How to cite: Zeğerek Altunbey, P. & V. Ortaçeşme, 2025. An investigation on cooling potential of micro scale parks in Antalya (Türkiye). Ege Univ. Ziraat Fak. Derg., 62 (3): 365-380, https://doi.org/10.20289/zfdergi.1650830

Research Article
(Araştırma Makalesi)

Ege Üniv. Ziraat Fak. Derg., 2025, 62 (3):365-380
https://doi.org/10.20289/zfdergi.1650830

Pınar ZEĞEREK ALTUNBEY[1]*

Veli ORTAÇEŞME[2]

[1] Niğde Omer Halisdemir University, Faculty of Architecture, Department of Landscape Architecture, 51240, Centre, Niğde, Türkiye

[2] Akdeniz University, Faculty of Architecture, Department of Landscape Architecture, 07070, Konyaaltı, Antalya, Türkiye

* Corresponding author (Sorumlu yazar):

zegerek.pinar@gmail.com

An investigation on cooling potential of micro scale parks in Antalya (Türkiye)

Antalya (Türkiye)'daki mikro ölçekli parkların soğutma potansiyeli üzerine bir araştırma

* This article has been summarized from the first author's doctoral dissertation.

Received (Alınış): **04.03.2025** **Accepted** (Kabul Tarihi):**28.05.2025**

ABSTRACT

Objective: This study examines the cooling effect of small-scale urban parks in a Mediterranean climate. The research aims to determine the temperature differences around the parks, analyze the relationship between this effect and spatial characteristics, and evaluate the microclimatic contributions of small-scale parks.

Material and Methods: Temperature measurements were taken in nine parks during the summer of 2021, and vegetation cover ratios were analyzed using satellite images. A regression analysis was performed between spatial characteristics and temperature measurements.

Results: Park size and vegetation density are decisive factors for cooling distance and effect. Parks larger than 2 hectares provide an average temperature reduction of 1°C compared to their surroundings, with this effect observed at a distance of 50 meters.

Conclusion: The study emphasizes the importance of more sustainable design strategies for urban green spaces in temperature regulation and ecosystem service contributions.

Keywords: Canopy, cooling effect, evapotranspiration, grass, urban heat island, urban parks

ÖZ

Amaç: Bu çalışma, Akdeniz ikliminde küçük ölçekli kent parklarının serinletici etkisini incelemektedir. Araştırma, parkların çevresindeki sıcaklık farklılıklarını belirlemeyi, bu etkinin mekânsal özelliklerle ilişkisini analiz etmeyi ve küçük ölçekli parkların mikroklimatik katkılarını değerlendirmeyi amaçlamaktadır.

Materyal ve Yöntem: 2021 yılının yaz aylarında dokuz parkta sıcaklık ölçümleri yapılmıştır ve bitki örtüsü oranları uydu görüntüleri kullanılarak analiz edilmiştir. Mekansal özellikler ile sıcaklık ölçümleri arasında regresyon analizi gerçekleştirilmiştir.

Araştırma Bulguları: Park büyüklüğü ve bitki örtüsü yoğunluğu soğutma mesafesi ve etkisi için belirleyici faktörlerdir. İki hektar'dan büyük parklar çevrelerine kıyasla ortalama 1°C'lik bir sıcaklık düşüşü sağlarken, bu etki 50 metre'lik bir mesafede gözlemlenmiştir.

Sonuç: Çalışma, kentsel yeşil alanlar için daha sürdürülebilir tasarım stratejilerinin sıcaklık düzenlemesi ve ekosistem hizmeti katkıları açısından önemini vurgulamaktadır.

Anahtar sözcükler: Kanopi, serinletme etkisi, evapotranspirasyon, çim alan, kentsel ısı adası, kent parkları

INTRODUCTION

Climate scenarios indicate that rising temperatures and increased frequency of weather events will have adverse effects, particularly on public health and the environment (Javadi & Nasrollahi, 2021). In this context, the impacts of urbanization on climate are gaining growing attention. One of the most prominent characteristics of the urban climate is the phenomenon known as the “urban heat island” (UHI), which refers to higher temperatures in urban areas compared to their surrounding rural areas (Oke, 1989). Accelerating urbanization has led to the replacement of natural landscapes with impervious surfaces, thereby intensifying the UHI effect and resulting in negative consequences for the thermal environment. In this process, Land Use/Land Cover (LU/LC) changes play a significant role in the formation of UHI by increasing surface temperatures (Silva et al., 2018; Zheng et al., 2019; Shahfahad et al., 2022).

Numerous strategies have been proposed in the literature to mitigate the UHI effect, which can generally be categorized into six main headings: (1) modification of urban geometry, (2) avoidance of dark-colored surfaces, (3) improvement of energy efficiency, (4) development of smart transportation systems, (5) use of permeable surfaces, and (6) expansion of vegetated surfaces (Oke, 1989; McPherson, 1994). The establishment of green spaces in urban landscapes is considered a key strategy in mitigating climate change and the UHI effect as well as promoting sustainable urban development (Busca & Revelli, 2022; Makvandi et al., 2023).

Green spaces, in addition to improving air quality, regulate the microclimate in their surroundings, reduce land surface temperature, and mitigate the UHI effect. This effect is achieved through the provision of shade, the reduction of solar radiation, and the promotion of evapotranspiration by green spaces (Upmanis et al., 1998; Shashua-Bar & Hoffman, 2000; Grimmond, 2007). Moreover, they offer a natural cooling mechanism as they absorb less solar radiation compared to concrete and asphalt surfaces (Matusiak & Arbab, 2022). Thus, vegetation can directly reduce both surface and air temperatures within urban areas, creating a local cool island (Chang et al., 2007; Algretawee, 2022; Ruiz et al., 2022) and contributing to a more balanced climate for urban residents (Javadi & Nasrollahi, 2021; Unal Cilek & Uslu, 2022; Wang et al., 2023).

To determine the cooling effect of green spaces, on-site observation using fixed stations or mobile equipment is a commonly used research method (Spronken & Oke, 1998; Upmanis et al., 1998; Shashua-Bar & Hoffman, 2000; Potchter et al., 2006; Chang et al., 2007; Adıgüzel & Küçükerbaş, 2018). According to studies on the cooling effect of vegetation, trees provide the greatest impact, followed by shrubs and grass (Shashua-Bar & Hoffman, 2000). In some cases, it has been indicated that even a single tree can significantly affect the surrounding air temperature (Saito, 1990). In addition, the size of the park, certain spatial characteristics, and vegetation composition be directly related to its cooling effect (Spronken & Oke, 1998; Chen et al., 2012; Wang et al., 2018; Xie & Li, 2020; Gallay et al., 2023; Gao et al., 2023). Furthermore, factors such as the park’s shape, its surroundings, and the presence of water bodies are also influence this effect (Chen et al., 2012; Shih, 2017).

Most urban heat island studies are conducted at the city scale; therefore, there is limited information regarding the microclimatic characteristics of individual and small green spaces (Cao et al., 2010; Feyisa et al., 2014; Amani-Beni et al., 2021). In field measurements, studies typically assess the impact of vegetation cover on temperature reduction. However, when planning green space systems, it is essential to have information on which sizes and types of green spaces provide more effective cooling. In this context, the research seeks to answer the following questions: How do temperatures in small parks differ from those in larger parks, and how does the spatial composition of these areas influence temperature? In green space design, how does the ground cover within the area (e.g., vegetation versus impervious surfaces) affect the cooling potential of the park? Are grasses as effective as trees and shrubs in providing cooling?

Conducting such studies is particularly important in cities with a Mediterranean climate, especially due to high temperatures. Indeed, studies have shown that the local heat island in Antalya city center expanded by 949 km^2 from the 1980s to 2015 (Şensoy et al., 2017) and surface temperatures have increased by 3.7°C over the past fifty years (Noreen, 2024). However, the active green spaces in Antalya are not evenly distributed across the city, with average sizes ranging between 2.5 and 4.5 hectares (Manavoğlu & Ortaçeşme, 2015). The answers to these questions addressed in the study require a regional investigation which may be related to the park's spatial characteristics. Based on this, the present study examines micro-scale parks located in the city center of Antalya. The main objective of this study is to determine the effect of parks in regions with a dense urban fabric on temperature compared to their surroundings; to prove that this effect varies between parks, and to investigate whether the temperature difference is associated with the spatial characteristics of the park. For this purpose, spatial characteristics were identified using remote sensing, and mobile temperature differences and composition of the selected parks were analyzed statistically.

MATERIALS and METHODS

Research site

Antalya is located in southern Türkiye on the Mediterranean coast, with an urban area of 138,000 hectares. The city has a typical Mediterranean climate with hot and dry summers and mild and rainy winters. According to the Köppen-Geiger climate classification, it is classified as Csa. The average sunshine duration in Antalya, which is 47 meters above sea level, is 8.3 hours. While the sunshine duration is longer in summer, it is shorter in winter. The prevailing wind direction changes from northeast in winter to south in spring (Sarı & İnan, 2010). Average temperatures in Antalya vary between 0°C and 30.5°C. While temperatures rise above 11°C as of March, they reach 23°C in May. This temperature increase is more pronounced, especially in coastal areas. In June, July, and August, the average temperature reaches 30.5°C. When the elevation of the coastline reaches up to 300 meters, the average temperature is 29.2°C. In September, temperatures range between 17.5°C and 24.6°C. In the transition to autumn, the highest temperature in October generally drops to 22°C. However, as the elevation increases, the temperature can drop further to 9°C. Temperature changes rapidly in November, with the lowest temperature dropping to 5°C in mountainous regions, while in the coastal strip, the temperature rises to 17°C when the elevation reaches up to 200 meters (Sancar & Güngör, 2005).

Sample selection

The study was conducted in 2021 only in Muratpaşa, Konyaaltı and Kepez districts among the 5 central districts of Antalya city. Aksu and Döşemealtı were excluded from the research as they retained their rural characteristics, unlike the other districts. The study focused on parks in districts which exhibit similar urbanization patterns and intense construction. A surface temperature map was created using the thermal band of satellite imagery from 2021, highlighting urban heat island regions, to identify the parks. Parks of various sizes were selected from the hottest spots (Figure 1). Criteria for selection included: a) square or rectangular shape; b) less than 25% impervious surfaces; c) similar surrounding building heights; and d) absence of large nearby water bodies of water or green spaces These criteria ensured that external influencing cooling effects were minimized. A total of 9 parks were selected across districts, all located in the hottest areas. The selection of micro-scale parks was based on the urban characteristic of the selected districts. According to municipal data, the average park size in the Muratpaşa, Konyaaltı and Kepez districts ranges from 2.5 to 3.8 hectares, with a total of approximately 947 parks. Due to the high degree of urbanisation in these districts, the selection of small parks allows for a more representative examination of how these smaller green spaces contribute to mitigating local microclimates. In addition, large parks are relatively scarce in these regions, making the investigation of micro- scale parks' cooling effects particularly valuable in understanding the potential role of urban green spaces in mitigating urban heat island effects.

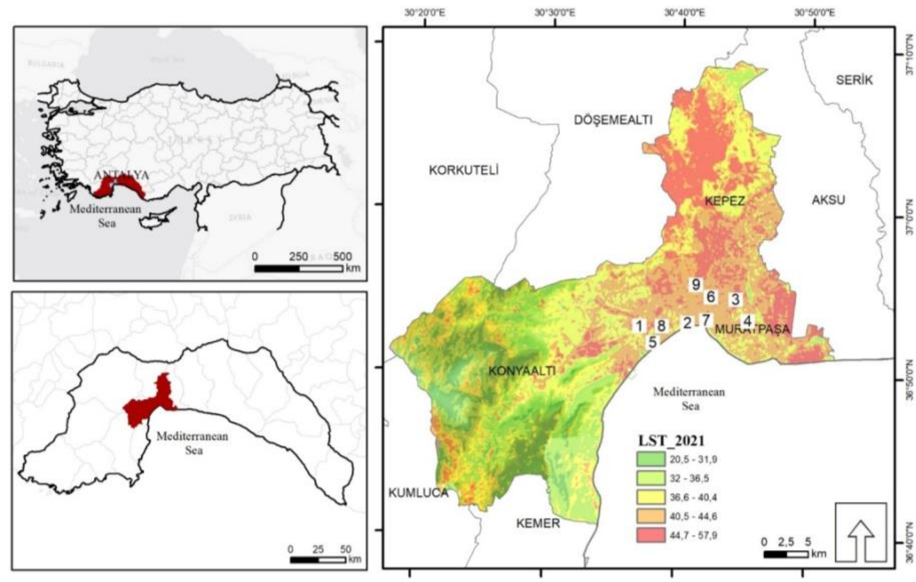

Figure 1. Location of parks: Özkanlar Park (1), Aydın Kanza Park (2), Ahmet Belen Park (3), Senatör Reşat Oğuz Park (4), Mustafa Karabulut Park (5), Sakarya Park (6), Yarbay Songül Yakut Park (7), EXPO 2016 Park (8) and Şehitler Park (9).

Şekil 1. *Parkların konumu: Özkanlar Parkı (1), Aydın Kanza Parkı (2), Ahmet Belen Parkı (3), Senatör Reşat Oğuz Parkı (4), Mustafa Karabulut Parkı (5), Sakarya Parkı (6), Yarbay Songül Yakut Parkı (7), EXPO 2016 Parkı (8) ve Şehitler Parkı (9).*

Focusing on the physical components of the parks, such as size, shape, impervious surface ratio, and vegetation cover, provides measurable and comparable criteria. These physical attributes are directly related to the parks' ability to mitigate urban heat island effects. Concentrating on these components allows for isolating external factors such as nearby green spaces or water bodies, ensuring that the observed effects are directly attributable to the park's characteristics. Thus, the selection of micro-scale parks in these districts is based on the typical urban features of the area and allows for a detailed examination of the local cooling effects of these parks, particularly in areas with high urban heat intensity.

The parks selected are as follows: Özkanlar Park (P1), Aydın Kanza Park (P2), Ahmet Belen Park (P3), Senatör Reşat Oğuz Park (P4), Mustafa Karabulut Park (P5), Sakarya Park (P6), Yarbay Songül Yakut Park (P7), EXPO 2016 Park (P8), and Şehitler Park (P9), which vary in size and vegetation cover. The parks were classified as very small (<1 ha), small (1-2 ha), and medium (2-3 ha) based on municipal lists. Details such as area size, vegetation size, and cover ratio are shown in Table 1.

Table 1. Sample selection

***Çizelge 1**. Örnek alan seçimi*

Park Names	Green Type (ha)	Park Total Area (m^2)	Latitude/Longitude
P1/Özkanlar	Very small sized < 1	6.800	36°53'24.33"N/ 30°37'56.02"E
P2/ Aydın Kanza		10.100	36°53'29.54"N/ 30°41'37.42"E
P3/ Ahmet Belen		12.000	36°54'52.59"N/ 30°44'11.12"E
P4/ Senatör Reşat Oğuz	Small sized 1-2	13.000	36°51'43.25"N/ 30°46'24.07"E
P5/ Ç. Mustafa Karabulut		15.300	36°52'43.90"N/ 30°37'45.87"E
P6/ Sakarya		20.250	36°55'8.01"N/ 30°42'36.65"E
P7/ Y. Songül Yakut	Medium sized > 2	21.750	36°54'13.70"N/ 30°41'8.13"E
P8/ EXPO 2016		28.000	36°53'8.67"N/ 30°38'27.30"E
P9/ Şehitler		33.500	36°53'32.79"N/ 30°39'13.80"E

Methods

Temperature measurements in and around the parks were conducted in July, August, and September 2021, between 12:00-14:00 pm, under sunny, clear, and windless conditions. A portable Extech 45160 anemometer was used at a height of 2 meters. In each park, five temperature measurements were taken at four points inside and around the park. For larger parks, additional measurements were taken at different points (wooded, grass, and structural areas) to ensure consistency. Temperature measurements around each park were taken three times in each direction, specifically in relation to the open façade of the park. The distance between the park's inner and surrounding measurement points was set at 50 meters, with a maximum distance of 200 meters, as per the zoning plan. The surrounding areas were divided into two main zones and three routes, with a total of 12 control points for each park (Figure 2).

To calculate the cooling effect, the temperature differences between each measurement point and the surrounding area were assessed using the formula (Eq. 1) where ΔT is the temperature difference, t_1 is the air temperature in the buffer zone, and t_2 is the air temperature inside the park.

$$\Delta T = t_2 - t_1 \tag{1}$$

Mobile temperature data were converted into spatial data, and temperature maps were generated using the Kriging method with ArcGIS and ArcMap 10.5 (ESRI) software. Land cover types such as tree and shrub, grass and ground cover, and impervious surface were determined using Sentinel 2A (European Space Agency) satellite images (16.08.2021, 10x10 m resolution). Vegetation density was calculated using the NDVI method with the formula (Eq. 2): Green areas within the parks were reclassified, and the percentage of green cover was calculated by subtracting the number of non-vegetated pixels from the total number of pixels, then dividing by the total area.

$$NDVI = {(NIR - Red)}/{(NIR + Red)} \tag{2}$$

Figure 2. Location of measurement points within and around the parks.

Şekil 2. *Parkların içindeki ve çevresindeki ölçüm noktalarının konumu.*

Data analysis

Four variables were derived from the temperature measurements and calculations for analysis:

I. Cool/heat island intensity of the park (°C): Calculated as the temperature difference between the park and control points, with four values calculated for each park.

II. Average cool/heat island intensity: The average of the four cool/heat values.

III. Area covered by the composition: Percentages of tree+shrub (Tr-shr), grass+ ground cover (Tu), and impervious surfaces were calculated.

IV. Park size (A, hectare)

Data were analyzed using a package program IBM SPSS v20, and tables were prepared using Excel 2016 (Microsoft). ANOVA and regression analyses were applied to the temperature values and average temperature differences. Due to high correlations between variables, a stepwise regression model was used. The relationship between park cool and heat island densities and park characteristics were analyzed. The dependent variable was park cool island (PCI) and the independent variables included park area size and land cover ratios. The analysis determined the effects of these factors on urban green spaces.

RESULTS

The primary finding of this study is that the density and type of vegetation are the most influential factors in the cooling effect of urban parks compared to surrounding built-up areas. Parks with higher tree and grass cover significantly impact temperature differences, especially when the urban heat island effect is strongest. All parks studied demonstrated microclimatic effects, influencing their surrounding areas to varying extents. Temperature measurements, particularly in summer (July to September 2021), showed that parks were approximately 1°C cooler than their surroundings, with variations in temperature differences based on park size and vegetation density.

Park local cooling distance and park size

A negative correlation was found between the cooling effect and park size ($p<0.001$). Very small parks exhibit a cooling effect within the first 50 meters of their boundaries, while small parks continue to demonstrate a cooling effect beyond this distance. On the other hand, medium parks maintain their cooling effect beyond 100 meters. Table 2 shows that the cooling effect of small parks is more pronounced within the first 50 meters, and begins to diminish beyond this point. For example, in summer, the temperature difference between the park area and the 50 meters zone ranged from 0.50°C to 1°C, while it was about 2°C at the 200 meters buffer zones However, variations were observed beyond the first 50 meters.

Table 2. The cooling effect of green spaces in summer

Çizelge 2. *Yaz aylarında yeşil alanların serinletici etkisi*

		Average The Cooling Effect on Buffer Zones (ΔT) ^{O}C			
Parks	Park size (ha)	50 m	100 m	150 m	200 m
P1, P2, P3	< 1	0.55	1.21	1.68	2.28
P4, P5, P6	1-2	0.68	1.48	1.94	2.63
P7, P8, P9	> 2	0.80	1.57	2.15	2.82

In small-sized parks, the temperature difference measured at 50 meters ranged from 0.50°C to 0.95°C, and the temperature difference at the 200 meters buffer zone was approximately 3°C. Based on this, it can be concluded that the cooling effect of small parks is significant within the first 50 meters, decreases to about 0.5°C at 100 meters, and begins to diminish beyond this distance. Therefore, while very small parks extend their cooling effect up to a maximum of 50 meters, small-sized parks maintain their cooling effect approximately 70 meters.

In medium parks, the temperature difference measured at 50 meters ranged from 0.70°C to 1.18°C, and the temperature difference at the 200-meter buffer zone was approximately 3°C. From this, it can be inferred that the cooling effect of medium parks is about 1.5°C at 100 meters, and the effect begins to decline beyond this point. In comparison to small parks, medium parks exhibit a larger extent of cooling imbalance, with a noticeable imbalance becoming apparent after 100 meters. The cooling curves based on distance for parks of within the buffer zones, from three different size categories, showed variations. Cooling curves based on distance are illustrated in Figure 3.

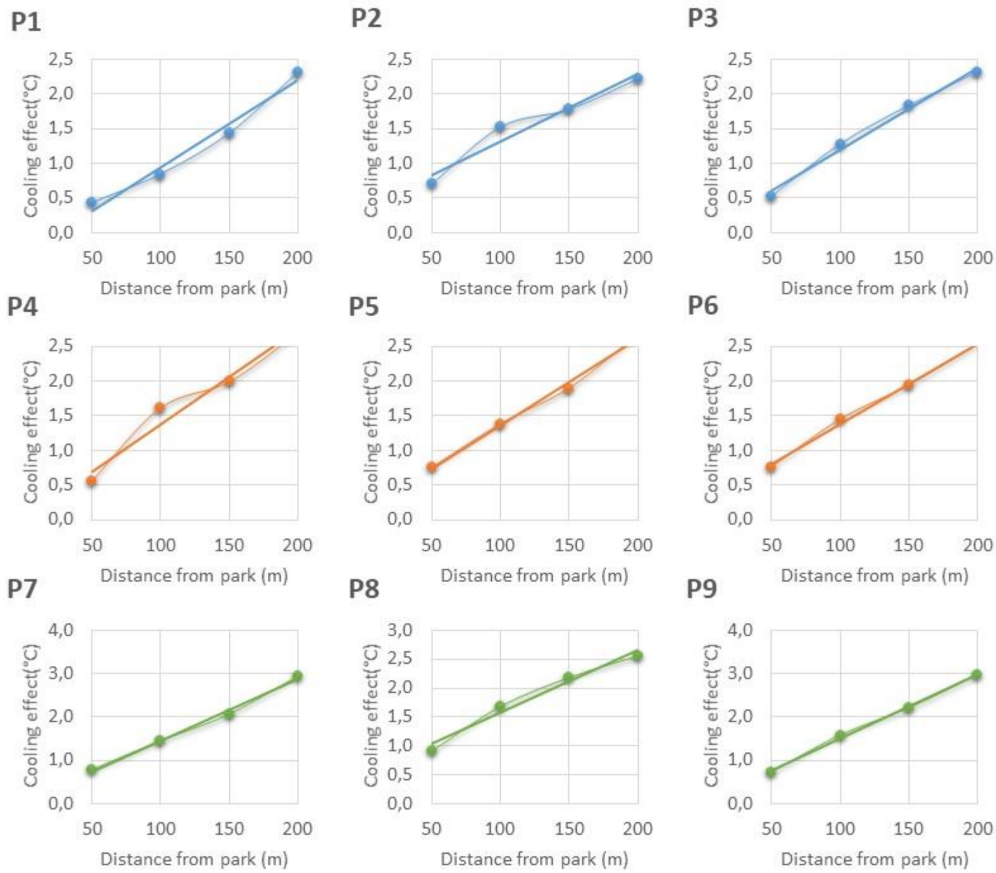

Figure 3. Cooling curves based on distance.

Şekil 3. *Mesafeye bağlı soğutma eğrileri.*

The analysis above indicates that the change in area size reflects a change in impact on air temperature, with the cooling effect becoming more extensive and effective over a wider area as the park size increases. The results suggest that during high-temperature periods, the urban cooling effect in the studied parks follows the order: medium > small > very small' parks. Accordingly, parks larger than 2 hectares are consistently cooler than their surroundings; parks between 1 and 2 hectares are generally cooler in most measurements compared to their surroundings; and parks smaller than 1 hectare show more variable temperature differences. Nevertheless, they still exhibit a cool island effect, although it was less intense than in their surroundings (Figure 4).

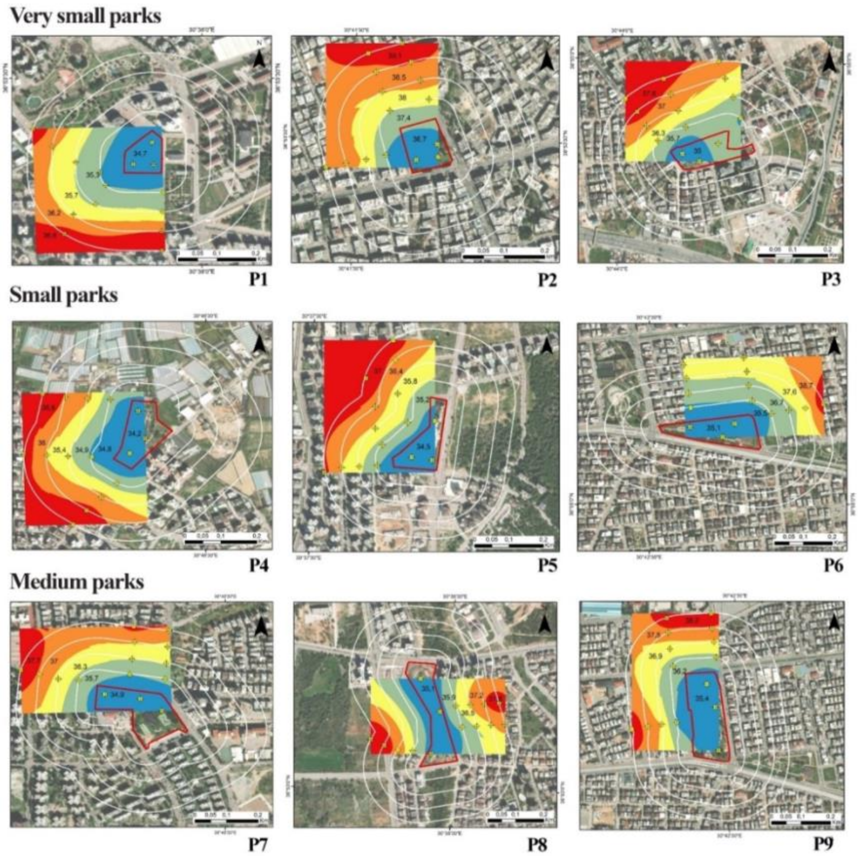

Figure 4. Temperature maps were produced from the mobile measurements.

Şekil 4. *Mobil ölçümlerden elde edilen sıcaklık haritaları.*

Very small parks

Özkanlar, Ahmet Belen, and Aydın Kanza, occupying less than 1 ha (Table 1), are the smallest parks evaluated. The land coverage of these parks is primarily vegetated (around 6% of the total area, Table 3). Özkanlar and Aydın Kanza parks have a dense tree canopy, whereas Ahmet Belen Park is mostly covered by grass. The mean cooling provided by these parks in midday summer was around 0.55°C (Table 2). However, the predicted cooling reduction in these three parks was close to 100% per meter. As a result, the cooling effect provided by these parks did not affect air temperatures beyond 50 meters away from the park boundary. After 50 meters, temperature measurements varied significantly.

Small parks

Senatör Reşat Oğuz, Ç. Mustafa Karabulut and Sakarya parks, ranging from 1-2 ha, are classified as small-sized. Compared to the other two parks, Senator Reşat Oğuz Park has a dense tree canopy throughout. The highest NDVI value was determined in this park. Sakarya Park has a tree line along the park, while Ç. Mustafa Karabulut Park has dense tree cover in two areas. These three parks have grass and tree canopies covering approximately 72-85% of their area (Table 3). The mean cooling effect for these parks in midday summer was around 0.68°C, with cooling extending from 50 m to 70 m. Therefore, these parks had a cooling effect beyond their boundaries.

Medium parks

Y. Songül Yakut, EXPO 2016, and Şehitler parks, each occupying over 2 ha, are classified as medium-sized parks. Y. Songül Yakut Park has a large proportion of tree canopy cover, while EXPO Park has a lower tree canopy. Şehitler Park, the largest, also has significant tree canopy cover but has more impervious surfaces than its green areas. All three parks have tree canopy cover corresponding to 60% of the area within the parks (Table 3). The mean cooling effect for these parks in midday summer was around 0.80°C, with cooling extending from 50 m to 100 m. Beyond 100 meters, the measurements were more unstable.

Table 3. Vegetation ratio

***Çizelge 3**. Bitki örtüsü oranı*

Park	Vegetation Cover (daa)	Ratio (%)	Unvegetated Area (daa)	Ratio (%)	Average NDVI
P1	5.4	79.4	1.4	20.1	0.29
P2	5.8	57	4.3	43	0.21
P3	7.2	59.5	4.9	32	0.21
P4	10.8	83	2.2	17	0.34
P5	13	85	2.4	15	0.23
P6	14.65	72	5.6	28	0.26
P7	15.05	69	6.7	31	0.20
P8	16.7	59.6	11.3	40.4	0.16
P9	22.6	67	10.9	33	0.24

Relationship between cooling effect and park size / composition

A regression analysis was conducted to examine the relationship between park size, vegetation cover, and the extent of the cooling effect in urban environments (Table 4). The results highlight a statistically significant, positive relationship between park size and the magnitude of the cooling effect, with larger parks generating a more substantial reduction in surrounding temperatures. A linear relationship was observed between the cooling distance and the mean extent of tree canopy and grass cover. This suggests that both the density of trees and the extent of ground cover are crucial for determining the cooling potential of urban parks.

Table 4. Cooling effect and its influencing factors

Çizelge 4. *Soğutma etkisi ve etkileyen faktörler*

Variables	B (b_0)	R^2	Adjusted R^2	Standardized Coefficient (Beta)	F	Sig.
Size	44.456	0.862	0.845	-	48.525	0.000*
Tree canopy ratio	40.996	0.776	0.762	0.534	57.172	0.000*
Grass cover ratio	41.692	0.762	0.762	-0.873	22.446	0.002*
Unvegetated area	37.351	0.304	0.072	0.552	1.310	0.158

* = P <0.05; b_0: unstandardized coeffificients (B)

However, the correlation between the cooling effect and the perimeter-to-area ratio of the parks was non-linear, indicating that while park size is important, the shape and layout of the park also play a role in how effectively the cooling effect spreads through the surrounding area.

In particular, the correlation coefficient between park size and the cooling effect was found to be 0.862 ($p < 0.01$), reflecting a strong and statistically significant relationship. This indicates that larger parks can cool a larger area, with their cooling effect extending further from the park boundaries. Additionally, a larger tree canopy cover significantly enhances the cooling impact, as tree canopies are crucial for providing shade and reducing solar radiation absorption in urban environments.

The results also highlight the importance of vegetation cover, particularly the tree canopy and grass areas, in increasing the cooling effect. The regression analysis revealed that the size of the tree canopy and the grass cover are key parameters that determine how far the cooling effect extends. Specifically, for a park to influence surrounding temperatures up to 50 meters, it should have a vegetation cover of at least 80%, and for a measurable cooling effect at a distance of 100 meters, a park should be larger than 3 hectares with a minimum vegetation cover of 70%. In conclusion, the findings of this study emphasize the importance of both park size and vegetation composition in mitigating urban heat island effects. The cooling effect of urban parks is enhanced by larger green spaces with dense tree canopies, suggesting that city planners should prioritize creating and maintaining parks that meet these criteria to maximize their impact on local climates and improve urban resilience to climate change.

Although this study did not conduct a quantitative analysis of the microclimatic effects of park composition, the dominant plant species in the parks were identified, and general inferences were made accordingly. The vegetation observed in the studied parks includes a variety of plant groups such as trees and shrubs, ground covers, bulbous and rhizomatous plants, climbing plants, succulents, and palms. Frequently encountered species among these groups include *Platanus orientalis, Bauhinia variegata, Ficus retusa* 'Nitida'*, Olea europea, Pinus brutia, Pinus pinea, Cupressus sempervirens, Lagerstroemia indica, Ligustrum japonicum, Nerium oleander, Hibiscus syriacus, Viburnum lucidum,* and *Pittosporum tobira* 'Nana'. The fact that the majority of these plant species are well-adapted to the Mediterranean climate, drought-tolerant, and possess dense foliage provides important insights into their potential effects on ambient temperature. The literature suggests that broad-leaved tree species and densely foliated shrubs contribute to lowering surface temperatures through shading and evapotranspiration. Accordingly, characteristics such as species diversity and vegetation density can be considered as factors that indirectly contribute to the cooling potential of urban parks.

DISCUSSION

Extreme weather events caused by climate change pose significant challenges for Türkiye, particularly in coastal cities such as Antalya. Therefore, it is vital to investigate the city's climatic conditions and assess the current situation. Green spaces play a crucial role in urban climate regulation by providing essential ecosystem services. The cooling effect of green spaces becomes especially prominent during periods of high UHI intensity, which typically occur under conditions of high temperature and low wind speed (Oke, 1989). The findings of this study confirm that parks effectively contribute to urban cooling, particularly when temperatures exceed 20°C. While many studies have focused on large green spaces (Chang et al., 2007; Gallay et al., 2023), this study highlights that even small green spaces, including individual trees, contribute to cooling. The data demonstrate that micro-scale parks can also have a significant cooling effect, especially when specific spatial characteristics are present. This is particularly relevant to Antalya, where many parks are micro-scale. Unlike previous research, this study evaluates the cooling effects of micro-scale parks in Antalya and investigates the cooling impact of parks up to 3 hectares in size.

Cooling services by green spaces

The findings presented in this study are derived from data collected at midday during the hot summer period. Studies in hot and humid cities have shown that under certain climatic conditions (e.g., clear skies and constant wind speed; Upmanis, 1998), parks are effective in cooling (Spronken & Oke, 1998; Potchter et al., 2006; Gioia et al., 2014; Shih, 2017). The temperature in Antalya is high from late spring to early fall. Therefore, the average cooling distances and intensities presented are assumed to represent the cooling provided by small-scale parks on calm and hot days within this period. The study determined the cooling effect of small-scale parks through four monthly measurements. Particularly with increasing humidity, cooling was observed at short distances around parks in July and August. The measurements indicated that cooling effects occurred in parks up to 3 hectares, although temperatures around them varied. Similarly, Chang et al. (2007) found that while large parks provide a more consistent cooling effect compared to their surroundings, parks smaller than 3 hectares show more variable temperatures.

Climate projections for Turkey for the period 2016-2099 predict an average annual temperature increase of 1.5-2.6°C (Ministry of Environment, Urbanization and Climate Change, 2015). The fact that the UHI effect becomes more pronounced on windless and hot days indicates that the cooling effect of green spaces will become increasingly important in the future. This situation emphasizes the necessity of protecting existing green infrastructure as well as expanding green areas. Strategies should be developed to enhance the cooling potential of green spaces, especially in areas where urbanization has just begun, considering climate scenarios. These and similar studies can assist urban planners and landscape architects in making informed decisions about the optimal size, number, shape, and composition of green spaces needed to improve the cooling effect.

Park size effects on cooling distance

Due to limitations in this study, several factors such as urban structures and materials surrounding parks, park shapes, and tree and shrub types were not included in the analysis. Therefore, some low regression results were excluded. Nonetheless, even the minimum park sizes and characteristics were sufficient to explain the cooling effect. The findings indicate that as the park area increases, its cooling capacity also improves.

The relationship between green space size, cooling distance, and cooling intensity has been established in numerous studies across different climatic conditions, although regional variations are apparent. For example, Chang et al. (2007) found that parks smaller than 2 ha in Taipei, Taiwan, were warmer than their surroundings during summer afternoons. In contrast, Upmanis et al. (1998) reported that two small green spaces (2.4-3.6 ha) in Gothenburg, Sweden, were up to 1.6°C cooler than their surroundings. In this study, the cooling effect of parks ranging from 1.3 to 3.3 ha was significant, extending to the surrounding areas during windless and clear days. A linear relationship between park size and cooling distance was observed, although differences in cooling intensity were also noted. For instance, despite its larger size, EXPO Park exhibited a relatively weak cooling effect, which can be attributed to its geometric configuration. The cooling intensity correlates with the perimeter-to-area ratio of green spaces, with Monteiro et al. (2016) suggesting that larger perimeter-to-area ratios tend to result in weaker cooling effects. Consistent with this finding, Wang et al. (2018) demonstrated that an increase in the perimeter-to-area ratio weakens the cooling performance of parks. Precisely, a 10-unit increase in this ratio corresponds to a 0.22°C reduction in cooling intensity and a 9.07 m decrease in cooling distance. Thus, for parks of equal size, more compact (i.e., rounder) shapes have the best cooling effect (Ren et al., 2013). However, this study did not analyze cooling intensity based on park shapes, due to the limited number of parks studied.

Antalya is undergoing rapid urbanization, and despite the cooling effect of the sea, the UHI effect is particularly concentrated in the city center, extending into developing areas. One of the key reasons for this is the insufficient size and continuity of green spaces in the city center. Land use studies for Antalya indicate that the green infrastructure is not adequately sized and lacks continuity within a systematic framework (Manavoğlu & Ortaçeşme, 2015). The findings of this study emphasize the importance of considering park size in urban planning. Previous research has also highlighted the significance of green space location in determining the cooling effect. For example, Gioia et al. (2014) found that the cooling effect of urban green spaces is weaker than that of green spaces outside urban areas. Therefore, integrating green infrastructure into urban planning could address this issue. Shashua-Bar & Hoffman (2000) demonstrated that even very small green spaces (0.1 ha) arranged in a green network at 200 meters intervals could create substantial cooling effects throughout the city.

The role of park composition on cooling

Trees affect surrounding temperatures through shading and transpiration. Though this study did not assess night-time temperatures, existing research has shown that trees are effective in reducing daytime air temperatures. For instance, Saito (1990) found that a small green area in Kumamoto, Japan, was up to 3.8°C cooler than its surroundings. Likewise, Oliveira et al. (2011) reported that a 0.24-hectare area in Lisbon was 6.9°C cooler than its surroundings. Studies in cities such as Gothenburg, Tokyo, and Kuala Lumpur have shown that green spaces are 4-6°C cooler than their surroundings (Spronken-Smith & Oke, 1998).

The research underscores that vegetation density, particularly the tree canopy, plays a crucial role in the cooling effect. Mixed and broadleaf forests are more effective than coniferous forests, and tree communities provide more cooling compared to shrubs and grasslands (Chang et al., 2007; Xiang et al., 2018; Gessesse & Melesse, 2019). Spronken-Smith et al. (1998) note that green spaces with high tree canopy maintain their cooling effect into the night, whereas grass-dominated areas provide this effect to a lesser extent and lose it more rapidly. However, this relationship may vary depending on the city's climatic region (e.g., tropical climates). Studies in Mediterranean climates have shown that temperature reduction is influenced by leaf density, tree height, shadow volume, and spatial distribution (Potchter et al., 2006).

In the present study, the findings align with previous research, indicating that higher vegetation coverage and grass percentages in green spaces also play a role in reducing surface temperatures, similar to the results reported by Gioia et al. (2014). Their Mediterranean regional study highlighted that larger green areas are 1.5 to 2.8°C cooler than their surroundings, and both the vegetation structure and the proportion of grass are valuable parameters for reducing temperatures. However, the effect of grass on park cool islands was observed to be negative or insignificant contributing to the study by Cao et al. (2010), which contrasts with previous studies (Shashua-Bar & Hoffman, 2000; Spronken-Smith et al., 2000). This negative impact of grass can be attributed to the unfavorable growing conditions observed in the studied environment. This indicates that the impact of grass on park cool islands depends on the growing conditions and coverage. Additionally, while grass irrigation practices can enhance cooling effects (Spronken-Smith et al., 2000), it is important to note that sustainable green space development should focus on natural vegetation cover rather than the extensive use of grass. The sustainable use of water resources, alongside the preservation of natural plant cover, will likely provide healthier and more effective cooling outcomes.

These findings suggest that larger green areas and the appropriate vegetation structure. Including both trees and grass can contribute to cooling. However, the integration of natural vegetation and responsible management practices is essential for achieving optimal results in terms of sustainability and cooling effects.

In particular, the tree canopy density in urban parks is the most effective factor in reducing temperature. Tree canopy density is associated with shading and both tree shading and transpiration are considered the two primary mechanisms of cooling. However, several studies have shown that shading plays a dominant role. For instance, Shashua-Bar & Hoffman (2000) found that in tropical and subtropical climate regions, approximately 80% of the cooling effect is attributed to tree shading. Similarly, the present study's findings are in line with those of Shashua-Bar et al. (2010) and Ren et al. (2013), reinforcing the notion that shading is a more significant contributor to cooling than transpiration. Therefore, it can be inferred that tree shading has a substantial impact on the magnitude of the cooling effect, particularly in temperate climates such as Mediterranean climate. Although the vegetative diversity of the parks was not analyzed in detail in the study, it is possible to make some inferences based on the dominant species and plant group identified. The majority of the species that make up the vegetation in the parks are plants that can adapt to the Mediterranean climate, are resistant to drought and have dense leaf tissue. In this context, for example, it is thought that tree species such as *Platanus orientalis, Pinus brutia, Bauhinia variegata, Ficus retusa* 'Nitida' have intense shading potential, while shrubs such as *Ligustrum japonicum and Viburnum lucidum* can attribute to the microclimate by affecting the air circulation at ground level. In the literature, it is stated that plants with high leaf area index have the potential to reduce ambient temperatures through evapotranspiration and shading (Xiao et al., 2018; Wang et al., 2023). For instance, Feyisa et al. (2014) found that *Eucalyptus*, *Olive,* and to some extent *Acacia* are more effective in cooling the urban environment than *Cupressus* species. In this context, it can be evaluated that the cooling effect measured in the study may be related not only to the park size and vegetation density but also to the morphological characteristics of the plant species forming this cover. Future studies examining the effects of different plant species on microclimate on a species basis will reveal the importance of plant selection in park design more clearly.

The effect of surrounding parks on cooling

The cooling effect of a green area is also influenced by urban characteristics such as location, canyon geometry, sky view factor, building materials, and prevailing wind direction (Monteiro et al., 2016). Additionally, factors such as the city's elevation, urban morphology, the proportion of impervious surfaces, and spatial configuration of trees contribute to the cooling effect (Adıgüzel & Küçükerbaş, 2018; Xiao et al., 2018). Due to the limited number of, this study focused on only 9 measurement points. The magnitude and distance of cooling effects were assessed independently of factors like wind direction. Further research with a larger sample size is needed to gain a more precise understanding of the cooling effect and offer better recommendations for urban planners. In conclusion, investigating differences in the cooling effects of parks provides valuable data for climate-sensitive urban planning and green space design. These data can help landscape architects make more informed decisions about species selection, green space size, and plant design.

CONCLUSION

This study examined the role of urban green spaces in mitigating the urban heat island effect in Antalya. Analysis based on satellite data and ground-based temperature measurements revealed that the cooling effect of green spaces varies according to physical characteristics such as park size, plant species composition, and tree cover density. Specifically, temperatures around medium-sized parks were measured to be 1.5-3°C lower, underscoring the microclimate regulatory function of green spaces. However, one of the primary limitations of such studies is that many variables cannot be measured at the same time when assessing the climatic conditions of urban areas. In this study, the presence of numerous variables and the fact that not all of them can be evaluated simultaneously emerges as a significant limitation.

Despite this, the findings indicate that the cooling effect provided by parks in Antalya is strongly related to the area covered by trees and grass. In cities with similar climatic characteristics to Antalya, green areas up to 3 hectares in size with 60% plant composition were observed to provide an average cooling effect of 1°C. As the impacts of climate change continue to intensify, the cooling functions of green spaces will become increasingly important. These findings contribute to a better understanding of how park characteristics influence cooling performance, especially emphasizing the critical role of canopy density. The ability of trees to lower surrounding temperatures through shading and transpiration stands out as a key factor in enhancing the cooling potential of parks.

At the urban planning level, it was observed that due to rapid urbanization in Antalya, the continuity of green spaces has been disrupted, exacerbating the UHI effect. Therefore, urban development plans should prioritize the connectivity of green areas and consider the strategic placement of parks to take advantage of sea breezes. Additionally, it is essential to evaluate not only the amount of green spaces per capita but also the climatic functionality of these areas. The shading and transpiration capacities of trees must be highlighted as vital features in increasing the cooling potential of parks.

At the design scale, planting strategies should consider factors such as tree species selection, canopy volume, and leaf density. Given the high water consumption of lawns, local and drought-resistant plant species should be preferred, and tree groupings that ensure over 60% canopy coverage should be encouraged. It should not be overlooked that parks create cooling effects not only within their boundaries but also in their surroundings. In conclusion, the findings obtained from the case of Antalya may serve as guidance for cities with similar climate zones. Planning and designing green spaces with attention to their climatic impacts can significantly contribute to creating livable, climate-resilient cities.

Data Availability

Data will be made available upon reasonable request.

Author Contributions

Conception and design of the study: VO, PZA; sample collection: PZA; analysis and interpretation of data: PZA, VO; statistical analysis: PZA; visualization: PZA; writing manuscript: PZA, VO.

Conflict of Interest

There is no conflict of interest between the authors in this study.

Ethical Statement

We declare that an ethics committee is not required for this study.

Financial Support

This study was not financially supported.

Article Description

This article was edited by Section Editor Assoc. Prof. Dr. İpek ALTUĞ TURAN.

REFERENCES

Adıgüzel, G. & E. V. Küçükerbaş, 2018. Investigation micro-climatic effects of urban green spaces; the case of Bornova, İzmir. Ege Üniversitesi Ziraat Fakültesi Dergisi, 55 (3): 255-263. https://doi.org/10.20289/zfdergi.390630

Algretawee, H., 2022. The effect of graduated urban park size on park cooling island and distance relative to land surface temperature (LST). Urban Climate, 45: 101255. https://doi.org/10.1016/j.uclim.2022.101255

Amani-Beni, M., B. Zhang, G. Xie & A. Odgaard, 2021. Impacts of the microclimate of a large urban park on its surrounding built environment in the summertime. Remote Sensing, 13 (22): 4703. https://doi.org/10.3390/rs13224703

Busca, F. & R. Revelli, 2022. Green areas and climate change adaptation in an urban environment: the case study of "Le Vallere" park (Turin, Italy). Sustainability, 14 (3): 8091. https://doi.org/10.3390/su14138091

Cao, X., A. Onishi, J. Chen & H. Imura, 2010. Quantifying the cool island intensity of urban parks using ASTER and IKONOS data. Landscape and Urban Planning, 96 (4): 224-231. https://doi.org/10.1016/j.landurbplan.2010.03.008

Chang, R. C., M. H. Li & S. D. Chang, 2007. A preliminary study on the local cool-island intensity of Taipei city parks. Landscape and Urban Planning, 80 (4): 386-395. https://doi.org/10.1016/j.landurbplan.2006.09.005

Chen, X., Y. Su, D. Li, G. Huang, W. Chen & S. Chen, 2012. Study on the cooling effects of urban parks on surrounding environments using Landsat TM data: a case study in Guangzhou, southern China. International Journal of Remote Sensing, 33 (18): 5889-5914. https://doi.org/10.1080/01431161.2012.676743

Feyisa, G. L., K. Dons & H. Meilby, 2014. Efficiency of parks in mitigating urban heat island effect: An example from Addis Ababa. Landscape and Urban Planning, 123: 87-95. https://doi.org/10.1016/j.landurbplan.2013.12.008

Gallay, I., B. Olah, V. Murtinová & Z. Gallayová, 2023. Quantification of the cooling effect and cooling distance of urban green spaces based on their vegetation structure and size as a basis for management tools for mitigating urban climate. Sustainability, 15 (4): 3705. https://doi.org/10.3390/su15043705

Gao, Y., H. Pan & L. Tian, 2023. Analysis of the spillover characteristics of cooling effect in an urban park: A case study in Zhengzhou city. Frontiers in Earth Science, 11: 1133901. https://doi.org/10.3389/feart.2023.1133901

Gessesse, A. A. & A. M. Melesse, 2019. “Temporal Relationships Between Time Series CHIRPS-Rainfall Estimation And MODIS-NDVI Satellite Images In Amhara Region, Ethiopia, 81-92”. In: Extreme Hydrology and Climate Variability: Monitoring, Modelling, Adaptation and Mitigation (Ed: A.M. Melesse, W. Abtew & G. Senay). Elsevier Inc. Amsterdam, 580 pp. https://doi.org/10.1016/B978-0-12-815998-9.00008-7

Gioia, A., L. Paolini, R. O. C. Malizia & A. Sobrino, 2014. Size matters: vegetation patch size and surface temperature relationship in foothills cities of northwestern Argentina. Urban Ecosystem, 17: 1161-1174. https://doi.org/10.1007/s11252-014-0372-1

Grimmond, S., 2007. Urbanization and global environmental change: local effects of urban warming. The Geographical Journal, 173 (1): 83-88. https://doi.org/10.1111/j.1475-4959.2007.232_3.x

Javadi, R. & N. Nasrollahi, 2021. Urban green space and health: The role of thermal comfort on the health benefits from the urban green space; a review study. Building and Environment, 202: 108039. https://doi.org/10.1016/j.buildenv.2021.108039

Makvandi, M., W. Li, X. Ou, H. Chai, Z. Khodabakhshi, J. Fu, P. F. Yuan & E.d.l.J. Horimbere, 2023. Urban heat mitigation towards climate change adaptation: an eco-sustainable design strategy to improve environmental performance under rapid urbanization. Atmosphere, 14 (4): 638. https://doi.org/10.3390/atmos14040638

Manavoğlu, E. & V. Ortaçeşme, 2015. Antalya kenti yeşil alanlarının çok ölçütlü analizi ve planlama stratejilerinin geliştirilmesi. Akdeniz University Journal of the Faculty of Agriculture, 28 (1): 11-19.

Matusiak, B. & S. Arbab, 2022. The impact of greenery and surface reflectance on solar radiation in perimeter blocks. Architectural Science Review, 65 (5): 359-369. https://doi.org/10.1080/00038628.2022.2101979

McPherson, E. G., 1994. “Cooling Urban Heat Islands with Sustainable Landscapes.” In: The Ecological City: Preserving and Restoring Urban Biodiversity (Eds: Platt, R. H., Rowntree, R. A. & Muick, P. C.) University of Massachusetts Press, Amherst, 204 pp.

Ministry of Environment, Urbanization and Climate Change, 2015. Türkiye iklim projeksiyonu. (Web page: https://mgm.gov.tr/iklim/iklim-degisikligi.aspx?s=projeksiyonlar) (Data accessed: May 2021).

Monteiro, M. V., K. J. Doick, P. Handley & A. Peace, 2016. The impact of greenspace size on the extent of local nocturnal air temperature cooling in London. Urban Forestry & Urban Greening, 16: 160-169. https://doi.org/10.1016/j.ufug.2016.02.008

Noreen, A., 2024. Antalya'da İklim Değişikliği Ve Turizm. Ankara University Institute of Social Sciences Department of Social Environmental Sciences (Unpublished) Phd Thesis, Ankara, 232 pp.

Oke, T.R., 1989. The micrometeorology of the urban forest. Philosophical Transactions of the Royal Society B: Biological. Sciences, 324 (1223): 335-349. https://doi.org/10.1098/rstb.1989.0051

Oliveira, S., H. Andrade & T. Vaz, 2011. The cooling effect of green spaces as a contribution to the mitigation of urban heat: a case study in Lisbon. Build and Environment, 46 (11): 2186-2194. https://doi.org/10.1016/j.buildenv.2011.04.034

Potchter, O., P. Cohen & A. Bitan, 2006. Climatic behavior of various urban parks during hot and humid summer ın the Mediterranean city of Tel Aviv, Israel. International Journal of Climatology, 26: 1695-1711. https://doi.org/10.1002/joc.1330

Ren, Z., X. He, H. Zheng, D. Zhang & X. Yu, 2013. Estimation of the relationship between urban park characteristics and park cool island intensity by remote sensing data and field measurement. Forests, 4 (4): 868-886. https://doi.org/10.3390/f4040868

Ruiz, M. A., M. F. Colli, C. F. Martinez & E. N. C. Cantaloube, 2022. Park cool island and built environment. A ten-year evaluation in Parque Central, Mendoza-Argentina. Sustainable Cities and Society, 79: 103681. https://doi.org/10.1016/j.scs.2022.103681

Saito, I., O. Ishiara & T. Katayama,1990-1991. Study of the effect of green areas on the thermal environment in an urban area. Energy and Buildings, 15 (3-4): 493-498. https://doi.org/10.1016/0378-7788 (90)90026-F

Sancar, M.C. & Ş. Güngör, 2022. Analysis of Antalya province bioclimatic comfort features according to heat index. International Journal of Eurasia Social Sciences, 13 (48): 710-723. http://dx.doi.org/10.35826/ijoess.3166

Sarı, S. & N. İnan, 2010. Antalya-Anamur kıyı bölgesindeki iklim farklılıkları. Marmara Coğrafya Dergisi, 22: 325-362. ISSN:1303-2429

Shahfahad, M. W. Naikoo, A. R. Md. Towfiqul Islam, J. Mallick & A. Rahman, 2022. Land use/land cover change and its impact on surface urban heat island and urban thermal comfort in a metropolitan city. Urban Climate, 41: 101052. https://doi.org/10.1016/j.uclim.2021.101052

Shashua-Bar, L. & M. E. Hoffman, 2000. Vegetation as a climatic component in the design of an urban street: an empirical model for predicting the cooling effect of urban green areas with trees. Energy Buildings, 31: 221-235. https://doi.org/10.1016/S0378-7788 (99)00018-3

Shashua-Bar, L. & O. Potchter, A. Bitan, D. Boltansky & Y. Yaakov, 2010. Microclimate modelling of street tree species effects within the varied urban morphology in the Mediterranean city of Tel Aviv, Israel. International Journal of Climatology, 30 (1): 44-57. https://doi.org/10.1002/joc.1869

Shih W., 2017. The cooling effect of green infrastructure on surrounding built environments in a sub-tropical climate: a case study in Taipei metropolis. Landscape Research, 42 (5): 558-573. https://doi.org/10.1080/01426397.2016.1235684

Silva, J. S., R. M. Silva & C. A. G. Santos, 2018. Spatiotemporal impact of land use/land cover changes on urban heat islands: A case study of Paço do Lumiar, Brazil. Building and Environment, 136: 279-292. https://doi.org/10.1016/j.buildenv.2018.03.041

Spronken-Smith, R. A. & T. R. Oke, 1998. The thermal regime of urban parks in two cities with different summer climates. International Journal of Remote Sensing, 198 (11): 2085-2104. https://doi.org/10.1080/014311698214884

Şensoy, S., L. Shahin, E. Yılmaz, N. Türkoğlu, İ. Çiçek, V. Darende & B. Yazıcı, 2017. “Antalya yüzey ısı adası özelliklerinin uydu verileri ile analizi, 133-145”. III. Meteorological Remote Sensing Symposium (16-19 September, Antalya) Proceedings, Turkish State Meteorological Service, 633 pp.

Unal Cilek, M. & C. Uslu, 2022. Modeling the relationship between the geometric characteristics of urban green spaces and thermal comfort: The case of Adana city. Sustainable Cities and Society, 79: 103748. https://doi.org/10.1016/j.scs.2022.103748

Upmanis, H., I. Eliasson & S. Lindqvist, 1998. The influence of green areas on nocturnal temperatures in a high latitude city (Göteborg, Sweden). International Journal of Climatology, 18: 681-700. https://doi.org/10.1002/(SICI)1097-0088 (199805)18:6<681::AID-JOC289>3.0.CO;2-L

Wang, X., H. Cheng, J. Xi, G. Yang & Y. Zhao, 2018. Relationship between park composition, vegetation characteristics and cool island effect. Sustainability, 10 (3): 587. https://doi.org/10.3390/su10030587

Wang, M., H. Song, W. Zhu & W. Yuncai, 2023. The cooling effects of landscape configurations of green-blue spaces in urban waterfront community. Atmosphere, 14 (5): 833. https://doi.org/10.3390/atmos14050833

Xiao, X. D., L. Dong, H. Yan, N. Yang & Y. Xiong, 2018. The influence of the spatial characteristics of urban green space on the urban heat island effect in Suzhou Industrial Park. Sustainable Cities and Society, 40: 428-439. https://doi.org/10.1016/j.scs.2018.04.002

Xie, Q. & J. Li, 2020. Detecting the cool island effect of urban parks in Wuhan: A city on rivers. International Journal of Environmental Research and Public Health, 18 (1): 132. https://doi.org/10.3390/ijerph18010132

Zheng, H., Y. Chen, W. Pan, Y. Cai & Z. Chen, 2019. Impact of land use/land cover changes on the thermal environment in urbanization: a case study of the natural wetlands distribution area in Minjiang River Estuary, China. Polish Journal of Environmental Studies, 28 (4): 3025-3041. https://doi.org/10.15244/pjoes/93743.