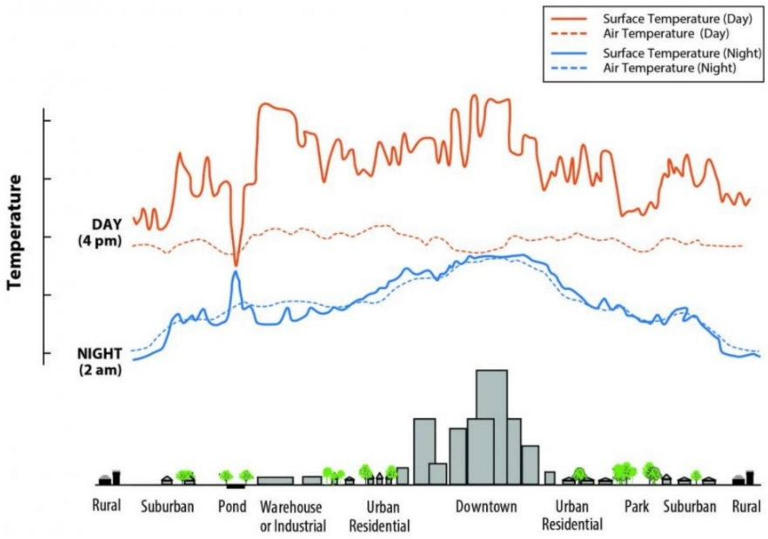

Figure 3. Distribution of afternoon temperatures in urban and rural areas (EPA, 2008)

There are two types of KIA: the superficial urban heat island (S-UHI) and the atmospheric urban heat island (A-UHI). Whereas Y-KIA is measured based on the surface temperature of the area, A-KIA is measured based on air temperature and is often classified as a cover layer urban heat island (S-UHI) and a boundary layer urban heat island (S-UHI) (Voogt & Oke, 2003). S-CIA in particular has attracted attention from politicians, health authorities, urban planners, urban investors and other different scientific communities due to its negative impacts on human health as well as air quality, precipitation, temperature, carbon storage, energy balance, etc. (Voogt & Oke, 2003). The table below shows the main characteristics of Y-KIA and A-KIA (Table 1).

Table 1. KIA types and key features (EPA, 2008)

Features	Y-KIA	A-KIA
Temporal change	• Always (Day and Night) • Peak in summer and during daylight hours	• Low density during daytime hours • More intense in winter and at night
The most intense situations	Change is high: Daytime 10-15 C^0 Night: 5-10 C^0	Change is small: Daytime: 1-3 C^0 Night: 7-12 C^0
Method of determination	Indirect measurement techniques: • Remote sensing	Direct measurement techniques: • Mobile stations • Constant meteorology
Visualization	• Thermal images	• Temperature graphs • Isotherm (co-temperature) maps

2.3 Key Factors Affecting the Urban Heat Island

Today, cities are in a process of struggle against the negative impacts of climate change. This struggle process has an important role in improving people's quality of life and ensuring sustainable urban development (Alusi et al., 2011). Based on the prediction that urbanization and population growth will continue, urban transformation, which is carried out to produce solutions to urban problems, especially in areas with dense unplanned settlements, aims to produce permanent solutions to the physical, environmental, social and economic problems of the area undergoing change. In the process of climate change, practices carried out within this scope contribute to both the creation of healthy living spaces and the improvement of people's quality of life (Thomas, 2003). In order for cities to become more resilient against both short-term and long-term urban heat island effects of climate change, they need to develop adaptation and mitigation policies within the framework of sustainability in urban planning of urban structure, architectural features and living spaces (Masson et al., 2014). At the beginning of these policies, nature-based solutions are important. Within the framework of sustainability, factors such as green infrastructure and thermal properties of materials used in buildings come to the fore (Figure 4). For instance, green infrastructure serves as an effective strategy to mitigate UHI impacts. Green infrastructure includes nature-based elements such as parks, green roofs, urban forests, permeable pavements, and rain gardens. These features improve the urban microclimate by reducing surface temperatures through evapotranspiration and shading. Moreover, green infrastructure contributes to thermal comfort, stormwater management, and overall urban resilience against the effects of climate change.

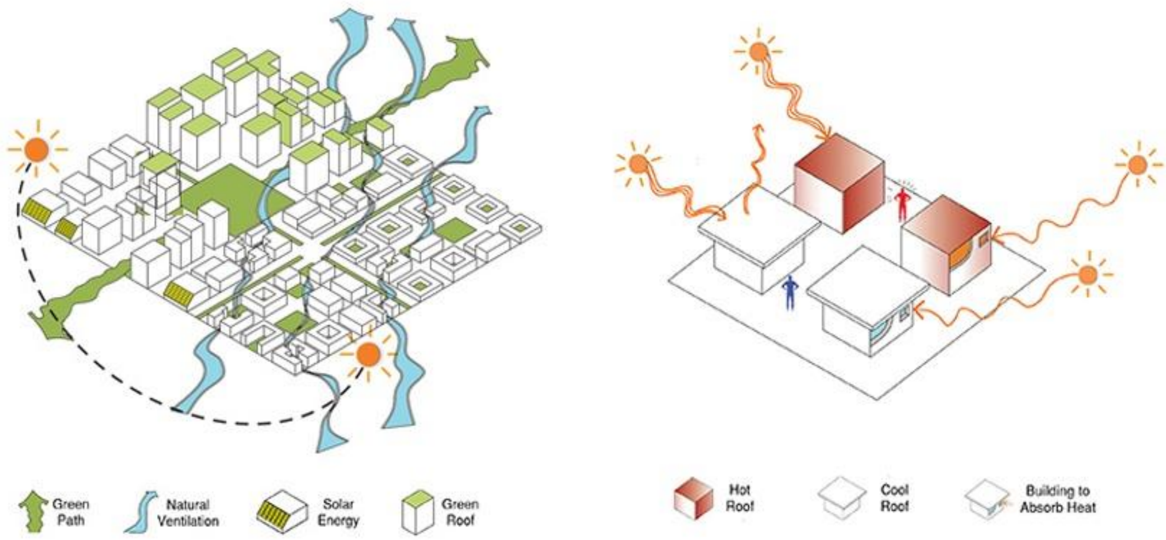

Figure 4. Parameters used to mitigate the urban heat island effect (Klein-Rosenthal & Raven, 2017)

It can be said that many parameters contribute to the formation of urban heat islands. Green infrastructure, albedo effect and urban geometry are the main ones (Klein-Rosenthal & Raven, 2017).

2.3.1. Green infrastructure

The increase in the use of fossil fuels in cities and greenhouse gases released into the atmosphere with industrialization has accelerated climate change and caused an increase in average temperatures (Intergovernmental Panel on Climate Change, [IPCC], 2022). As a result of neoliberal urbanization in the last fifty years, there have been significant changes in the urban landscape. While cities are growing vertically, they are also expanding horizontally. The formation of urban heat islands has become inevitable in cities where green areas are decreasing and construction is intensifying (Aksak et al., 2023).

Green infrastructure is a system with functions such as vegetation, shading, water utilization, green roofs and walls. The systems create living environments by controlling rainwater runoff, protecting air quality and biodiversity. Green roof systems, parks and afforestation projects are especially important in reducing the urban heat effect.

Green Roof Systems: Roofs are the most open surfaces exposed to the sun on urban surfaces. Its task is to protect the top of the buildings from external and atmospheric effects. Therefore, they play an important role in the formation of the urban heat island. Green roofs keep the humidity level under control by absorbing the sun's rays in summer with the vegetation used. In winter and in the absence of the sun, heat energy is released from the plants and green roof elements into the atmosphere. In this case, urban heat island effects are reduced in cities thanks to the ability of green roofs to keep the heat cool and the cold warm (Tozam, 2016). Green roof systems provide the plants with the nutrients they need and create an environment for the roots to grow (Abbass et al., 2022). In addition, the plants used on the roof prevent sunlight from reaching the underlying roof membrane. Because the amount of sunlight passing through the shade of the plant is important. In summer, usually only 10 to 30% of the sun's energy reaches the soil beneath a plant, the rest is absorbed by the leaves and used for photosynthesis, and some is reflected back into the atmosphere (EPA, 2008). In winter, green roofs contribute to stormwater management by reducing water runoff from buildings by 54-62%, depending on system characteristics and climatic conditions (Abbass et al., 2022). With these effects, the use of green roofs contributes to the reduction of the urban heat island (Figure 5).

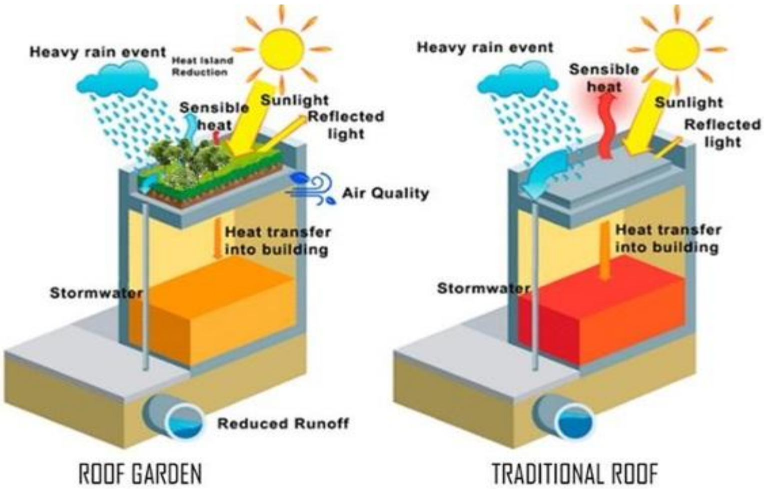

Figure 5. Comparison diagram of water flow and solar radiation between a traditional roof and a green roof (EPA, 2008)

Vertical gardens: Green space structures applied to building facades, bridge abutments, screening or boundary walls, billboards or other wall surfaces are called vertical gardens. Vertical gardens are important and necessary because they provide the opportunity to create green space in cities where it is difficult to increase the amount of green space. The planting of various vertical surfaces in the city contributes to urban ecology and life, and helps to reduce the urban heat island. For example, vertical gardens reduce the effect of impervious hard surfaces such as concrete and asphalt in turning the city into a heat island. This is because dry walls, roofs and asphalt streets absorb some energy and reflect some from hard surfaces. After the sun goes down, the heat absorbed by the hard surfaces during the day is released and forms heat islands that cover the city in the shape of a dome. Vertical gardens contribute positively to the microclimate of the city by trapping dust and other pollutants in the air with the help of plants, creating a healthier environment and absorbing carbon dioxide gas and oxygenating the atmosphere.

Parks, greenways/corridors and afforestation projects: Urban green spaces and urban forests provide many benefits to the city, such as food supply, urban temperature regulation, runoff mitigation, noise reduction, pollination and seed dispersal, amelioration of environmental extremes, air purification, climate regulation, recreational and mental development, animal monitoring (Baggethun & Barton, 2013; Tülek & Mirici, 2019; Salmond et al, 2016; Livesley et al., 2016; Nyelele et al., 2022; Davies et al., 2017; O'Brien et al., 2017; Elma & Ortaçeşme, 2024). In the fight against climate change in cities, green areas that positively change the air quality of the city and at the same time reduce the heat island effect and create a living space for living things are important. Murphy et al. (2011) and Kuşçu Şimşek & Şengezer (2012) stated in their studies that areas with dense plants reduce the urban climate by 4 ^{0}C on average (Bayramoğlu & Seyhan 2022; Sakar et al., 2024). Green infrastructure systems are recognized as the most effective urban air quality improvement mechanism after the elimination and removal of pollutant sources (Hewitt, 2020). When the wind direction is taken into account when positioning green areas in the city, the temperature decrease is not only within the green areas themselves, but also contributes to bioclimatic comfort by cooling and filtering the air around them (Elma & Ortaçeşme, 2024). When the issue is examined in terms of carbon cycle; plants that store carbon dioxide (CO2) in the air in their biomass and soil transform CO2 into organic compounds to be used in growth and development stages (Sakar et al., 2024).

2.3.2 Albedo Effect

Due to the unplanned expansion of cities, natural vegetation and land covers are deteriorating. Factors such as the albedo effect of materials used in buildings and urban surfaces, thermal properties, urban building density and sky openness play an active role in urban heat island formation Üstündağ et al., 2023).

Albedo is defined as the capacity of a surface to reflect electromagnetic energy falling on it, in other words, the reflective power of the surface. Albedo values vary depending on the surface area, color and texture of each element (Yılmaz & Öztürk, 2023). Items with light colors have a high albedo and reflect most of the light that hits them. On the other hand, elements with dark colors absorb the sun's rays during the day and emit these rays at night. In this context, dark colored elements increase the formation of urban heat islands (Üstündağ et al., 2023). The correlation between temperature and surface ozone in urban areas with air pollution shows that temperature has a detrimental effect on air quality (Jacob & Winner, 2009; Yıldız et al., 2024). In addition, the thermal properties of pavements frequently used by people in urban areas differ from thermal and reflective properties of surface materials such as albedo, thermal conductivity, climatic conditions and geographical location. However, although the albedo of pavements varies according to the surface material, it is generally gray in color and between 0.35-0.40. As time passes, the albedo value decreases as the surface of the pavement wears. Dirt accumulation on the pavement surface also reduces the albedo value. For this reason, it is important to maintain pavements at regular intervals and repair them with appropriate materials.

2.3.3 Urban Geometry and Heat Island Effect

Since urban heat island formation is directly related to the shape and geometry of cities, urban growth increases surface temperatures and the level of heat stress experienced by urban residents. Many studies have shown that urban form indicators are among the most important factors affecting urban heat island formation (Mathew et al., 2016).

Urban form is defined by features such as open spaces, building and street features, structural density, building forms and scales, and parcels and street patterns. Valleys and transportation axes within the urban landscape assume the function of ventilation corridors (Yıldız et al., 2024). The temperature and its distribution in urban settlements and their immediate surroundings do not have a constant value throughout the day, but vary over time (Tsoka, 2011; Canan, 2017). The intensity of the urban heat island reaches high values starting from sunset. Its effect during night hours is higher than daytime hours (Mathew et al., 2016; Canan, 2017). The geometric structure of the city has a leading role in determining the interaction of the urban environment with the atmosphere. Urban geometry, vertically rising building surfaces in cities create extra surfaces and this causes more exposure to shortwave solar radiation. Sky View Factor, the vertical visibility of the sky through tall buildings, is very low in cities.

The street depth ratio is the ratio of the average height of buildings on both sides of the street (Y) to the average width of the street (G) (Santamouris, 2013). (Y/G) When this ratio increases, the depth increases. The close proximity of the side surfaces (facades) in deep streets causes the sun's rays to be reflected back to the sky and heat all surfaces along the cross-section. A low street depth ratio and tree planting, together with cool roofing material with increased reflectivity, allow less heat to be stored across the cross-section (Santamouris, 2013). Indoor spaces can become less hot while outdoor spaces can become more comfortable. Plants both utilize and radiate solar energy, providing shade on vehicles and building facades (Santamouris, 2013) (Figure 6).

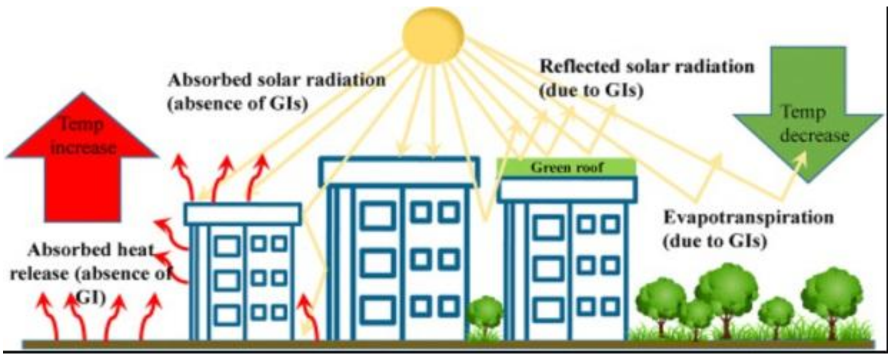

Figure 6. Cross section of a street with a high street depth ratio (Y/G) (Tozam, 2016)

The geometry of the city determines the speed of the wind and the level of energy absorption on complex urban surfaces (Canan, 2017). Again, due to the canyon geometry created by high-rise buildings (Oke, 1981), air movements in cities slow down and heat transport by turbulence/ advection decreases. The roughness of urban surfaces (the presence of tall buildings) limits horizontal (advective) air movements and has the effect of breaking strong winds coming from outside. Therefore, cities have windless air.

In dense urban green areas, buildings close to each other block a certain amount of open sky, making it difficult for them to radiate the heat stored during daytime hours into the atmosphere at night (Unger, 2009). This is caused by the trapping of long-wavelength radiation (infrared) in the dense fabric, which wants to escape from buildings and various surfaces towards the atmosphere (Debbage, 2014; Canan, 2017). As a result of the inability of the stored heat to escape, the urban heat island effect occurs. In short, the relationship between urban geometry and landscape plays a decisive role in the formation of the ecological, functional and spatial quality of the urban environment. Urban geometry refers to the physical structure including building density, building height, street pattern, distribution of open and green areas and land use patterns. These geometric features directly affect the position, form and continuity of landscape elements within the urban fabric. High-density settlements and narrow street canyons reduce the amount and continuity of green spaces, limit natural air circulation and negatively affect urban microclimate conditions. In contrast, well-planned urban forms supported by low-density settlements, permeable surfaces and green corridors enable landscape systems to integrate more effectively within the city and increase ecosystem services. Furthermore, the harmony between urban geometry and landscape design facilitates access to public green spaces, enhances social interaction and improves urban quality of life. Therefore, urban geometry and landscape planning should be handled with a holistic and interdisciplinary approach in the creation of sustainable and livable cities.

3. SUCCESSFUL EXAMPLES APPLIED IN URBAN LANDSCAPE AREAS FOR REDUCING URBAN HEAT ISLAND AND CREATING RESILIENT CITIES

3.1. Examples Discussed Within the Framework of Green Infrastructure:

In the city of Utrecht in the Netherlands, plans have been made to green every roof with plants or equip it with solar panels to reduce the urban heat island. This step was implemented following the municipality's success in a similar project for bus stops (Boffey, 2020). Similarly, the policy of "there should be no unused roof" is implemented to increase biodiversity in the city and create a happier environment (Figure 7). These roofs capture particles that cause air pollution, store rainwater and provide cooling during the summer months (Boffey, 2020).

Figure 7. Bus stops with green roofs, Netherlands (Boffey, 2020)

In Melbourne, Australia, a green infrastructure program called “Urban Landscape Team” was launched in 2010 to prevent extreme heat, severe drought and water shortages that occurred between 1995 and 2009. Since 2010, major investments have been made in urban forests and heathlands, green spaces and rainwater harvesting, permeable surfaces, protection of waterways and wetlands, while green spaces aim to reduce the city's temperature by 4 degrees and save water (Shears, 2009). For nearly 20 years, the role of trees in Melbourne has grown from an aesthetic element to an important part of the complex blue-green infrastructure within the city. The Melbourne urban forest strategy assesses a range of environmental, economic and social parameters that can be measured in terms of community health, energy savings, air quality improvement and carbon sequestration (Shears, 2009). It was targeted to increase tree canopy cover from 20% to 40% and to increase rainwater harvesting to 50% of the city's water supply. Increasing permeable surfaces and expanding the green space network by 7.6% are among the objectives of the open space strategy. A regional plan for seven urban forests was developed under the city government's Green Development Principles and the Australian Urban Green Infrastructure Guidelines were published (Shears, 2009) (Figure 8).

Figure 8. Melbourne City Forest (Shears, 2009)

The two-level outer ring road "Anillo Periférico" in Mexico is one of the most heavily traveled roads not only in Mexico but also in South America. Its heavy traffic is one of the main factors that make it one of the most polluted cities in the world. In 2016, to address both air and noise pollution, the Green Road (Via Verde) project was developed to install vertical gardens on the pillars of the ring road (Figure 9). In particular, "green pillars" were planted next to highways and under overpasses, creating pollutant-reducing green walls along the road. As part of the Green Road project, more than a thousand pillars were covered with green plants. This green space is expected to remove 27 thousand tons of polluting gases and 10 tons of heavy metal particles. In addition to their aesthetic contribution, the plants produce oxygen equivalent to the use of 25 thousand people.

Figure 9. Green road project (Via Verde), Mexico (Istanbul City Council Climate Crisis Working Group, 2020)

New York is a city that experiences severe weather events due to climate change-induced rapid sea level rise and rising temperatures. Various plans, programs and initiatives are being developed to cope with these challenges and increase the resilience of the city. The vision of local governments to create cities resilient to natural disasters is critical for New York City's planning and management processes. In line with this vision, PlaNYC, a sustainable city plan created in 2007, aims to reduce the city's emission level by 30% by 2030. Within the scope of the plan, a total of 132 initiatives have been launched. These initiatives aim to reduce greenhouse gas emissions by 10%. PlaNYC's implementations include projects such as the "Greener, Bigger Buildings Plan, Clean Heat Program and Cool Roofs Program". The 2050 strategy document titled "A Strong and Just New York City", which was prepared in 2019 in a multi-participatory process and includes nine main chapters and detailed sub-headings on resilient cities, has served as a good model and resource for other cities developing projects on resilience work.

With a similar strategy, the CheongGye River, which passes through the center of Seoul, was turned into a closed canal in 1971 (Figure 10). A highway and viaduct were built on it. In time, the city experienced problems such as air pollution, heat island effect, noise and the viaduct was outdated. The road and viaduct were removed, ecological improvement work was carried out on the riverbed, and the river corridor was reconstructed. After the realization of the project, it was determined that biodiversity increased, the air temperature on and around the riverbank was 3-6 degrees cooler than the other parts of the city, the movement speed of the wind increased by 2-7%, and the pollutant particles in the air decreased by 35% (Coşkun Hepcan, 2019).

Figure 10. CheongGye River before and after ecological improvement (Coşkun Hepcan, 2019)

3.1 Examples considered within the scope of albedo effect

The “cool pavements” strategy is supported by the European Commission DG Environment and the US Environmental Protection Agency. It is now up to project leaders to consider the Urban Heat Island effect in the context of a contemporary vision for urban public spaces. In the 2022 Tokyo Climate Change Adaptation Plan, projections indicate that by 2090, the number of days that are unsafe for outdoor work will increase by 30-40% compared to today, and that rising temperatures will increase heat stress and heat stroke as a public health problem (Tokyo Municipality, 2022). In order to take precautions against extreme temperature increases throughout the city, studies such as creating cool spots in densely populated centers, preferring coating materials that block solar heat, increasing the number of urban open and green areas, and diversifying heat measures in residences are carried out (Tokyo Municipality, 2022). For reducing the urban heat island effect, a total of 106 km of roads were constructed using road surface material with low albedo value in order to control the temperature increase caused by road surface heat throughout the city (Tokyo Municipality, 2022) (Figure 11).

Figure 11. Azabudai Hills complex in Tokyo and low albedo road surface materials (Tokyo Municipality, 2022)

In addition, it was aimed to reduce the urban heat island by using light-coloured materials in the squares in Brussels (European Concrete Paving Association, 2023) (Figure 12).

Figure 12. Atomium Square (left) and Rogier Square (right), Brussels (European Concrete Paving Association, 2023)

3.2 Examples Considered within the Framework of Urban Geometry

As an island country in Asia, Singapore is vulnerable to the impacts and risks of climate change. Increasing its resilience against climate change-induced disasters with the projects it has developed, Singapore has a strong infrastructure and rapid response system against natural disasters such as frequent monsoon rains, floods and severe storms. Measures such as emergency plans, disaster scenarios and raising public awareness against disasters set an example for other countries to increase their resilience against disasters (Robles et al., 2023). These measures taken by Singapore against climate change and disasters are important not only within the country's own borders, but also as a model on a global scale. Since the 1960s, Singapore has transformed into a highly livable and resilient city. There has been a focus on long-term urban planning and developing contingency plans for various scenarios in a holistic manner. Particular emphasis has been placed on urban heat island mitigation designs. For example, air corridors have been created by creating V-shaped designs in urban landscapes (Robles et al., 2023) (Figure 13).

Figure 13. V-shaped air corridors created in Yishun Park (Robles et al., 2023)

Open spaces were created by placing trees and plants at the center of the buildings. Thus, while the trees provide shade, the heat from the sun is absorbed (Figure 14). Plants also cool the area by releasing water into the air as vapor and function like a conveyor belt that carries heat from the ground to the air (Robles et al., 2023).

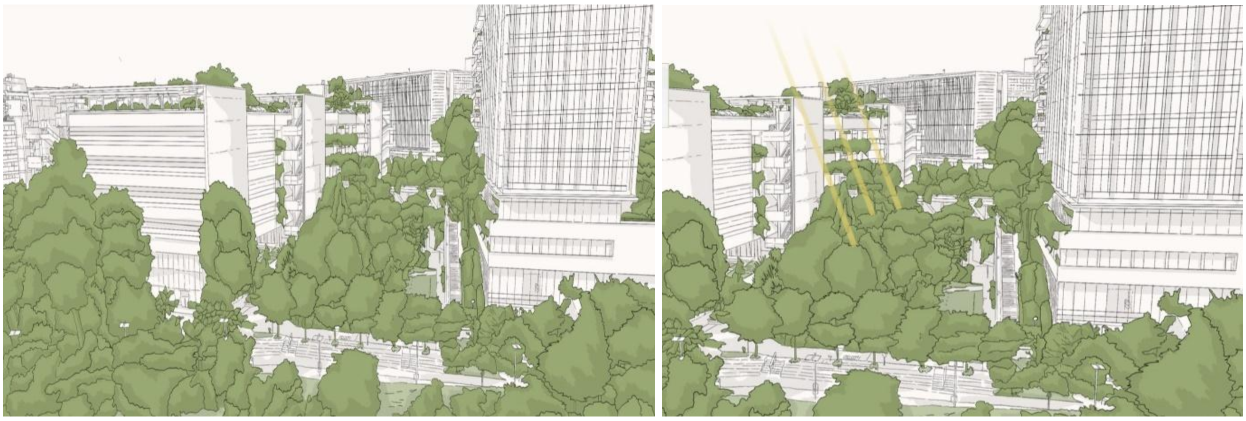

Figure 14. Trees and plants located in the center of Yishun Park (Robles et al., 2023)

Similarly, the "Gardens by the Bay", a 250-acre park in Singapore, has an array of trees and other greenery that cools its surroundings (Figure 15). Studies show that the larger the green space, the greater the cooling effect. Dense skyscrapers in city centers often limit wind flow and trap heat. However, tall, medium and short buildings here work like a sail to capture cool sea breezes and direct them to the pedestrian level (Robles et al., 2023).

Figure 15. Gardens by the Bay, Singapore (Robles et al., 2023)

4. CONCLUSION AND SUGGESTIONS

Sprawling cities and urban activities (industrial production, transportation, domestic heating, intensive resource consumption, limited recycling practices, etc.) are among the most affected by global climate change and climate-related disasters. The vulnerability of cities increases significantly due to both the built environment elements (impermeable surfaces, heat retaining materials, lack of green areas, etc.) and the dense population they host. Urban heat island is seen as the most alarming of these impacts (Nakata & Souza, 2013; Allegrini et al., 2015; Canan, 2017; Yılmaz & Öztürk, 2023; Bogenç et al., 2023).

There are many negative consequences of the urban heat island effect, which is one of the main factors that make urban areas with dense population and building stock more vulnerable. Based on the fact that the global average surface temperature has been increasing over time and cannot be stabilized at 1.5°C, it has become a necessity to reduce the urban heat island effect that triggers global climate change. Preparation of emergency action plans of cities and determination of their resilience status help in the face of any adverse situation. It is important to integrate the city's land use plans, building shape and layout plans with the city's resilience plan. In cities, it is especially valuable to protect areas such as wooded areas and forests that act as natural buffers (Cartalis, 2014). If cities continue to grow vertically, climate change, which is already at red alert level, will make our world uninhabitable.

In this study, it was deemed necessary to address the very important functions of urban landscapes both in mitigating the negative consequences of climate change and in creating cities compatible with climate change, and what kind of methods should be used to reduce the urban heat island was examined. Within the scope of descriptive analysis, the most effective factors (albedo effect, urban geometry, green infrastructure) in reducing the urban heat island were taken into consideration. As a result, the urban heat island effect, which plays a key role in ensuring urban resilience from the perspective of landscape architecture discipline, has been emphasized, and suggestions have been made on what strategies can be compatible with global climate change and which adaptation policies can be developed to increase urban resilience.

The main steps that can be taken in this context can be listed as follows:

- *Dissemination of applications for urban geometry*

In urban planning studies, it is of vital importance to include climatic and meteorological data as an input to the strategies and policies to be developed. Especially the direction and amount of incoming sunlight and wind should be taken into consideration. Re-evaluation of the building layout in order to create air corridors in urban areas and the positioning of buildings parallel to the wind direction to utilize the cooling effect of the wind are examples of possible applications. From this point of view, ensuring energy efficiency especially in buildings, reducing electricity consumption for heating and/or cooling and decreasing the use of natural resources will be provided by using existing climatic data.

- *Review of choices for material type*

The use of building materials (asphalt, concrete, roofing materials, etc.) that form impermeable surfaces and have low albedo values in urban areas causes the elements that make up the built environment (buildings, roads, etc.) to retain more heat. In order to prevent this situation and reduce the urban heat island effect, the use of materials with high albedo values should be preferred, especially for land uses that form large surfaces. Another problem observed with impervious surfaces is the disruption of the rainfall-moisture balance due to the inability of seasonal precipitation to be absorbed by the soil. The use of materials that allow rainwater to be absorbed will provide significant benefits in order to prevent this situation, which leads to reduced cooling in urban areas.

- *Bringing the stock of open and green areas to a qualified and sufficient level*

Open and green spaces are known to play an important role in mitigating the urban heat island effect. Among the many known benefits, these areas can help minimize pollutant emissions by absorbing CO2 and provide a cooling effect through evaporation and evapotranspiration cycles that are directly related to rainfall. In addition, the role of vegetation in mitigating this effect is undeniable. In particular, it is clear that shade-forming tree species, which help to reduce the perceived temperature in buildings and urban open spaces, significantly improve the quality of life of individuals living in urban areas. Considering the mentioned benefits, it is a vital necessity to maintain the balance between the built environment and the natural environment in urban areas. Therefore, increasing the amount of open and green areas per capita in urban areas and protecting existing natural areas should be among the strategies that should be prioritized.

- *Adoption of ecological planning approach*

Today, practices known as 'green systems' emphasize the importance of open and green spaces and water availability in reducing the urban heat island effect. These practices include green-blue infrastructure systems, green buildings, green walls and green roofs. Considering that the amount of green space per capita in cities does not meet the necessary and sufficient conditions, it is clear that strategies that can be developed at the building scale with a change in scales can serve the ecological planning approach. Through green systems that can be applied to building walls and roofs, the albedo value can be increased and the humidity - evapotranspiration cycles in the urban area can be restored. In addition, these systems, which will provide significant benefits in reducing air pollution, will enable the integration of ecological approach models into urban planning processes.

It can be seen that there is no unsolvable situation against the urban heat island effect that emerges as a cause and consequence of global climate change processes. It is clear that technology-based and innovative solution proposals will make significant contributions to increasing urban resilience not only against climatic and meteorological disasters caused by climate change, but also against all types of disasters. In other words, with the adaptation studies that can be carried out in urban areas where population density and related consumption activities tend to increase, cities can be transformed into living spaces with high quality of life.

Acknowledgements and Information Note

The Role of Urban Landscape in Creating Resilient Cities: An Evaluation in The Context of Urban Heat Island Effect is a paper presented at the IIIrd International Conference On Sustainable Cities and Urban Landscapes (2024).

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

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