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A STUDY ON THE DEFICIENCIES OF THE TURKISH URBAN LEGISLATION SYSTEM REGARDING URBAN CLIMATE: THE CASE OF OPEN AND GREEN SPACES OF ISTANBUL

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INTRODUCTION

The world has experienced unprecedented urban growth since the Industrial Revolution. While only 11% of the global population lived in urban areas before industrialisation, this figure increased to 25% in the 1950s and rose to 50% by 2020 (OECD, 2012; World Cities Report, 2022). Today, more than 4 billion people live in cities, and this number is projected to rise further reaching 58% of a global population of over 9 billion by 2070. This rapid urbanisation is considered one of the major anthropogenic drivers of global climate change and is known to significantly affect local climatic conditions through changes in land cover, energy balance, and urban morphology (Bibi and Kara, 2023; Ye et al., 2021).

Climate change, accelerated by industrialisation and urbanisation, has introduced complex challenges for urban systems. Among its most severe effects are extreme weather events such as floods, landslides, and tornadoes- which pose fatal risks. However, studies have shown that heatwaves cause even higher mortality rates, largely because they overwhelm the human body's thermoregulatory system (Sachindra et al., 2016; Lim, 2020; Kearl and Vogel, 2023; Zhu et al., 2023). Urban areas are particularly vulnerable to heatwaves due to their high population densities, impervious surfaces, and anthropogenic heat emissions (Dodman et al., 2022). As urbanisation intensifies, heatwaves are becoming an increasingly serious threat, especially for vulnerable groups such as the elderly, children, and low-income populations (Puley, 2022). In this context, the concept of urban heat resilience, a sub-dimension of broader climate resilience, has become critically important. This evolving framework not only addresses the need to mitigate thermal extremes such as heatwaves but also highlights the dual role of cities as both contributors to and victims of the climate crisis.

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Urban areas play a dual role in the climate crisis, both as victims and contributors. Reports from the United Nations and the World Bank emphasize cities as key arenas for both climate action and exposure (UN-Habitat, 2011; World Bank, 2010). Notably, the Mediterranean Basin (including Turkey) has been identified as one of the regions most vulnerable to the effects of climate change (**1**) (Wilby, 2007; WWF, 2021). Recent data from Turkey indicate a continuous rise in summer temperatures and a sharp increase in meteorological disasters (TSMS, 2020), underscoring the urgency of urban climate adaptation (**2**).

Despite this, the relationship between climate and urban space has not been adequately addressed in Turkey's planning practice or academic discourse. International consensus is growing around the importance of nature-based solutions such as green and blue infrastructure as essential tools for climate adaptation, particularly in urban areas (McPhearson et al., 2018; Andersson et al., 2019). Green infrastructure, especially urban open and green spaces (OGS), plays a crucial role in mitigating heat stress and enhancing resilience to a range of climate-related hazards. However, Turkish planning regulations continue to treat these functionally distinct spaces under a single classification. This approach assumes uniform environmental performance across all types of open and green spaces, disregarding critical differences in vegetation density, surface materials, and cooling potential. This creates a gap between ecological function and legal designation, which may limit the effectiveness of planning strategies aimed at improving urban climate resilience.

This legislative and functional gap is addressed in this study through an analysis of the thermal performance of various urban OGS types that are legally defined under the same category in Turkey's Spatial Plans Construction Regulation. Using spatial and statistical analyses based on satellite-derived surface temperature and vegetation data (NDVI), this research evaluates the effectiveness of these areas in mitigating urban heat. The study focuses on Istanbul, one of Turkey's most urbanized and climatically vulnerable cities. The aim is to empirically assess the functional diversity among OGS categories and to advocate for evidence-based zoning reforms that reflect their differing climatic impacts.

Literature Review

Due to climate change, the increasing frequency and intensity of heatwaves pose a serious threat to human health (Matte et al., 2024; Damte et al., 2023), often resulting in fatal consequences particularly in urban areas (Li et al., 2024; Darmanto et al., 2019; Zhang et al., 2018; Qaid et al., 2016). For example, it is estimated that 70,000 people died during the European heatwaves of 2003, and 55,000 people perished in Russia in the summer of 2010 (Grigorieva and Revich, 2021). In the summers of 2022 and 2023, reported deaths in Europe reached 62,000 and 47,000, respectively (Yang and Chen, 2023). According to the WHO (2024), the number of people exposed to extreme heat is growing exponentially in all world regions due to climate change, resulting in a significant rise in heat-related mortality. For those over 65 years of age, heat-related deaths increased by approximately 85% between 2000–2004 and 2017–2021. Studies from 2000–2019 show that about 489,000 heat-related deaths occur annually, with 45% happening in Asia and 36% in Europe (Zhaoa et al., 2021). Unfortunately, these new findings show that in the two decades since 2003, Europe has fallen short in preparing for heat waves, which are expected to increase in the future, and it will be even more inadequate in the future to protect

1. Wilby (2007) stated that the Mediterranean Basin, Central and South America and South Africa are the places where water scarcity will be most felt. It has been revealed in models that temperatures will rise 20% faster than the global average in the Mediterranean Basin, as a result of which the sea length will increase by 1 meter on average in 2100 years and one-third of the region will be negatively affected economically by this process (WWF, 2021).

2. When we look at the average temperature data of Turkey between 1971 and 2020, it is seen that summer temperatures in all years between 1998 and 2020 are above the long-term average of 23.40°C. When the data on the number of meteorological disasters is examined, it is seen that there was a regular increase after 2000 and the highest value was reached in the period between 1940 and 2020 with 984 disasters of meteorological character in 2020 (TSMS, 2020).

its vulnerable population (Ballester et al, 2023). Therefore, it is clear that cities are the areas that need to be looked at first in terms of both the causes and effects of climate change and intervened first in order to overcome the emerging crisis.

Studies on the effects of urbanization on climate and heat islands date back to the 1930s (Kratzer, 1935; Arakawa, 1937; Fukui, 1957; Chandler, 1962; Oke, 1973). The subject started to attract attention after the 2000s; the effects of climate change that have become evident in the last 20 years and the measures to be taken against these effects are among the priority issues. Urban form, building configurations, and the vegetation rate play a critical role in mitigating and preventing the climate change impacts on cities (Stone et al., 2010). It is underlined by many authors that urban planning is the most important tool for creating climate resilient and highly adaptative urban spaces aiming to increase the comfort of life depending on climatic conditions (Brown, 2011; Greiving and Fleischhauer, 2012; Picketts et al., 2014; Macintosh et al., 2015).

Nevertheless, although the study of urban climate dates back to the early decades of the last century and has gained momentum over time, the necessary steps toward implementing climate-sensitive urban planning have yet to be taken in Turkey. Most academic studies in Turkey addressing the relationship between climate and urban environments tend to focus on policy, management capacity, and governance models. In comparison to other countries, spatial-level research on this topic remains limited.

Balaban (2012, 39) noted that spatial structures and elements in Turkish cities need to be rehabilitated and renewed to make them more resilient to climate change. Gedikli (2017) emphasised that climate change is an issue that needs to be addressed at both local and central levels, and that planning has an important role to play in this sense. In line with these perspectives, a comprehensive assessment has been carried out on how climate change is addressed within Turkey's strategic planning framework.

A review of the literature on the climate-city relationship in Turkey reveals a significant focus on institutional capacity and governance (Eroğlu and Erbil, 2021; Peker and Ataöv, 2024; Kazancı and Tezer, 2021; Erbil and Erbil, 2019), as well as on policy-level discourse (Eraydın and Köroğlu, 2021). and Balaban (2012, 39) have also contributed to this field of study. Additionally, research has been conducted on the relationship between urban macroform and urban texture with climate (Moradi and Tamer, 2017; Dursun et al., 2016; Peker, 2021). Balaban (2012) has also made notable contributions to this field. Additionally, studies have examined the relationship between urban macroform and urban texture and their climatic implications (Moradi and Tamer, 2017; Dursun et al., 2016; Peker, 2021). Overall, the existing literature on the relationship between climate and urban development in Turkey aside from a few notable exceptions remains primarily concerned with policy frameworks and institutional capacity.

However, the broad scope of the subject makes it difficult to identify the issues solely by examining the legal framework and existing local climatic characteristics. Due to the complexity and multi-layered nature of the urban climate problem, a comprehensive understanding of current regulatory shortcomings requires analysis through a wide range of illustrative examples. Expanding the number of such examples can help raise awareness of the urgent need to develop legal frameworks that explicitly address the challenges posed by climate change.

In this context, the article aims to make a partial contribution to this important gap. For this purpose, within the scope of the article, open and green spaces, which are defined in the Spatial Plans Construction Regulation and have an important role in the urban structure, are analysed and the effects of these areas on the urban climate are defined. The effects of these areas on the urban climate are discussed through selected examples specific to Istanbul Province. Also based on the results of the discussions, it has been evaluated to find out how adequate and sensitive the Zoning Law (İmar Kanunu) in Turkey and the relevant regulations, which determine the construction of the spaces in Turkey, are in terms of making cities resilient to climate change.

MATERIAL AND METHODS

Study Area

In this study, the definitions and uses outlined under the title Open and Green Spaces in the Spatial Plans Construction Regulation (including squares, recreation areas, groves, parks, botanical gardens, hippodromes, stadiums, and fair centers) were taken as reference. The main purpose of this study is to compare the local climatic structures of the areas (square, recreation area, grove, park, botanical garden, hippodrome, stadium and fair center) defined as Open and Green Spaces in a single class in the Turkish Spatial Plans Construction Regulation, with statistical analyzes based on surface temperature data.

In this context, sample areas that align the definition of open and green spaces as described in the regulation were selected (**Figure 1**). However, in this selection process, specific characteristics such as the ideal vegetation density, surface materials, the ratio of impervious surfaces, traffic density and morphological characteristics of the surrounding environment were not taken into account. Instead, the study addresses the issue at a broader scale, treating it primarily as a classification problem. Istanbul was selected as a case area because it contains nearly all types of open and green spaces (OGS) defined by Turkish spatial planning regulations, enabling a comprehensive examination of legal classifications within a single urban context. The use of a single province minimized geographic variability, allowing for a more controlled comparison of thermal effects across different land use types. The city’s high vulnerability to heat-related climate risks, coupled with its urban diversity, further supported its selection. The selected sites (such as Taksim Square, Maltepe Recreation Area, Yıldız Woods, Liberty Park, Nezahat Gökyiğit Botanical Garden, and the CNR Expo Fair Center) were chosen for their clear representation of distinct land use categories, the availability of high-quality satellite imagery, and their official designation under Turkish spatial planning legislation.

According to the Köppen-Geiger Climate Classification, Istanbul is characterized by a hot-summer Mediterranean climate (Csa) (TSMS, 2022), with average summer temperatures generally ranging between 25°C and 30°C. Beyond its spatial typology and regulatory relevance, Istanbul was selected due to its increasing exposure to heat-related climate risks. Climatological studies confirm a statistically significant warming trend in the city over recent decades. For example, data from the Atatürk Airport

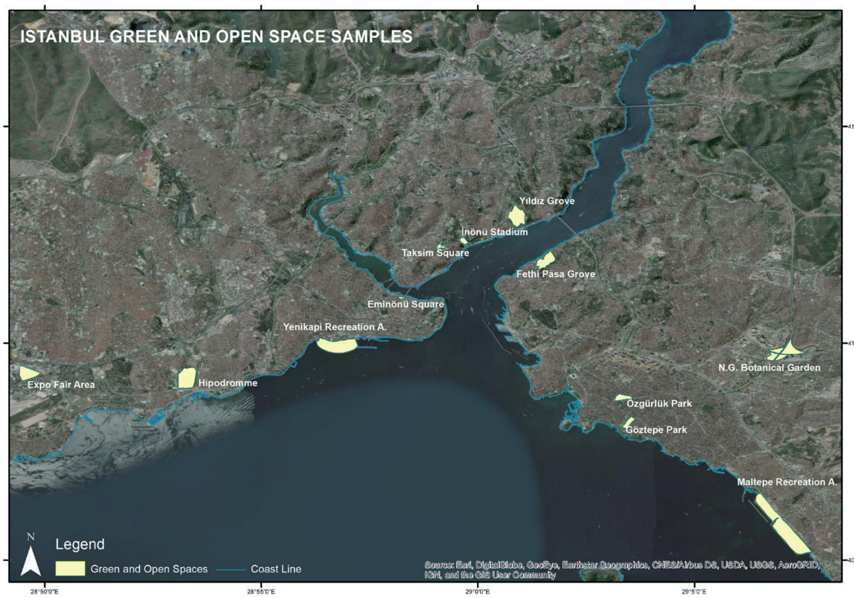


Figure 1. Map of the study area

synoptic weather station show that the annual mean temperature increased by approximately 0.06°C per year between 1973 and 2023, with a sharper increase of 0.08°C per year in summer months. During this period, the summer seasonal average rose from 22.4°C to 24.7°C (Çapraz, 2024). Complementary analysis from Florya and Göztepe stations reported an annual temperature rise of 0.9–1.1°C between 1960–1974 and 1999–2013, and a shift in climate classification from semi-humid to arid and less-humid, according to the Thornthwaite system (Turoğlu, 2014). These trends substantiate the city's climatic vulnerability and support its selection as an appropriate case area for studying urban thermal resilience.

Data

The legal foundation of the study is the Spatial Plans Construction Regulation under the Zoning Law No. 3194. As primary application data, surface temperature, Normalized Difference Vegetation Index (NDVI), and land surface emissivity images derived from Landsat 8 satellite imagery dated 1 June 2020 were used. The boundaries of the selected open and green spaces were delineated using high-resolution imagery from Google Earth and vector data from OpenStreetMap. In addition, a 300-meter buffer was applied around each selected site to extract perimeter data for comparative analysis.

Method

The primary objective of this study is to compare the local climatic characteristics of the areas (square, recreation area, grove, park, botanical garden, hippodrome, stadium and fair center) that are grouped under a single category as Open and Green Spaces in the Turkish Spatial Plans Construction Regulation. This comparison is conducted through statistical analyses based on surface temperature data. The study highlights that these legally unified yet functionally diverse spaces should be treated separately in the context of developing climate-resilient cities.

It is evident that a regulation which considers Botanical Park or Recreation Area and City Square at the District Border level and Urban Forest or

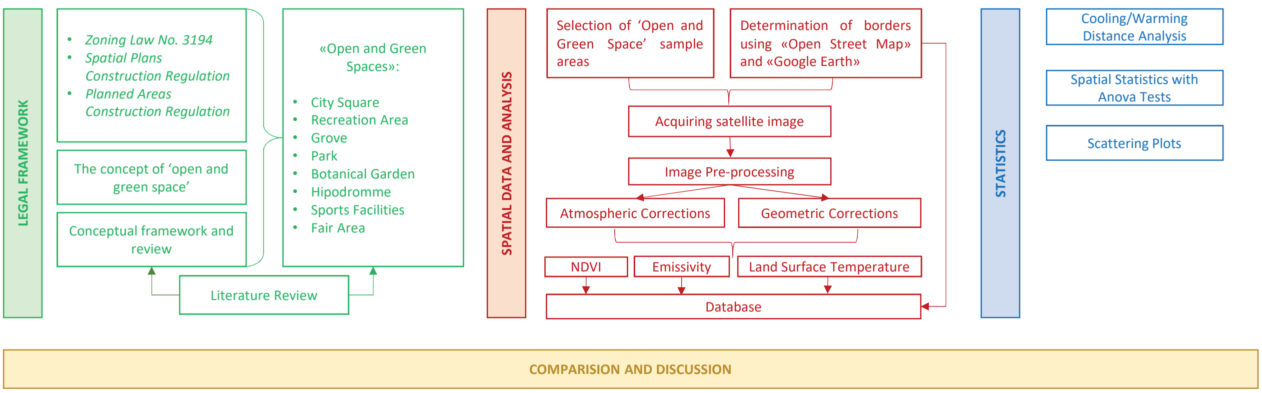
Afforestation Area and Fairground as equivalent uses that can be designed interchangeably will fail to create urban constructions that are resilient to climate change in terms of minimising the negative effects of urban warming. While some of these uses are natural and semi-natural areas, others are urban uses that have been constructed entirely with artificial material surfaces. In other words, the effects of these areas on the negative effects of urban heat waves are quite distinct. Consequently, the current regulation, which sets the fundamental spatial standards, must be wholly revised and re-evaluated in order to construct urban environments that demonstrate resilience to climate change.

In this context, spatial analyses and legal evaluations were carried out parallel to each other in this study. In the spatial analysis phase, surface temperature data derived from the thermal band of satellite images were used. At this stage, the micro-climatic structure of each "Urban Open Space" sample, their relationship with their 300 m perimeter and their differentiation from one another were statistically evaluated. In the second phase, based on the results obtained in the first stage, the adequacy of the basic principles, standards, methods and definitions put forward by the Zoning Law No. 3194, which is the legal basis of urban planning in Turkey, Spatial Plans Construction Regulation and Planned Areas Construction Regulation issued in accordance with this law, was discussed. In this way, the adequacy of the basic legal documents that determine the spatial structuring in Turkey in terms of creating climate resilient cities have been tried to be revealed. These two dimensions; spatial analysis and legal evaluation were operationalized through a structured three-phase workflow: (1) legal framework analysis, (2) spatial data processing, and (3) statistical analysis. This overall process is detailed in the Methods section and visually represented in Figure 2.

Legal Analysis of Spatial Planning System in Turkey in terms of Adaptation to Climate Change

The primary legal instruments guiding the spatial planning process in Turkey are the Zoning Law No. 3194 (*İmar Kanunu*), the Spatial Plans Construction Regulation (*Mekansal Planlar Yapım Yönetmeliği*), and the Planned Areas Construction Regulation (*Planlı Alanlar İmar Yönetmeliği*) all enacted in accordance with this law. Although the Zoning Law No. 3194, which came into force on 03.05.1985, has been amended many times, no change has been made in this law so far in terms of adapting to the new paradigm that has emerged in the field of climate.

Figure 2. Workflow



The Zoning Law No. 3194 essentially defines the planning processes, plan types and the relations between these plan types. According to the law, the spatial plan levels were determined as Spatial Strategy Plan, Territorial Plan (1/250.000-1/50.000), Master Zoning Plan (1/25000-1/5000) and Implementation Development Plan (1/1000). In this law, no relationship has been established in terms of adaptation to climate change at any of these plan levels. The only plan type in which climate-sensitive plans are presented as an "option", without being bound by an obligation, has been determined as the plans to be made in rural areas. The relevant article regarding the content of the plans to be made in rural areas is as follows.

> "Article 8: Preparation and implementation of plans: h) (Annex: 12/7/2013-6495/73 art.) Studies and projects of structures in villages and other rural settlements may be prepared by architects and engineers of the relevant administration or the provincial organization of the Ministry. By the Ministry; energy efficient, climate sensitive and ecological plans and projects can be prepared or prepared for the settlements within the scope of this Law, these qualified structures can be built or supported by long-term loans." (TLIS (a), 2023)

Within the scope of the Zoning Law No. 3194, which outlines the fundemental principles of planning in Turkey and sets out the basic definitions, only rural settlements are discussed in order to create climate-sensitive settlements. While it is now an accepted reality all over the world that the climate change process is a problem that should be included in the planning process at all scales; it is seen that climate change is not considered as a risk in any plan type and scale listed in the Zoning Law No. 3194, and creating climate-sensitive spaces is not adopted as a priority.

The primary secondary legal instrument governing spatial planning in Turkey is the *Spatial Plans Construction Regulation*, which was enacted based on Zoning Law No. 3194. This regulation defines the types of plans included in the hierarchical structure established by the law and outlines the principles to be followed in their preparation. However, despite its central role in shaping spatial planning practices, the regulation does not address climate change as a planning issue, leaving a critical gap in the legal framework for climate-responsive urban development. In any type of plan, the definitions and contents of which are determined in this regulation, has not been put forward as a principle to create cities that are resilient to climate change under the title of "Planning Principles". The Spatial Strategy Plan is the only type of plan where studies on climate change can be carried out in the parts where the documents to be prepared and the mandatory works to be done are determined during the preparation phase of the plans. In this type of plan, it is not obligatory to make analyzes on climate change. The statement regarding the work to be done and the data to be produced on climate change under the heading Data Structure and Analysis in the relevant plan type is as follows:

> "Article 17 b) Areas whose development will be restricted or with special conditions; Areas where there is a certain danger such as earthquakes, landslides, floods, climate change, areas that are important for biodiversity, endemic species such as agricultural ecosystems and forests, freshwater ecosystems and water resources, coastal ecosystems or ecologically important areas and nature protection areas, special environmental protection zones, national park, nature reserve, wildlife protection area, protected areas and similar issues." (TLIS (b), 2023)

As can be seen from Article 17-b, it addresses climate change together with disasters such as earthquakes, landslides and floods that have a risk factor specific to a particular place or region. Turkey, which is located in the Mediterranean climate zone, faces the negative effects of climate change not only in certain regions but also as a whole. Moreover, climate change is an issue that needs to be addressed with an integrated approach on a wide scale, from macro to micro. However, in Turkey, one of the countries where the negative effects of climate change will be felt the most, in the Spatial Strategy Plan, which is prepared at the country level and gives reference to all other sub-scale plan types, the issue of climate change is addressed incompletely and incorrectly under the heading of data and analysis. This attitude clearly shows how much the spatial planning practice in Turkey ignores the climate change process.

Spatial Plans Construction Regulation; besides determining the basic principles, approaches and methods regarding planning processes, has a decisive role in terms of the relationship between climate and space, as it is the main document that determines the spatial standards of Turkish cities. Within this regulation, the rate and types of minimum social and technical equipment areas that should be included in the cities were determined. The criteria for minimum standards as the main factors that shape the design and reveal the quality in the planning process are presented in Table 1.

As can be seen, many social reinforcement areas and green areas, within two scales determined as province and district, are considered together under the title of "open and green spaces". It is clearly seen that this standard, which is determined as 10 square meters (minimum condition) per person in all cities, regardless of any variables such as population and density, has no scientific consistency when considered in terms of the relationship between climate change and spatial planning. In this regulation, fair and festival area" and urban forest are determined as interchangeable areas. Therefore, in accordance with this regulation, it is possible to design settlements that do not actually have any green areas, but that meet the open and green area standard of 10 m^2 per person according to the Spatial Plans Construction Regulation.

When both the Law and the related regulation are analysed from a legal perspective, it is seen that climate change is not considered as a risk factor in the planning systematic in Turkey. In this sense, climate is not taken

Table 1. Table of standards and minimum area sizes for minimum social and technical infrastructure aeas. (TLIS (b), 2023

Infrastructure Areas			Population Groups (m2/ person)			
			0 – 75.000	75.001 – 150.000	150.001 – 500.000	501.000 - …
Open and Green Spaces	In Planning Made Within District Borders	Child Garden, Park, Square, Sports Field, Botanical Park, Recreation Area	10.00	10.00	10.00	10.00
	Planning Made Across Provincial Borders	Zoo, Urban Forest, Afforestration area, Fair and Festival Area, Hipodromme	5.00	5.00	5.00	5.00

into account in the preparation of any type of plan, nor in the analyses and standards established.

Spatial and Statistical Analyses of Open Green Spaces in Istanbul

In the first stage of spatial and statistical analyses of OGS, the necessary corrections of the Landsat satellite images were made and the surface temperatures were calculated. Before using the satellite images, preprocessing is applied in which atmospheric and radiometric corrections are made (USGS, 2018). Thermal data were corrected using the Landsat 8 formulas given in the handbook and the calibration parameters given in the metadata.

In calculating surface temperatures from satellite images, it is necessary to calculate NDVI and the emissivity values that vary according to the incoming radiation spreading properties of different cover types.

NDVI (Normalized Difference Vegetation Index) is a numerical indicator that uses remote sensing measurements to assess whether the target being observed contains live green vegetation or not. It is calculated (Eq 1) by using visible and near infrared bands of satellite.

$$NDVI = (NIR - RED) / (NIR + RED) \quad (1)$$

In this study, the pixel-level land surface emissivity ($\varepsilon\lambda$) was calculated using a threshold-based NDVI classification method originally proposed by Jeevalakshmi et al. (2017). This approach remains widely adopted in recent remote sensing applications (Li et al.,2024; Tand et al., 2015), due to its flexibility in differentiating surface types based on vegetation cover. The method is structured around Equation (2), which computes the proportion of vegetation (Pv) using two threshold NDVI values: NDVIs = 0.2 for bare soil and NDVIv = 0.5 for fully vegetated areas.

$$Pv = [\,(NDVI - NDVI_s) / (NDVI_v - NDVI_s)\,]^2 \quad (2)$$

Based on this proportion, the surface emissivity ($\varepsilon\lambda$) is determined using the rule-based structure shown in Eq. 3:

$$\varepsilon_\lambda = \begin{cases} \varepsilon_{w\lambda} & NDVI<0 \\ \varepsilon_{S\lambda} & NDVI< NDVI_s \\ \varepsilon_{v\lambda} P_v + \varepsilon_{S\lambda} (1- P_v) +C & NDVI_s \leq NDVI< NDVI_v \\ \varepsilon_{v\lambda}+C & NDVI> NDVI_v \end{cases} \quad (3)$$

In this formulation, NDVIv (0.5) refers to the typical NDVI value of fully vegetated areas, NDVIs (0.2) represents bare soil, and NDVI values below 0 are interpreted as water surfaces (NDVIw). Correspondingly, εv, εs, and εw denote the land surface emissivity values for vegetated, soil, and water-covered surfaces, respectively.

Brightness values were calculated using the "radiative transfer" method given by Jiménez.-Muñoz et al. (2009). In the last step, surface temperature images were obtained by converting the brightness values (Eq. 4) to surface temperatures (Eq. 5).

$$L_\lambda(TS) = [(L_{\lambda} - L_\lambda atm\uparrow) / (\tau\, \varepsilon_\lambda)] - [(1- \varepsilon\lambda)^* L_\lambda atm\downarrow / \varepsilon_\lambda] \quad (4)$$

$$TS=1260.56/Ln\,[(607.76/L_\lambda)+1] \quad (5)$$

In this formulation, εw, εs, and εv correspond to emissivity values for water, soil, and vegetation surfaces, respectively, and C denotes a correction factor for surface roughness. This method ensures accurate emissivity estimates by accounting for sub-pixel land cover variation, particularly in heterogeneous urban environments. After the NDVI, emissivity and Land Surface Temperature (LST) images were obtained, they were transferred to the database prepared in GIS environment for spatio-statistical analyses.

In the second stage of the analysis, a pixel-by-pixel approach was employed to examine statistical differences in NDVI, emissivity, and land surface temperature (LST) values across different classes of open and green spaces (OGSs), including squares, groves, parks, and other typologies. For this purpose, Landsat 8 OLI/TIRS satellite imagery with a spatial resolution of 30 meters (i.e., 900 m^2 per pixel) was used, allowing each OGS to be represented by hundreds of valid pixels. This pixel-based structure enabled the detection of subtle spatial variations in thermal and vegetation characteristics, and provided a statistically reliable basis for comparing different types of open and green spaces. In the spatial and statistical analysis phase, a univariate ANOVA was applied to determine whether statistically significant differences (at the 0.01 significance level) existed among OGS categories in terms of NDVI, emissivity, and LST. To address the lack of homogeneity in group variances, Tamhane's T2 post-hoc test a method specifically suited for unequal variances was employed for multiple comparisons. Following this, a Spearman correlation analysis was conducted to assess the relationship between land surface temperature (LST) and both NDVI and emissivity values, revealing a strong negative correlation between LST and NDVI ($r = -0.754$, $p < 0.01$). Furthermore, a multiple linear regression model was applied to explore the combined effects of NDVI, emissivity, and OGS categories on surface temperature. For this purpose, dummy variables were constructed to represent the categorical OGS types. The model achieved a high explanatory power with $R^2 = 0.818$.

Regression and ANOVA results obtained in this study indicate that both NDVI and surface emissivity are significant determinants of land surface temperature (LST), particularly in vegetated OGS typologies such as parks and groves. These results align with previous studies (Guha et al., 2018; Li et al., 2024), supporting the conclusion that vegetation density and surface emissivity are key factors in shaping and regulating land surface temperature patterns in urban environments.

In addition to statistical modeling, a pixel-based distance analysis was conducted to determine the spatial extent of thermal influence around each OGS. For this purpose, satellite images were cropped to a 300-meter buffer surrounding each sample site and transferred to the analysis database. Surface temperature values were then evaluated in relation to their distance from the OGS boundaries using pixel-level data (Fig. 3). The initial point at which a significant increase or decrease in temperature occurred along the distance gradient was considered the threshold for determining the effective cooling or warming influence of each site.

Then, the images were cropped to cover the 300m perimeter of each sample area and transferred to the database and the heating/cooling effects on the 300 m perimeter of each sample area were investigated by distance analyses. Cooling/warming distance analyzes are based on the relationship between the pixel-level surface temperature data and the distance to the sample site (Fig. 3). In this method, the first break point in the direction of heating or cooling (increase or decrease) gives the heating or cooling effect distance of the site.

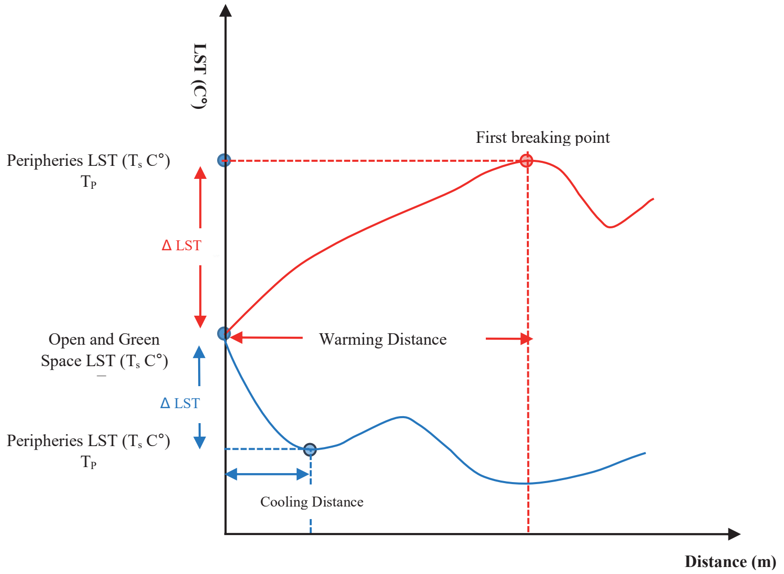


Figure 3. Cooling/warming distance analysis

The cooling distance was determined through a synthesis of existing literature and the findings of related studies conducted in Istanbul. Prior studies suggest that the climatic influence of urban green spaces can extend up to 500 meters (Keikhosravi et al., 2023; Güldü and Kuşçu Şimşek, 2022), although this range is highly dependent on urban morphology (Guo et al., 2024; He et al., 2024). In Istanbul, where urban density is high and spatial continuity is often interrupted by built structures, detecting uninterrupted temperature gradients beyond 300 meters is rarely feasible. In site-specific studies, cooling effects were observed to reach up to 300 meters in vegetated zones of Göztepe and Özgürlük Parks, while dropping to 50–75 meters in segments surrounded by high-rise or impervious areas (Kuşçu Şimşek et al., 2022). Earlier work on mid-sized parks such as Maçka, Gezi, and Serencebey indicated that temperature differentials became negligible beyond approximately 150 meters (Kuşçu Şimşek, 2016). Taking into account these location-specific findings, along with the spatial complexity of Istanbul, the 300-meter threshold was chosen as a reasonable and methodologically sound distance for capturing the measurable climatic influence of OGSs without interference from surrounding urban structures.

RESULTS

As a result of the analysis, firstly, surface temperature maps of each sample area were created (Fig. 4). When the maps obtained were interpreted visually, it was seen that the sample areas showed different climatic characteristics within themselves. However, as a result of the Anova tests applied to check whether these differentiations exhibit a significant differentiation according to the definitions of “open and green space”, it was determined that the groups were largely separated from each other (Table 2). According to these findings, it was determined that the grove, park, botanical garden, square and fair area were separated from each other significantly. However, the surface temperatures of recreation areas, sports facilities and hippodrome were similar.

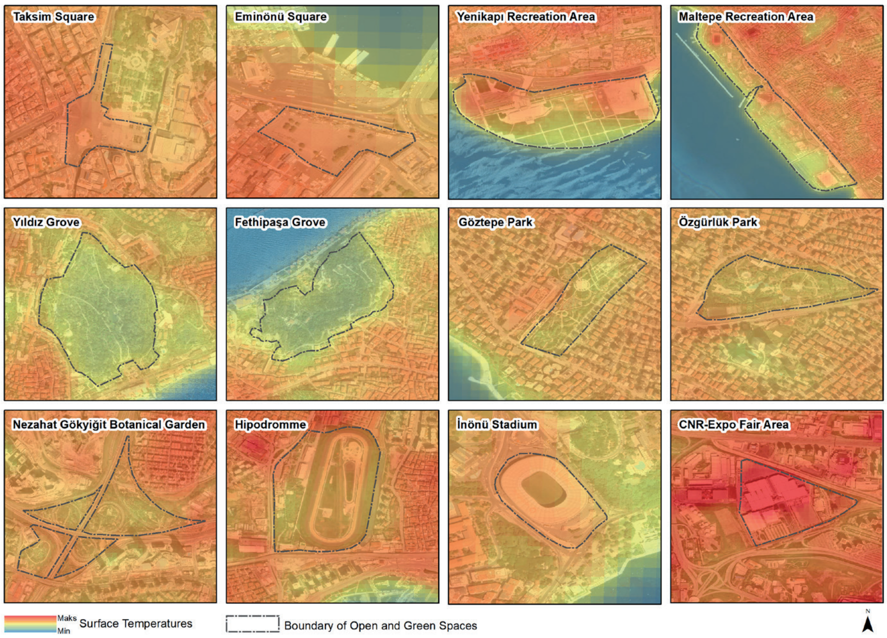


Figure 4. Local climate maps of open and green spaces

When the differentiation of NDVI and emissivity values, which are the most important factors affecting the surface temperature, according to the 'Open and Green Space' classes were analysed, it was seen that the classes were separated from each other in a way to support the surface temperature differences (Table 2). In addition, when the correlations of NDVI and emissivity factors with LST were analysed (Table 3), it was found that vegetation density and emissivity had -0.754 (high) and -0.234 (relatively low) correlations with LST at 0.001 significance level, respectively.

Table 2. Tamhane's Statistics

Tsurface

	Land Use_Code	N	Subset for alpha = 0.05								
			1	2	3	4	5	6	7	8	Sig.
Tamhane	1 (Grove)	635	33,68								0,00
	2 (Park)	203		38,12							0,00
	3(Botanical Garden)	428			39,72						0,00
	4 (Recreation)	285				38,95					0,00
	5 (Sports Facilities)	50					40,71	40,39			0,58
	6 (Hipodromme)	484					40,71	40,39			0,58
	7 (Fair Area)	52							48,59		0,00
	8 (City Square)	279								41,82	0,00

Means for groups in heterogeneous subsets are displayed.
The mean difference is significant at the 0,01 level

Spearman's rho		LST	NDVI	Emissivity
LST	Correlation Coefficient	1	-0.754**	-0.234**
	Sig. (2-tailed)	0.00	0.00	0.00

**Correlation is significant at the 0.01 level (2-tailed).

Table 3. Correlations of NDVI and emissivity factors with LST

Vegetation density (NDVI), which absorbs and reflects solar radiation energy and controls latent sensible heat exchange, directly affects LST (Ullah et al., 2023; Garaiet al., 2022).

When NDVI classes and NDVI densities according to Open and Green Space (OGS) (Table 4) are evaluated together, it is found that there are no high density green areas in Istanbul sample areas; the highest green density is found in groves; parks and botanical garden are in the low class. On the other hand, sport facilities, fair area and city square are classified as very low. In addition, when post-hoc Tamhane tests were analysed between NDVI values and OGS type, it was found that 88% of the groups were significantly separated from each other at 0.01 level, and only botanical garden/recreation area; recreation area/hypodrome and sports facility/fairground were mixed. These findings clearly show that when the NDVI and surface temperature correlations (**Table 3**) and the scatter plot (**Figure 5**) are evaluated together, it is evident that considering the open and green space classes together in terms of climatic impact and cold island potential may lead to non-significant interpretations about heat resilience.

On the other hand, emissivity, which is an important parameter in surface energy balance research, refers to the ability of a surface to emit thermal radiation (Zhong et al., 2022). However, the measured emissivity of materials may vary depending on properties such as surface roughness, moisture content or weather conditions. For example, differences in precipitation can lead to significant emissivity variations even for similar materials. Therefore, although emissivity is an important parameter in surface temperature measurements, it can produce variable effects. It was found that 76% of the emissivity values of the sample areas used in this study were significantly different from each other at 0.01 level.

Then, a linear regression test was performed to examine the effects of NDVI, emissivity and each of the OGS classes (grove, park, botanical garden, recreation, sport facilities, hippodromme, fair area and city square) on LST. As a result of the test where R^2 value was 0.818, it was determined that NDVI and emissivity values and grove areas had significant

Vegetation Class	NDVI Value
Bare soil or water	NDVI < 0
Very Low	0 < NDVI ≤ 0.2
Low	0.2 < NDVI ≤ 0.4
Moderately Low	0.4 < NDVI ≤ 0.6
Moderately High	0.6 < NDVI ≤ 0.8
High	0.8 < NDVI ≤ 1

Table 4. Vegetation class and NDVI value (Aquino et al., 2018).

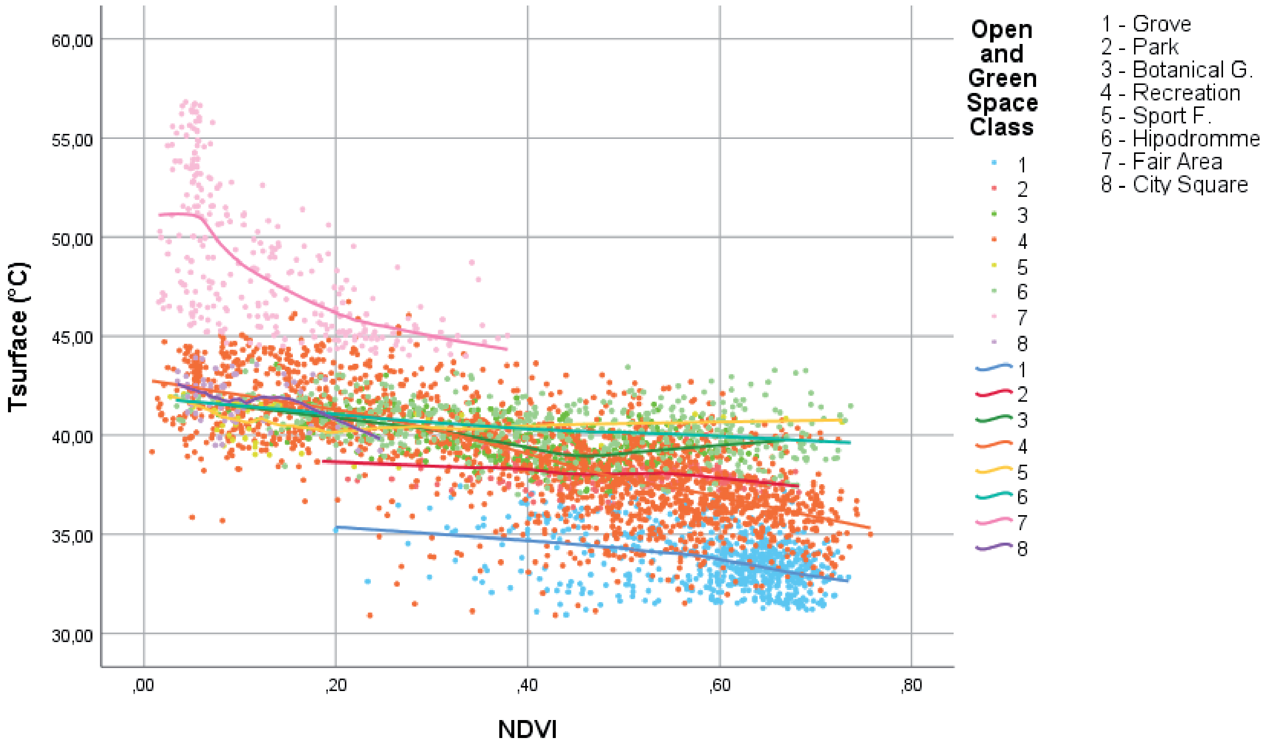


Figure 5. Scatter plots between LST and NDVI according to each OGS class

decreasing effects on LST, while other OGS areas either had no significant effect or had increasing effects.

These statistical analyses revealed that vegetated OGS types particularly groves and parks exhibited significantly lower surface temperatures and higher NDVI and emissivity values compared to non-vegetated types such as squares. ANOVA and post-hoc results confirmed that these differences were statistically significant, highlighting the superior cooling capacity of densely vegetated spaces. The regression analysis further supported this finding, showing that NDVI and emissivity together account for a substantial proportion of LST variation, especially within vegetated OGS typologies. These findings provide a robust empirical basis for prioritizing vegetated OGS designs in urban climate adaptation strategies.

Also, when the relations of open and green space samples with their 300m surroundings are examined by cooling/warming distance analysis (**Figure 6**), it is seen that the effects on the perimeters of the fields are also different from each other. Forests, green areas, coasts and wetlands, which have natural cooling potentials of urban areas, can cool their peripheries up to 1 km. However, this cooling effect distance varies according to the land use status of the surroundings and the morphological structure of the urban area (Kuşçu Şimşek et al., 2022; Güldü and Kuşçu Şimşek, 2022). On the other hand, it is known that buildings, roads and large impermeable surfaces as parts of the urban area exhibit the opposite effect and exhibit a heating effect up to a certain distance in the urban area (Arshad et al., 2022).

According to the findings obtained from this study, it is seen that the heating or cooling effect changes according to the characteristics of the field in the examples of open and green spaces with a wide definition range in the legislation. Therefore, it has been determined that these areas

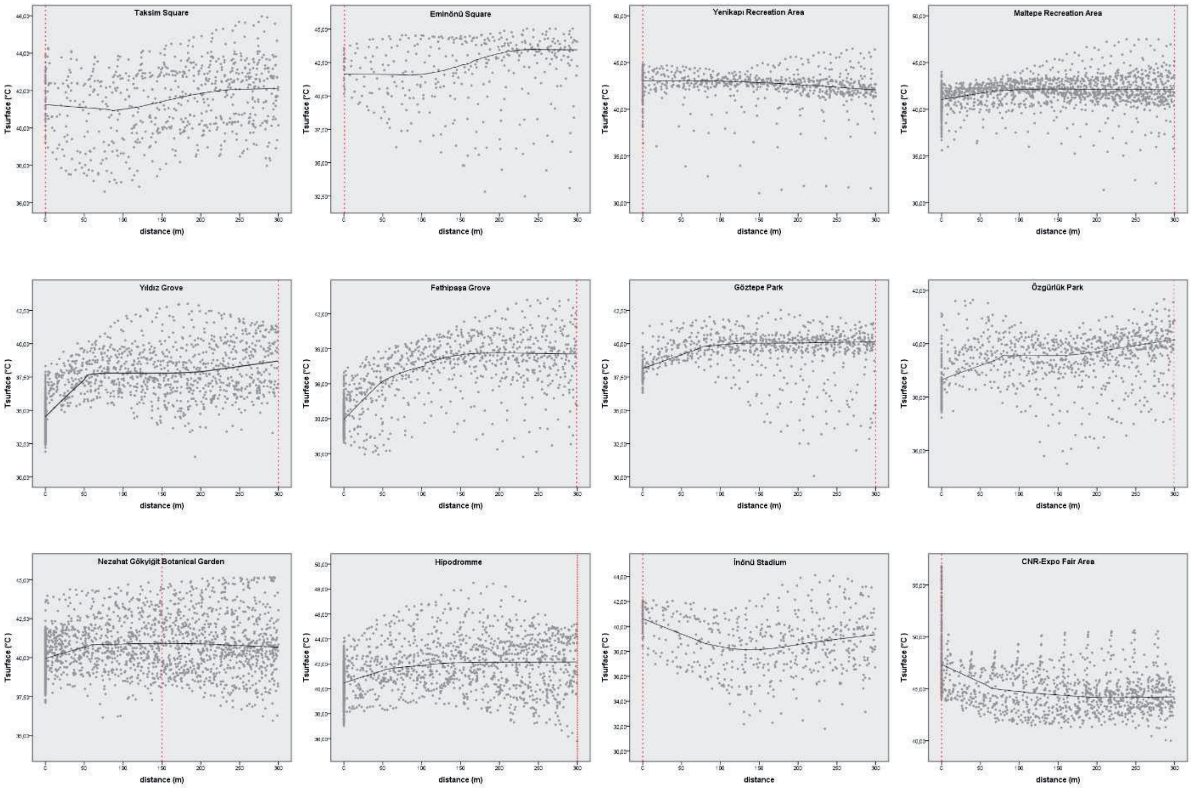


Figure 6. Heating/cooling effect on 300 m peripheries of open and green spaces samples

do not exhibit a consistent behavior on the urban area in terms of climatic conditions. For example, as a result of the general evaluation (**Figure 6**); while the park, grove and hippodrome samples have a cooling effect up to 300m in their surroundings, it has been determined that the exhibition center and stadium samples have a warming effect. On the other hand, it is seen that Yeni Kapı and Maltepe samples, which are examined as recreation areas, have opposite effects, and the heating or cooling effects change according to the landscape structure of the area.

In the final stage of the study, a comprehensive table (**Table 5**) was created to summarize the findings and reinforce the results. The table provides an integrated evaluation of open and green space (OGS) types, their average surface temperatures, mean normalized difference vegetation index (NDVI) values, cooling distances, and the corresponding surface temperature differences (ΔTsurf °C) observed within those distances. The compiled data clearly demonstrate distinct stratification among different types of open and green spaces.

The enhanced classification table clearly shows that areas categorized as natural, notably Fethipaşa and Yıldız Groves, have the greatest cooling impact. These areas have surface temperature differences ranging from 5°C to 15°C compared to semi-natural and artificial areas. Conversely, sites such as the İnönü Stadium, Taksim Square, Eminönü Square, and the CNR Expo Fairgrounds have higher surface temperatures and provide no discernible climatic benefit to their surroundings.

The table also highlights two particularly noteworthy cases. First, the Botanical Garden, though classified as semi-natural, exhibits a shorter

Site Name	OGS Type	Surface Temp. (°C)	NDVI Range	NDVI_Avr	Cooling Dist. (m)	ΔT (°C) At Breakpoint	Cooling Effect	Proposed Classification
Fetihpaşa Grove	Grove	32,87	Moderately High	0,6	300	5,4	Strong	Natural
Yıldız Grove	Grove	34,25	Moderately High	0,6	300	3,6	Strong	Natural
Göztepe Park	Park	37,8	Moderately Low	0,5	300	1,3	Moderate	Semi-Natural
Özgürlük Park	Park	38,35	Moderately High	0,6	300	1,4	Moderate	Semi-Natural
Maltepe Recreation Area	Recreation	38,43	Low	0,4	300	0,8	Low	Semi-Natural
Nezahat Gökyiğit Botanical Garden	Botanical Garden	39,72	Low	0,4	150	0,5	Low	Semi-Natural
Yenikapı Recreation Area	Recreation	40,02	Low	0,3	0	0	None	Semi-Natural
Hippodrome	Hippodrome	40,39	Low	0,4	300	1	Low	Artificial
Inönü Stadium	Sport Facility	40,71	Very Low	0,2	0	0	None	Artificial
Taksim Square	City Square	41,71	Very Low	0,1	0	0	None	Artificial
Eminönü Square	City Square	42,09	Very Low	0,1	0	0	None	Artificial
CNR Expo Fair	Fair Area	48,6	Very Low	0,1	0	0	None	Artificial

Table 5. Synthesis table

cooling distance than parks. This is likely due to its location, encircled by highway infrastructure, which amplifies ambient heating and diminishes the green area's cooling reach. Second, the Hippodrome is an exception among artificial structures because, despite its general building form, it demonstrates a measurable cooling influence. This is attributed to the landscaped green belt surrounding the facility, which has a relatively high NDVI value of 0.4, similar to that of the Maltepe Recreation Area. These findings underscore the potential for improving the climatic performance of artificial spaces through appropriate landscape design and vegetation integration.

Together, these insights validate the necessity of differentiating OGS typologies not just by intended use but also by their observed ecological and climatic functions, paving the way for evidence-based planning strategies aimed at climate resilience.

DISCUSSIONS

Within the scope of this article, the adequacy of the Spatial Plans Construction Regulation, Planned Areas Construction Regulation and the Zoning Law No. 3194, which are the main documents used when determining the spatial structure of Turkish cities, in terms of creating cities that are resilient to climate change have been examined. Fort this purpose open and green spaces mentioned in the legal documents were analised. Furthermore, the structural adequacy of legal documents on climate change has been evaluated alongside the examples of open and green spaces.

In the studies conducted at two levels, the following findings were reached regarding the structural and technical adequacy of legal documents on climate change:

- It is clear that the relationship between urban climate and spatial planning is not established in any plan type within the Turkish zoning system. Among the plan types defined in the Zoning Law No. 3194 and the Spatial Plans Construction Regulation, which shape the planning practice in Turkey, climate change is considered as a problem only in the plans for rural settlements.
- In the Spatial Plans Construction Regulation, which determines the ratio and type of social reinforcement standards in cities, the uses under the heading of 'open and green spaces', which have very different effects on the urban climate, are regulated as interchangeable. As can be seen from the analyses, the surface temperature produced by each urban use differs significantly from each other. The Uses with a difference of nearly 20 degrees in surface temperature are considered under the same heading and as alternatives to each other is incompatible with the scientific approach in terms of creating cities resilient to climate change (**Figure 5**, **Figure 6**). When compared to the immediate surroundings of the groves and parks, it is revealed that the surface temperatures are lower than the surrounding areas. On the contrary, it is seen that the temperatures in fairgrounds and city squares are higher when compared to their immediate surroundings and even radically differ as in the example of the CNR Expo Fair Center. When the examples taken from Istanbul of the urban uses mentioned in the Spatial Plans Construction Regulation are examined, it is seen that the climatic variation is statistically evident (Table 5).
- The Planned Areas Zoning Regulation addresses the relationship between climate change and space only at the building scale. In this regulation, it is seen that only building-based measures regarding climate change are developed.
- It is seen that there is no systematic approach to the use of 'open and green space' at the urban scale in Planned Areas Zoning Regulation as well. The definition of green areas is made under many different headings and without a qualitative differentiation. In the regulation, green areas are defined as 'Green areas including playgrounds, children's gardens, recreational, picnic, entertainment, recreation and recreactive areas allocated for the benefit of the public (Fairgrounds, botanical and animal gardens and regional parks at metropolitan scale are within the scope of these areas), the functions and construction conditions specified in Article 19" (TLIS (c), 2017). As it can be seen, areas with quite different climatic effects are used

together in this regulation like Spatial Plans Costruction Regulation. In addition, picnic and recreation areas, national gardens and parks are included in this regulation as similar definitions in terms of content. However, no descriptive numerical qualification has been specified for the differentiation of these uses and no standard has been established. In summary, the blindness that exists in the Spatial Plans Construction Regulation continues to exist in this regulation.

- Considering the fixed ratio of 10 m2 /person open and green space in accordance with the existing legal documents, it is legally possible to create cities that do not have green spaces in the actual situation and can be built with many usage decisions that affect the urban climate in the opposite direction with green spaces.

In light of these findings, it can be concluded that the prevailing structural and technical approach to legislation and regulation is insufficient for the creation of climate-sensitive cities. So it is obvious that, there are fundamental changes that need to be made at the level of laws and regulations in order to minimise the effects of heat waves, one of the most deadly impacts of climate change, and climate change in general.

- First of all; it is necessary to reconsider the framework determined for the plan type, purpose and working methods in the basic legal documents that determine the spatial planning hierarchy and planning process, taking into account climate change. In this sense, climate change should be defined as a problem in all scales and types of plans within the Spatial Planning hierarchy.
- The only type of plan in which climate-sensitive planning is presented as an 'option', without any obligation, is the rural plan. In the analysis phase of the plans, the integration of climate change research into planning practice is a necessity. In this context, it should be obligatory to carry out analyses of the spatial impact of climate change, according to the level of detail required by the scale of each type of plan.
- The separation of open and green spaces, which are vital in the urban climate, by taking into account the effects on the urban climate, is one of the arrangements that should be made as a priority in terms of creating cities that are resistant to climate change. While making this these areas should be categorised by considering their effects on the urban climate. In this sense, natural areas, semi-natural areas and artificial areas should be organised under separate headings. And the subcomponents of each subheading should be used interchangeably only among themselves.

However, there is no universally accepted, clear definition of urban open and green spaces. While these areas are generally classified as natural (e.g., forests, woodlands) and semi-natural (e.g., urban parks, botanical gardens), they are conceptualized in various ways across the literature. In this context, Won Kyung Kim (2011) highlights the lack of a unified framework in defining "open space" and "green space" and identifies five different conceptualizations found in the literature: (1) definitions of open space that encompass green space; (2) definitions that jointly consider open and green space; (3) definitions that treat them as separate entities; (4) definitions of green space that encompass open space; and (5) definitions that treat them as distinct but overlapping categories. Similarly, James et al. (2009) draw attention to this conceptual diversity and propose a reclassification of green spaces based on their ecological, recreational, and spatial functions. This conceptual ambiguity reveals that the need for definitional clarity, both in academic discourse and in regulatory frameworks.

In line with this, the present study evaluates how the vague definitions of "open and green spaces" in Turkey's Spatial Plans Construction Regulation present a barrier to developing climate-resilient cities. Under the current legal framework, entirely artificial spaces such as squares and fairgrounds are grouped under the same category as green areas and are considered interchangeable land uses. However, the findings of this study reveal that these different land uses have markedly different effects on the urban microclimate, highlighting the necessity of differentiating between types of open and green spaces based on their climatic impacts.

Therefore, to enhance the resilience of cities to climate change, this conceptual clarity must first be reflected in planning legislation. In this regard, the classification of open and green spaces based on their ecological and climatic performance, as proposed in this study, offers a concrete alternative to address existing definitional ambiguities and inform more effective regulatory frameworks.

Building on this perspective, the spatial analyses conducted within the scope of this study suggest a refined classification of legally recognized open and green space categories into three subtypes: (1) Natural areas, such as urban forests, natural forests, and afforestation zones; (2) Semi-natural areas, including parks, botanical gardens, zoos, and hippodromes; and (3) Artificial areas, such as fairgrounds, urban squares, and sports fields. This tripartite framework is grounded in the observed differences in surface temperature, vegetation density (NDVI), and cooling distance, and is intended to better align land use classifications with their actual climatic functions in urban environments.

The unsystematic complex structure regarding green areas in Planned Areas Zoning Regulation should be simplified and this regulation should be regulated according to the structure and standards to be established in the Spatial Plans Construction Regulation.

To summarise as a result of all these findings; it is necessary to renew the documents that determine the standards and uses in determining the spatial pattern in Turkey, taking into account international definitions and practices. Green infrastructure is a particular feature of urban areas that performs this function (EEA, 2012). And In 2013, the European Commission (EC) put forward a Green Infrasturucture (GI) strategy to ensure that the protection, restoration, creation, and enhancement of GI become standard and integral parts of spatial planning and territorial development whenever they complement or offer a better alternative to standard gray choices (Pozoukidou, 2020). In this framework, the definitions made by the European Commission should be taken into account and these uses should be separated.

The European Commission defines green infrastructure as "…a strategically planned network of high quality natural and semi-natural areas with other environmental features". This can encompass, for example, vegetated areas, parks, gardens, wetlands, natural areas, green roofs and trees (EEA, 2012).

As seen in both definitions, strengthening and establishing green infrastructure is one of the most important policies to create climate-resilient cities in terms of mitigating and preventing the devastating effects of urban warming. In this sense, natural or semi-natural areas and artificial areas should be separated from each other.

CONCLUSION

Cities are at the forefront of the places most affected by the devastating consequences of climate change, due to their human population. It has been revealed in many studies that; the spatial pattern of cities is one of the main factors that determine the urban climate. So land use planning which determine the spatial patterns of cities has a great impact on the development of the adaptation capacity of the urban area to climate change. In this sense, the legal bases of land use plans are the guiding factor of this process.

In many countries, the relationship between land use decisions and climate is established and strategies are developed accordingly. However, the amount of gap between legislation and practice in Turkey is quite large. The relationship between spatial planning and climate is not a subject that has been comprehensively discussed in any plan type. So, there is a need for an integrated transformation at all scales, including open and green spaces, at the point of creating cities that are resilient to climate change in Turkey.

In this article, the main deficiencies in the basic legal documents that determine the method and content of the spatial plans that determine the spatial organisation of the cities and what should be done against these deficiencies are tried to be discussed. Of course, making cities resilient against climate change is a multi-dimensional and multi-scale issue. This issue needs to be addressed at many complementary scales such as material, building, street, city and region. These issues and the definition of basic spatial standards will be the necessary studies to be addressed in the following studies. Studies to be carried out on this comprehensive issue at these scales will be of great importance in terms of making cities in Turkey resilient to climate change.

REFERENCES

ANDERSSON, E., LANGEMEYER, J., BORGSTRÖM, S., MCPHEARSON, T., HAASE, D., KRONENBERG, J., BARTON, D. N., DAVIS, M., NAUMANN, S., RÖSCHEL, L., BARÓ, F. (2019) Enabling Green and Blue Infrastructure to Improve Contributions to Human Well-Being and Equity in Urban Systems, *BioScience*, 69(7), 566–574.

AQUINO, D.D.N., ROCHA, O.C.D., MOREIRA, M.A., TEIXEIRA, A.D.S., ANDRADE, E.M.D. (2018) Use of remote sensing to identify areas at risk of degradation in the semi-arid region, *Revista Ciência Agronômica* 49(3) 420-9.

ARAKAWA, H. (1937) Increasing air temperatures in large developing cities, *Beitr. Geophys* (50) 3-6.

ARSHAD, S., AHMAD, S.R., ABBAS, S., ASHARF, A., SIDDIQUI, N.A., ISLAM, Z.U. (2022) Quantifying the contribution of diminishing green spaces and urban sprawl to urban heat island effect in a rapidly urbanizing metropolitan city of Pakistan, *Land Use Policy* (113) 105874.

BALABAN, O. (2012) Climate change and cities: a review on the impacts and policy responses, *METU Journal of Faculty of Architecture* 29(1) 21-44.

BALLESTER, J., QUIJAL-ZAMORANO, M., MÉNDEZ TURRUBIATES, R.F., PEGENAUTE, F., HERRMANN, F.R., ROBINE, J.M., BASAGAÑA, X., TONNE, C., ANTÓ, J.M., ACHEBAK, H. (2023) Heat-related mortality in Europe during the summer of 2022, *Nature Medicine*, 29, 1857–1866.

BIBI, T. S., KARA, K. G. (2023) Evaluation of climate change, urbanization, and low-impact development practices on urban flooding, Heliyon, 9 (1).

BROWN, D. (2011) Making the linkages between climate change adaptation and spatial planning in Malawi, *Environmental Science and Policy*, (14) 940-949.

BULKELEY, H. (2006) A changing climate for spatial planning, *Planning Theory & Practice*, (7:2) 203-214.

CHANDLER, T . J. (1962) London's urban climate. *The Geographical Journal*, (128) 279-302.

ÇAPRAZ, Ö. (2024). Trend analysis of air temperature in a megacity between two continents: the synoptic weather station in İstanbul Atatürk Airport, Environmental Systems Research.

ÇİLEK, M.Ü. ÇİLEK, A. (2021). Analyses of land surface temperature (LST) variability among local climate zones (LCZs) comparing Landsat-8 and ENVI-met model data, *Sustainable Cities and Society*, 69, 102877.

DAMTE, E., MANTEAW, B. O. and WRIGLEY-ASANTE, C. (2023). Urbanization, climate change and health vulnerabilities in slum communities in Ghana, *The Journal of Climate Change and Health*, 10, 100189.

DARMANTO, N.S., VARQUEZ, A.C.G., KAWANO, N. and KANDA, M. (2019). Future urban climate projection in a tropical megacity based on global climate change and local urbanization scenarios, *Urban Climate*, (29) 100482.

DCC (DIRECTORATE OF CLIMATE CHANGE), https://iklim.gov.tr/en [31 August 2023]

DODMAN, D., B. HAYWARD, M. PELLING, V. CASTAN BROTO, W. CHOW, E. CHU, R. DAWSON, L. KHIRFAN, T. MCPHEARSON, A. PRAKASH, Y. ZHENG, and G. ZIERVOGEL, (2022): Cities, Settlements and Key Infrastructure. In: Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. PÖRTNER, D.C. ROBERTS, M. TIGNOR, E.S. POLOCZANSKA, K. MINTENBECK, A. ALEGRÍA, M. CRAIG, S. LANGSDORF, S. LÖSCHKE, V. MÖLLER, A. OKEM, B. RAMA (EDS.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 907–1040,

DURSUN, D., YAVAŞ, M. and GÜLLER, C. (2016). Kış Kenti Erzurum'da İklim, Planlama ve Yerel Yönetim Politikalarının Etkileşim Düzeyi, *Planlama,* 26(2), 147-159. https://doi.org/10.14744/planlama.2016.73644.

EEA (EuROPEAN ENVIRONMENT AGENCY), (2012). Urban adaptation to climate change in Europe: Challenges and opportunities for cities together with supportive national and European policies. Luxembourg: Office for Official Publications of the European Union.

ERAYDIN, A.,KÖROĞLU, T. (2021). Planlamanın Yeşil Gündemi: İklim Değişikliği, Temiz Enerji, Çevreye Saygılı Bir Gelecek, *Planlama*, 31(2), 280-287.

ERBİL, T., ERBİL, A. Ö. (2019). Türkiye'de bölgesel kalkınma ajanslarının 2010-2017 yılları arasında iklim değişikliğine yönelik faaliyetleri üzerine bir inceleme, Planlama 2019;29(1):10–22.

EROĞLU, M., ÖĞÜT ERBIL, A. (2021). İklim değişikliği odaklı politika üretim ve planlama süreçlerinde bilim-politika arayüzlerinin yeri: İstanbul ve İzmir Kalkınma Ajansları, *Planlama*, 31(2), 321-336.

FRANTZESKAKI, N., J. WITTMAYER AND D. LOORBACH, (2014) The role of partnerships in 'realising'urban sustainability in Rotterdam's City Ports Area, The Netherlands, *Journal of Cleaner Production*, 65, 406–417.

FUKUI, E. (1957). Increasing Temperature due to the Expansion of Urban Areas in Japan. *Journal of the Meteorological Society of Japan,* Ser. II, (35A) 336–341.

GEDIKLI, B. (2017). Approaches to Clımate Change in Spatıal Planning and Design: International And Turkish Experiences, *METU Journal of the Faculty of Architecture,* 2018/1 35(1) 89-109.

GREIVING, S., FLEISCHHAUER, M. (2012). National climate change adaptation strategies of European States from a spatial planning and development perspective, *European Planning Studies*, (20:1) 27-48.

GRIGORIEVA, E. A.,, REVICH, B. A. (2021). Health risks to the Russian population from temperature extremes at the beginning of the XXI century, *Atmosphere*, 12(10), 1331.

GUHA, S., GOVIL, H., DEY, A., GILL, N. (2018). Analytical study of land surface temperature with NDVI and NDBI using Landsat 8 OLI and TIRS data in Florence and Naples city, Italy, *European Journal of Remote Sensing*, 51(1), 667–678.

GUO, A., YUE, W., YANG, J., LI, M., ZHANG, Z., XIE, P., ZHANG, M., LU, Y., HE, T. (2024) Quantifying the cooling effect and benefits of urban parks: A case study of Hangzhou, China, *Sustainable Cities and Society*, 113, 105706 .

GÜLDÜ, E., KUŞÇU ŞIMŞEK, Ç. (2022). İklime uyumlu kentsel planlamada, kent morfolojisi ve soğuk ada ilişkilerinin incelenmesi, Kriz Bildiriler Kitabı, TMMOB Şehir Plancıları Odası Yayını, ISBN: 978-605-01-1492-8

HE, T., HU, Y., GUO, A., CHEN, Y., YANG, J., LI, M., ZHANG, M. (2024). Quantifying the impact of urban trees on land surface temperature in global cities, *ISPRS Journal of Photogrammetry and Remote Sensing*, 210, 69-79.

IPCC 6th Assessment Report (2021), Chapter 6: Cities, settlements and key infrastructure, https://www.ipcc.ch/report/ar6/wg2/chapter/chapter-6/ [10.10.2024]

JEEVALAKSHMI, D., REDDY, S. N. AND MANIKIAM, B. (2017). Land surface temperature retrieval from LANDSAT data using emissivity estimation, *International Journal of Applied Engineering Research*, 12(20), 9679-9687.

JAMES, P., TZOULAS, K., ADAMS, M. D., BARBER, A., BOX, J., BREUSTE, J., ELMQVIST, T., FRITH, M., GORDON, C., GREENING, K. L., HANDLEY, J., HAWORTH, S., KAZMIERCZAK, A. E., JOHNSTON, M., KORPELA, K., MORETTI, M., NIEMELÄ, J., PAULEIT, S., ROE, M. H., SADLER, J. P., WARD THOMPSON, C. (2009) Towards an integrated understanding of green space in the European built environment, *Urban Forestry & Urban Greening*, 8(2), 65–75.

JIMÉNEZ-MUÑOZ, J.C., CRISTÓBAL, J., SOBRINO, J.A., SÒRIA, G., NINYEROLA, M., PONS, X. (2009) Revision of the single-channel algorithm for land surface temperature retrieval from landsat thermal-infrared data, *IEEE Transactions on Geoscience and Remote Sensing*, 47(1):339-349

KAZANCI, G.,TEZER, A. (2021). İklim Değişikliğine Uyumda Mekânsal Planlama ve Akıllı Yönetişim Çerçevesinde Türkiye, *Planlama*, 31(2), 302-320.

KEARL, Z., VOGEL, J. (2023). Urban extreme heat, climate change, and saving lives: lessons from Washington state, *Urban Climate*, 47, 101392.

KEIKHOSRAVI, G., KHALIDI, S., SHAHMORADI, M. (2023). Effects of climates and physical variables of parks on the radius and intensity of cooling of the surrounding settlements. Urban Climate, 51, 101601.

KIM, W. K. (2011). Understanding Open Spaces in an Arid City (Doctoral dissertation, Arizona State University).

KRATZER, A. (1935). Das Klıma Der Städte, *Geographische Zeitschrift*, 41(9), 321–339. http://www.jstor.org/stable/27814567

KUŞÇU ŞIMŞEK, Ç., SERTER, G., ÖDÜL, H. (2022) A Study on the Cooling Capacities of Urban Parks and Their Interactions with the Surrounding Urban Patterns, *Applied Spatial Analysis and Policy*, 15, 1287–1317.

LI, X., WANG, G., ZAITCHIK, B., HSU, A., CHAKRABORTY, T. C. (2024). Sensitivity and vulnerability to summer heat extremes in major cities of the United States, *Environmental Research Letters*, 19(9), 094039.

LI, X., WU, H., NI, L., LI, J., ZHANG, X., FAN, D., CHENG, Y. (2024). A practical machine learning approach to retrieve land surface emissivity from space using visible and near-infrared to short-wave infrared data, *International Journal of Applied Earth Observation and Geoinformation*, 134, 104170.

LIM, C. L. (2020). Fundamental concepts of human thermoregulation and adaptation to heat: a review in the context of global warming. *International Journal of Environmental Research and Public Health,* 17(21), 7795.

MACINTOSH, A., FOERSTER, A., MCDONALD, J. (2015). Policy design, spatial planning and climate change adaptation: a case study from Australia, *Journal of Environmental Planning and Management*, (58:8) 1432-1453,

MATTE, T., LANE, K., TIPALDO, J.F., BARNES, J., KNOWLTON, K., TOREM, E., ANAND, G., YOON, L., MARCOTULLIO, P., BALK, D., CONSTIBLE, J., ELSZASZ, H., ITO, K., JESSEL, S., LIMAYE, V., PARKS, R., RUTIGLIANO, M., SORENSON, C., YUAN, A. (2024) NPCC4: Climate change and New York City's health risk, *Annals of the New York Academy of Sciences*, 1539(1), 185–240.

MCPHEARSON, T., PICKETT, S.T.A., GREN, Å., HAASE, D., HAMSTEAD, Z., PIEKET-WESTERDIJK, K., SETO, K.C. (2018) Urban ecosystems and biodiversity, Climate Change and Cities: Second Assessment Report of the Urban Climate Change Research Network, eds. C. Rosenzweig, W. Solecki, P. Romero-Lankao, S. Mehrotra, S. Dhakal and S.A. Ibrahim, Cambridge University Press, Cambridge; 257–318

MORADI, M., and GÖRER TAMER, N. (2017) Bursa örneğinde kentsel büyümenin yerel iklim değişikliği üzerine etkisi, *Planlama*, 27(1), 26-37.

MOURATIDIS, K. (2021) Urban planning and quality of life: A review of pathways linking the built environment to subjective well-being, *Cities*, 115, 103229.

OECD (Organisation For Economic Co-Operation And Development) (2012) *OECD Environmental Outlook to 2050: The Consequences of Inaction*, OECD Publishing, Paris,

OKE, T. R. (1973). City size and the urban heat island. *Atmospheric Environment*, (7:8) 769–779.

ORSETTI, E., TOLLIN, N., LEHMANN, M., VALDERRAMA, V.A., MORATÓ, J. (2022) Building Resilient Cities: Climate Change and Health Interlinkages in the Planning of Public Spaces, *International Journal of Environmental Research and Public Health*, 19, 1355.

PEKER, E., ATAÖV, A. (2024) Planlamadan uygulamaya yerel iklim eyleminde yaşanan zorluklar: Belediyeler için bir yönetişim modeli önerisi, *Planlama*, 34(1), 22-35.

PEKER, E. (2021) Bir Şehircilik Problemi: Değişen İklimde Termal Konforu Sağlamak, *Planlama*, 31(1), 106-119.

PICKETTS, I.M., DÉRY, S.J., CURRY, J.A. (2014) Incorporating climate change adaptation into local plans, *Journal of Environmental Planning and Management*, (57:7) 984-1002,

POZOUKIDOU, G. (2020) Designing a green infrastructure network for metropolitan areas: A spatial planning approach, *Euro-Mediterranean Journal for Environmental Integration*, 5:40

PULEY, G. (2022). Extreme heat: Preparing for the heatwaves of the future. United Nations Office, https://www.unocha.org/publications/report/world/extreme-heat-preparing-heatwaves-future-october-2022 [03.10.2024]

QAID, A., LAMIT, H.B., OSSEN, D.R., SHAHMINAN, R.N.R. (2016). Urban heat island and thermal comfort conditions at micro-climate scale in a tropical planned city, *Energy and Buildings*, (133) 577-595,

SACHINDRA, D. A., NG, A. W. M., MUTHUKUMARAN, S., PERERA, B. J. C. (2016). Impact of climate change on urban heat island effect and extreme temperatures: a case-study, *Quarterly Journal of the Royal Meteorological Society*, 142 (694), 172-186.

STONE, B., HESS, J.J., FRUMKIN, H. (2010) Urban Form and Extreme Heat Events: Are Sprawling Cities More Vulnerable to Climate Change Than Compact Cities ?, *Environmental Health Perspectives,* 118:10

TANG, B.-H., SHAO, K., LI, Z.-L., WU, H.,TANG, R. (2015) An improved NDVI-based threshold method for estimating land surface emissivity using MODIS satellite data, *International Journal of Remote Sensing*, 36(19), 4864–4878.

TLIS (Turkish Legislation Information System) (a), (2023) https://www.mevzuat.gov.tr/MevzuatMetin/1.5.3194.pdf, [08.01.2023]

TLIS (Turkish Legislation Information System) (b), (2023) https://www.mevzuat.gov.tr/File/GeneratePdf?mevzuatNo=19788&mevzuatTur=KurumVeKurulusYonetmeligi&mevzuatTertip=5, [08.01.2023]

TLIS (Turkish Legislation Information System) (c), (2024) https://www.mevzuat.gov.tr/mevzuat?MevzuatNo=23722&MevzuatTur=7&MevzuatTertip=5, [20.11.2024]

TSMS (Turkish State Meteorological Service), (2020). Türkiye 2020 İklim Değerlendirmesi Raporu, https://www.mgm.gov.tr/FILES/iklim/yillikiklim/2020-iklim-raporu.pdf [03.01.2022]

TUROĞLU, H. (2014) Detection of Changes on Temperature and Precipitation Features in Istanbul (Turkey). Atmospheric and Climate Sciences, 4(4), 549–562.

UN-HABITAT, (2011) Cities and Climate Change Global Report on Human Settlements 2011 United Nations Human Settlements Programme. Earthscan, London. https://unhabitat.org/global-report-on-human-settlements-2011-cities-and-climate-change [30.11.2021]

USGS (United States Geological Survey), (2018) Landsat 8 (LT8) Data Users Handbook, https://www.usgs.gov/media/files/landsat-8-data-users-handbook, [15.03.2021]

WENDE, W., HUELSMANN, W., MARTY, M., PENN-BRESSEL, G.,BOBYLEV, N. (2010) Climate protection and compact urban structures in spatial planning and local construction plans in Germany, *Land Use Policy*, 27(3), 864–868. ope, Denmark. https://www.who.int/publications/i/item/heat-waves-risks-and-responses, [18.12.2021]

WHO (World Health Organization) (2024) Heat and Health, https://www.who.int/news-room/fact-sheets/detail/climate-change-heat-and-health [03.10.2024)

WILBY, R. L., (2007) A Review of Climate Change Impacts on the Built Environment, *Built Environment* (1978-), (33:1), 31–45. http://www.jstor.org/stable/23289471

WMO (World Meteorological Organization) (1983) Abridged final report, 8th session. Geneva, Commission for Climatology and Applications of Meteorology, WMO-No.600, https://library.wmo.int/?lvl=notice_display&id=9716#.YfHHgOpBxPY [21.12.2021]

WORLD CITIES REPORT, (2022) Envisaging the Future of Cities. United Nations Human Settlements Programme 2022, ISBN Number: 978-92-1-132894-3, https://unhabitat.org/wcr.

WORLD-BANK, (2010) Cities and Climate Change: Responding to an Urgent Agenda. https://openknowledge.worldbank.org/handle/10986/2312, [15.12.2021]

WWF (WORLD WILDLIFE FUND), (2021) İklim Değişikliği'nin Akdeniz'deki Etkileri: Aşırı Isınan Bir Denizden Altı Hikaye, https://www.wwf.org.tr/?10920/Iklim-Degisikliginin-Akdenizdeki-Etkileri, [05.01.2022]

YANG, Y., CHEN, Z. (2023) Severe Situation of Human Impact on Climate Change, Impact on Infectious Diseases and Solutions, In SHS Web of Conferences (Vol. 152, p. 05001). EDP Sciences.

YE, B., JIANG, J., LIU, J., ZHENG, Y.,ZHOU, N. (2021) Research on quantitative assessment of climate change risk at an urban scale: Review of recent progress and outlook of future direction, *Renewable and Sustainable Energy Reviews*, 135, 110415.

ZHANG, L., ZHANG, Z., YE, T., ZHOU, M., WANG, C., YIN, P., HOU, B. (2018) Mortality effects of heat waves vary by age and area: A multi-area study in China, Environmental Health, 17, Article number: 54.

ZHAO, Q., GUO, Y., YE, T., GASPARRINI, A., TONG, S., OVERCENCO, A., URBAN, A., SCHNEIDER, A., ENTEZARI, A., VICEDO-CABRERA, A.M., ZANOBETTI, A., ANALITIS, A., ZEKA, A., TOBIAS, A., NUNES, B., ALAHMAD, B., ARMSTRONG, B., FORSBERG, B., PAN, S.C., ÍÑIGUEZ, C., AMELING, C., DE LA CRUZ VALENCIA, C., ÅSTRÖM, C., HOUTHUIJS, D., DO VAN DUNG, D., ROYÉ, D., INDERMITTE, E., LAVIGNE, E., MAYVANEH, F., ACQUAOTTA, F., DE'DONATO, F., DI RUSCIO, F., SERA, F., CARRASCO-ESCÓBAR, G., KAN, H., ORRÜ, H., KIM, H., HOLOBAĆA, I-H., KYSSELÝ, J., MADUREIRA, J., SCHWARTZ, J., JAAKKOLA, J.J.K., KATSOUYANNI, K., HURTADO DIAZ, M., RAGETTLI, M.S., HASHIZUME, M., PASCAL, M., DE SOUSA ZANOTTI STAGLIORIO COÉLHO, M., VALDÉS ORTEGA, N., RYTI, N., SCOVRONICK, N., MICHELOZZI, P., MATUS CORREA, P., GOODMAN, P., NASCIMENTO SALDIVA, P.H., ABRUTZKY, R., OSORIO, S., RAO, S., FRATIANI, S., DANG, T.N., COLISTRO, V., HUBER, V., LEE, W., SEPOSO, X., HONDA, Y., GUO, Y.L., BELL, M.L., LI, S. (2021) Global, regional, and national burden of mortality associated with non-optimal ambient temperatures from 2000 to 2019: A three-stage modelling study, The Lancet Planetary Health, 5(7), e415-e425.

ZHONG, X., ZHAO, L., ZHANG, X., YAN, J., REN, P. (2022) Investigating the effects of surface moisture content on thermal infrared emissivity of urban underlying surfaces, *Construction and Building Materials*, 327, 127023.

ZHU, H., WANG, Y., HU, S., MA, L., SU, H., WANG, J. (2023) Cognitive performances under hot-humid exposure: An evaluation with heart rate variability, *Building and Environment*, 238, 110325.

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Anahtar Sözcükler: Kentsel ısı adası; Açık ve yeşil alanlar; İklim direnci; İmar mevzuatı; Yüzey sıcaklığı.

TÜRK İMAR MEVZUATININ KENT İKLİMİ AÇISINDAN EKSİKLİKLERİ ÜZERİNE BİR ARAŞTIRMA: İSTANBUL'UN AÇIK VE YEŞİL ALANLARI ÖRNEĞİ

Kentsel alanlar iklim değişikliğinin etkilerine karşı giderek daha savunmasız hale gelmektedir ve sıcak hava dalgaları, özellikle İstanbul gibi Akdeniz coğrafyasında bulunan şehirlerde en önemli tehditlerden birini oluşturmaktadır. Kentsel ısıyı azaltma ve termal konforu destekleme kapasiteleri nedeniyle, kentsel açık ve yeşil alanlar (OGS) kentsel dirençlilik stratejileri içerisinde önemli bir yer tutmaktadır. Ancak Türkiye'nin Mekânsal Planlama Yönetmeliği'nde geçen açık ve yeşil alanlar terimi, ekolojik ve termal özellikler açısından birbirinden çok farklı özelliklere sahip arazi kullanım biçimlerini kapsaması nedeniyle yasal açıdan belirsizliklere sebebiyet verirken, işlevsel olarak da tutarsızlıkları içerisinde barındırmaktadır.

Bu çalışma yasal olarak aynı OGS kategorisi altında gruplandırılan parklar, rekreasyon alanları, korular, botanik bahçeleri, fuar alanları, stadyumlar ve şehir meydanları gibi İstanbul şehrinde bulunan çeşitli arazi kullanımlarının iklimsel performansını incelemektedir. Landsat 8 görüntüleri ve mekansal analiz araçları kullanılarak, 12 seçilmiş örnek alan için yüzey sıcaklığı verileri ve bitki örtüsü indeksleri (NDVI) analiz edilmiştir. Arazi kullanım türleri arasındaki sıcaklık farklarını değerlendirmek için ANOVA ve Tamhane'nin post-hoc testleri uygulanırken, regresyon analizi NDVI ile termal davranış arasındaki ilişki araştırılmıştır.

Bulgular, yoğun bitki örtüsüne sahip alanların (örneğin parklar ve korular) 300 metrelik bir tampon bölgede tutarlı bir soğutma etkisi sergilediğini, fuar alanları ve asfaltlanmış meydanlar gibi geçirimsiz yüzeylerin ise önemli ölçüde daha yüksek yüzey sıcaklıkları gösterdiğini ortaya koymaktadır. Bu sonuçlar, ekolojik ve termal açıdan farklı arazi kullanımlarını tek bir yasal tanım altında gruplandırmanın, iklime duyarlı planlamayı zayıflattığını göstermektedir. Bu çalışma, kentsel ısı direncini desteklemek için işlevsel iklim performansını imar düzenlemelerine entegre etmeye yönelik ampirik kanıtlar sunmaktadır.

A STUDY ON THE DEFICIENCIES OF THE TURKISH URBAN LEGISLATION SYSTEM REGARDING URBAN CLIMATE: THE CASE OF OPEN AND GREEN SPACES OF ISTANBUL

Urban areas are increasingly vulnerable to the impacts of climate change, with heatwaves posing one of the most significant threats, particularly in Mediterranean cities like Istanbul. Urban resilience strategies often emphasize open and green spaces (OGS) due to their capacity to mitigate urban heat and supporting thermal comfort. However, in the Turkish Spatial Plans Construction Regulation, the term open and green spaces remains legally ambiguous and functionally inconsistent, encompassing a wide range of land uses with differing ecological and thermal characteristics.

This study investigates the climatic performance of various land uses legally grouped under the same OGS category; such as parks, recreation areas, groves, botanical gardens, fairgrounds, stadiums, and city squares within the city of Istanbul. Using Landsat 8 imagery and spatial analysis tools, surface temperature data and vegetation indices (NDVI) were analyzed for 12 selected locations. ANOVA and Tamhane's post-hoc tests were applied to evaluate temperature differences among land use types, while regression analysis explored the relationship between NDVI and thermal behavior.

The findings reveal that spaces with dense vegetation (e.g., parks and groves) exhibit a consistent cooling effect within a 300-meter buffer zone, whereas impervious surfaces like fairgrounds and paved squares demonstrate significantly higher surface temperatures. These results demonstrate that grouping ecologically and thermally distinct land uses under a single legal definition undermines climate-sensitive planning. This study contributes empirical evidence for integrating functional climate performance into zoning regulations to support urban heat resilience.

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