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ASSESSMENT OF THE THERMAL REGULATION CAPACITY OF SERIK NATIONAL GARDEN USING SATELLITE-BASED LST ANALYSIS

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Abstract

This study aims to evaluate the thermal regulation capacity of Serik National Garden by examining changes in land surface temperature (LST) before and after its construction using remote sensing technology. In the study, the boundaries of the national garden were digitized using ArcGIS Basemap data, and the study area covering the national garden and its surroundings was determined. Surface temperature data was derived from Landsat 8 OLI/TIRS satellite images for the summer seasons of 2014 and 2024. Raster calculator was used to calculate LST changes, while the zonal statistics tool was used for statistical analysis. The analysis results show that the average surface temperature decreased by –1.7±0.6 °C in the area where the national garden was built and by –0.3±0.2 °C in the surrounding zone. The most important factor limiting the environmental cooling effect of the national garden is that the area has been newly established and the vegetation is still low in height and has a limited crown volume. In conclusion, the findings demonstrate that national gardens possess a thermal regulation capacity that can be quantitatively determined through remote sensing technologies, functioning as nature-based solutions within the scope of urban green spaces that combat the urban heat island effect. The maturation of plants within the national garden over time will provide a more effective nature-based solution in combating the urban heat island effect.

Keywords: Urban landscape, green spaces, national garden, thermal regulation, LST

SERİK MİLLET BAHÇESİ'NİN TERMAL DÜZENLEME KAPASİTESİNİN UYDU TABANLI LST ANALİZİ İLE DEĞERLENDİRİLMESİ

Özet

Bu çalışma, Serik Millet Bahçesi'nin inşa öncesi ve sonrası dönemlerindeki arazi yüzey sıcaklığı (Land Surface Temperature, LST) değişimlerini uzaktan algılama teknolojisi aracığıyla inceleyerek, millet bahçesinin termal düzenleme kapasitesini değerlendirmeyi amaçlamaktadır. Araştırmada, millet bahçesinin sınırları ArcGIS Basemap verileri kullanılarak sayısallaştırılmış ve ardından millet bahçesini ve yakın çevresini kapsayan çalışma alanı oluşturulmuştur. Yüzey sıcaklığı verileri, 2014 ve 2024 yıllarının yaz mevsimine ait Landsat 8 OLI/TIRS uydu görüntülerinden türetilmiştir. LST değişimlerinin hesaplanmasında Raster Calculator, istatistiksel analizlerde ise Zonal Statistics aracı kullanılmıştır. Analiz sonuçları, millet bahçesinin inşa edildiği alanda ortalama yüzey sıcaklığının –1,7±0,6 °C azaldığını, çevresindeki zonda ise –0,3±0,2 °C azaldığını ortaya koymuştur. Millet bahçesinin çevresel soğutma etkisinin sınırlı kalmasındaki en önemli etken, alanın yeni tesis edilmiş olması ve bitki örtüsünün henüz düşük boya ve sınırlı taç hacmine sahip olmasıdır. Sonuç olarak, çalışmada elde edilen bulgular, kentsel ısı adası ile mücadelede doğa temelli bir çözüm olarak kabul edilen kentsel yeşil alanlar kapsamında, millet bahçelerinin uzaktan algılama teknolojisi aracılığıyla termal düzenleme kapasitesine sahip olduğunu nicel olarak ortaya koymaktadır. Millet bahçesi içerisindeki bitkilerin zamanla olgunlaşması, kentsel ısı adası ile mücadelede daha etkili bir doğa temelli çözüm sağlayacaktır.

Anahtar sözcükler: *Kentsel peyzaj, yeşil alanlar, millet bahçesi, termal düzenleme, LST*

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1. Introduction

The deterioration of natural ecosystems and the proliferation of impermeable surfaces in land cover resulting from urbanization substantially influence the microclimatic attributes of urban regions (Grimm et al., 2008; Seto et al., 2012; Kahraman & Kaya, 2022). The elevated thermal storage capacity and diminished albedo of urban surfaces result in greater temperatures in urban centers relative to rural areas, a phenomenon referred to as the urban heat island (UHI) effect in scholarly literature (Oke, 1982; Voogt & Oke, 2003; Oğuz & Zengin, 2011; Olgun et al., 2024). Surface temperature variations identified through satellite-based thermal band analysis are referred to as the surface urban heat island (SUHI) (Martin et al., 2015; Medina Fernández et al., 2023). Satellite-based observations utilize LST (Land Surface Temperature) data from Landsat and MODIS images with thermal bands to evaluate the spatial distribution of the heat island effect in metropolitan regions (Weng, 2009; Li et al., 2013; Olgun et al., 2025). Rising temperatures in the Mediterranean climate zone result in heightened energy consumption, augmented heat stress, and diminished quality of life in urban areas (Rizwan et al., 2008; Berger et al., 2017; Keppas et al., 2021; ÇŞİDB, 2024; Sezik & Dokuyucu, 2025). In this context, urban green spaces are becoming increasingly significant due to their diverse contributions to the sustainable operation of urban ecosystems (Doğan et al, 2023; Şatır et al., 2023; Zhang and Qian, 2024; Olgun & Karakuş, 2024; Yao et al., 2025). These contributions include diverse ecosystem services such as supporting biodiversity, sequestering carbon dioxide, producing oxygen, regulating urban microclimates, enhancing the aesthetic quality of urban landscapes, and offering various physical and psychological benefits to urban inhabitants (Celikyay et al., 2007; Akkurt and Akten, 2021; Uygur and Özkan, 2022; Güneş et al., 2025). Ecosystem services, characterized as natural outputs derived from ecological processes that directly enhance human well-being, are categorized into four fundamental types: resource-providing, regulatory, supporting, and cultural services (Akkurt and Akten, 2021; Şatır et al., 2023; Yao et al., 2025).

Urban green spaces are characterized as locations with plant materials or integrated with such materials in external spaces or openings beyond architectural structures and traffic zones (Gül and Küçük, 2001). Urban green spaces encompass parks, median strips, cemeteries, botanical gardens, zoos, urban forests and groves, gardens associated with public institutions and organizations, communal housing gardens, and green facade and roof systems (Gül and Küçük, 2001; Selim et al., 2014; Doygun et al., 2015; Akkemik et al., 2021; Şahin et al., 2023, Aydemir et al., 2024). In recent years, the escalating strain of urbanization in Türkiye has highlighted the necessity for accessible and high-quality green areas (Olgun, 2019; Sağlık et al., 2019; Uzun and Şenol, 2020). Since 2018, there has been a notable rise in the number of National Garden projects under the "Green City Vision" initiative executed by the Ministry of Environment, Urbanization, and Climate Change. These initiatives, designed and executed across several provinces of Türkiye, employ landscape strategies that enhance the ecological integrity of urban regions, establish high-quality recreational spaces, and enrich urban identity (TMMOB Chamber of Landscape Architects, 2018). National gardens serve various functions, including enhancing interaction with the environment, maintaining ecological equilibrium, showcasing endemic species, and offering secure gathering spaces during emergencies (Bingöl, 2021). National gardens are a crucial element of contemporary landscape design and sustainable urbanization strategies, serving as multifunctional green spaces that enhance ecological equilibrium in urban areas, facilitate recreational pursuits, and elevate quality of life

(Şahin and Tuncay, 2024; Selçuk, 2025). TOKİ (Housing Development Administration of Türkiye) aims to develop a national garden in each of the 81 provinces, with numerous projects either completed or underway, resulting in extensive landscaped areas (TOKİ, 2021).

Literature on national gardens adopts a multifaceted perspective, encompassing design principles, accessibility, ecological functions, social roles, and their connection to urban identity. Sağlık et al. (2019) conducted a comprehensive evaluation of the design and implementation process of the Kahramanmaraş 15 July National Garden, whereas Uzun and Şenol (2020) analyzed national green space policies in Türkiye and addressed the role of national gardens within this framework. Biçen (2023) examined the accessibility criteria of national gardens for users, whereas Ferah and Poyraz (2025) assessed the spatial suitability of these locations according to physical and sensory aspects. Şenik and Uzun (2021) explored the socio-ecological benefits of national gardens, whilst Doğan (2024) analyzed national gardens within the framework of urban change processes. Birol and Aydın (2019) did a thorough analysis of national gardens regarding their quality and quantity, whereas Zülkadiroğlu (2022) assessed the user-centered attributes of these spaces. Selçuk (2025) assessed the significance of national gardens in the urban landscape via the lens of urban ecology theory.

This work is distinguished from prior research by its empirical evidence of the thermal regulating impacts of national gardens utilizing Landsat-based LST data. The LST values of the Serik National Garden were assessed prior to construction and following its inauguration, with alterations in surface temperatures analyzed and evaluated through zonal spatial statistics methods, encompassing both the core areas of the national garden and its adjacent surroundings. The results revealed regional and temporal variations in surface temperature and quantitatively assessed the thermal control capacity of the national garden. The research seeks to measure the cooling impact of urban green spaces, namely national gardens, as a component of their regulatory ecosystem services, by analyzing surface temperature, which is a crucial element of nature-based solutions to mitigate the urban heat island effect. The study seeks to provide an original contribution to literature by presenting empirical evidence that national gardens are a significant component of urban green spaces that aid in urban heat management through nature-based solutions.

2. Materials and Methods

2.1. Study Area

The Serik National Garden, situated in the Serik district of eastern Antalya province, was designated as the research location. Serik is situated in the Mediterranean region of Türkiye, roughly 40 km east of Antalya's city center. Manavgat is situated to the east by the district, Aksu to the west, Burdur and Isparta to the north, and the Mediterranean Sea to the south (Figure 1). The Serik district headquarters is a hamlet located roughly 8 km inland from the shore, predominantly situated on a plain at an elevation of 26 m above sea level (Serik Municipality, 2020; Olgun et al., 2022). The district experiences a Mediterranean climate, marked by hot, arid summers and warm, wet winters. This climatic framework significantly influences the development of the region's natural and cultural landscape, directly impacting agricultural practices, vegetation distribution, and the utilization of urban green spaces. Serik, a prominent tourism hub in Türkiye, encompasses an area of 122,000 hectares and has a population of 143,435 as of 2024. The construction of Serik National Garden, situated on the northwestern boundary of the city at coordinates 36° 55' 28" N and 31° 5' 24" E, including an area of 63468.08 m², commenced in 2021 and was inaugurated in 2023. (Url1, 2025).

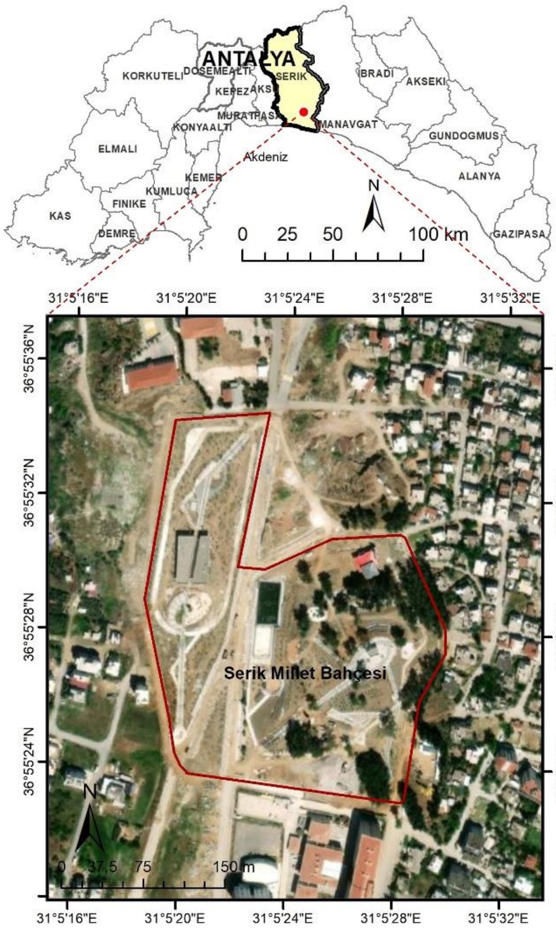

Figure 1. Location of the research area

2.2. Dataset

The research has three primary phases: data collection, analysis, and conclusion. Initially, open-access data was examined, followed by the creation of a dataset to delineate the study area's boundaries and land surface temperature. The study area boundaries were established using Turkish provincial administration borders, which are available for free download from the General Directorate of Mapping (HGM) website. The data, encompassing the entire nation, was refined to align with the provincial and district boundaries of Antalya and subsequently transformed to the WGS84_36N datum and projection. The Serik district was excluded from the processed data.

Landsat 8 OLI/TIRS satellite imagery, including thermal bands, was obtained from the United States Geological Survey (USGS) 'Earth Explorer' website as part of the satellite imagery dataset (USGS, 2025a). Prior to the establishment of the National Garden, picture ID LC08_L1TP_178034_20140703_20200911_02_T1 was utilized, but after its inauguration, image ID LC08_L1TP_178034_20240730_20240801_02_T1 was employed. The 4th Band (Red), 5th Band (NIR), and 10th Band (TIR) photos from the Landsat 8 OLI/TIRS satellite were cropped to the research region borders (Table 1).

Table 1. Satellite images used in the research

	Pre-construction of the National Garden	Post-construction of the National Garden
Acquisition date	03.07.2014	30.07.2024
WRS	WRS-2	WRS-2
Path	178	178
Row	034	034
Cloud Cover	%0,85	%0,08
Landsat 8 OLI/TIRS spektral bands		
Spektral band	**Wavelength**	**Resolution**
Band 4 - Red	0.64 - 0.67µm	30 m
Band 5 - (NIR)	0.85 - 0.88 µm	30 m
Band 10 - TIRS 1	10.6 - 11.19 µm	100 m*

* Band 10 (TIRS) is resolution acquired at 100 m, but have been resampled to 30 m in the delivered data product.

2.3. Methods

The initial phase was the analysis of open access spatial data sources. A data set was subsequently established to delineate the study area's boundaries and ascertain (LST). To guarantee spatial compatibility, all data within the dataset were defined in the WGS84_36N datum and projection system, and open source data was transformed into this coordinate system.

The LST computation using Landsat 8 OLI/TIRS satellite images use the single-channel method commonly referenced in academic literature (Artis & Carnahan, 1982; Sobrino et al., 2004). The LST map was derived in six stages utilizing the Red, NIR, and TIR bands from Landsat 8 OLI/TIRS satellite images (Karakuş and Eyileten, 2022; Selim et al., 2023; USGS, 2025b). Initially, pixel brightness values were transformed into spectral radiance values utilizing the thermal band of Landsat 8 OLI/TIRS data. During the second stage, radiance values

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were transformed into temperature values via thermal conversion formulas. During the third stage, the Normalized Difference Vegetation Index (NDVI) was computed utilizing the fourth (NIR) and fifth (Red) bands of satellite imagery. The plant cover ratio (Pv) was computed in the fourth stage utilizing the NDVI data. The fifth stage involved the determination of surface emissivity. During the sixth stage, a LST map was produced by integrating surface temperature measurements and emissivity characteristics (Artis and Carnahan 1982; Anandababu et al., 2018; Ardahanlıoğlu, 2024; Karakuş & Kahraman, 2025; USGS, 2025b). The thermal impacts of national gardens were illustrated by LST maps generated on annual basis. The alterations in land surface temperature attributed to the national garden were spatially derived by contrasting the 2014 LST maps with the 2024 LST map, which predate the establishment of the national gardens. Empirical data regarding alterations in the 500x500m study areas, which include national gardens and their adjacent environments, were acquired by the zonal statistics approach utilizing ArcGIS software. The thermal effects of the national gardens were assessed utilizing this data.

3. Findings

The thermal effects of Serik National Garden were illustrated using zonal statistical analysis of LST data acquired from Landsat 8 OLI/TIRS satellite imagery. LST maps of the research area are illustrated in Figure 2. Figure 2 illustrates that the LST data from the periods preceding the establishment of Serik National Garden (2014) and after its inauguration (2024) reveal alterations in the surface temperature dynamics of the region.

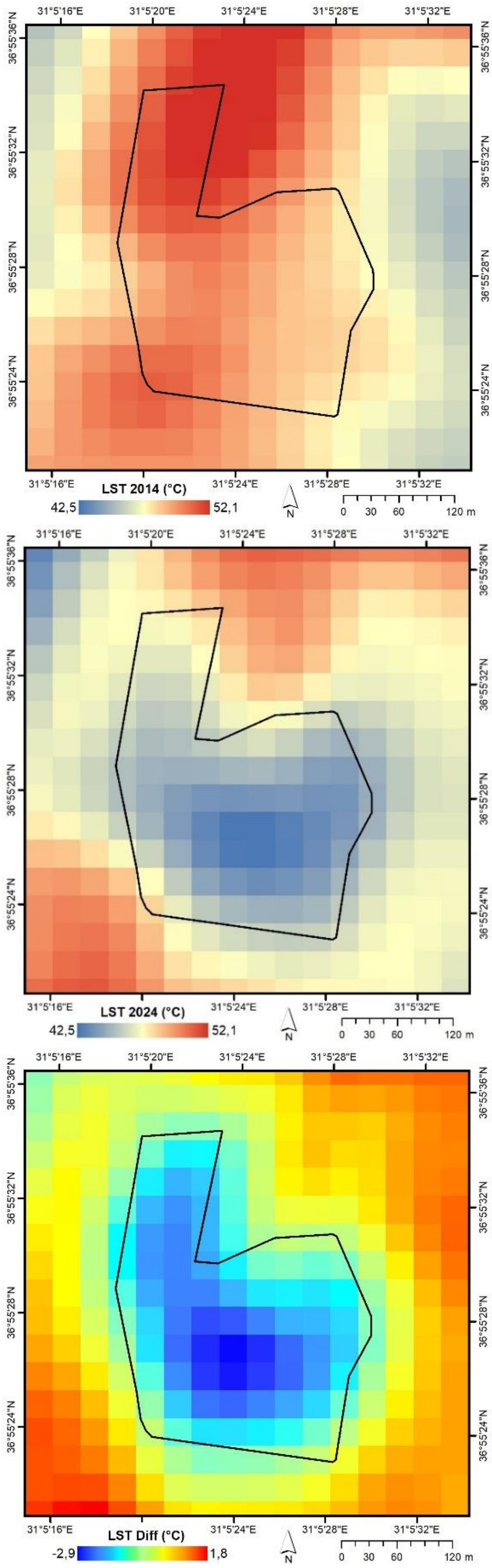

Figure 2. Maps depicting pre-construction (LST 2014), post-construction (LST 2024), and LST changes of Serik National Garden

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The 2014 LST map indicates that prior to the establishment of Serik National Garden, the land surface temperature in the proposed region ranged from 47.6 to 49.7 °C, with an average of 48.4±0.5 °C. The 2024 LST map, following the garden's completion and inauguration, indicates a surface temperature range of 45.5 to 48.5 °C, with an average surface temperature of 46.7±0.7 °C (Table 2).

The 2014 LST map indicates that the surface temperature in the vicinity of the garden ranged from 46.5 to 49.8 °C, with an average surface temperature of 47.9±0.8 °C. The 2024 LST map indicates that these values fluctuate between 45.8 and 50.1 °C, with a mean surface temperature of 48.2±0.9 °C.

Table 2. LST data of the research area

Location	Time	Minimum	Maximum	Mean
National Garden	LST 2014	47.6	49.7	48.4±0.5
	LST 2024	45.5	48.5	46.7±0.7
	LST Diff	-2.1	-1.2	-1.7±0.6
Its surroundings	LST 2014	46.5	49.8	47.9±0.8
	LST 2024	45.8	50.1	48.2±0.9
	LST Diff	-0.7	0.3	0.3±0.2
The difference between the national garden and its surroundings	LST 2014	-1.1	0.1	-0.5±0.2
	LST 2024	0.3	1.6	1.5±0.4
	LST Diff	1.4	1.5	2.0±0.5

The surface temperature difference map indicates that, following the construction of the National Garden, temperature variations ranging from –2.9°C to –0.4 °C were observed in the vicinity of the garden, resulting in an average surface temperature reduction of –1.7±0.6 °C relative to the pre-construction period. The temperature variation in the vicinity of the National Garden ranged from –1.8 °C to 1.8 °C, with an average surface temperature reduction of –0.3±0.2 °C.

In 2014, the surface temperature disparity between the National Garden and the adjacent area varied from –1.1°C to 0.1 °C, with a mean difference of –0.5±0.2 °C. In 2024, the variation spanned from 0.3 °C to 1.6 °C, with a mean difference of 1.5±0.4 °C. The variation in LST change ranged from 1.4 to 1.5 °C, with a mean difference of 2.0±0.5 °C.

Figure 3 illustrates the surface temperature distribution of the Serik National Garden prior to construction (2014) and after construction (2024) along a west-east axis, revealing a pronounced thermal gradient both within the national garden boundaries and its adjacent areas. Post-construction LST values are typically 1–1.5 °C lower in the western direction (0–150 m), indicating that the national garden has a modest cooling impact towards the west. The most pronounced cooling effect occurs in the national garden (150–360 m), where surface temperatures decreased from 48–49 °C in 2014 to 45–46 °C in 2024. This indicates a net cooling effect of roughly 2–3 °C. In the eastern direction (360–510 m), the LST curve ascends once more in the post-construction phase, signifying that the garden's cooling impact disseminated more restrictively in this orientation.

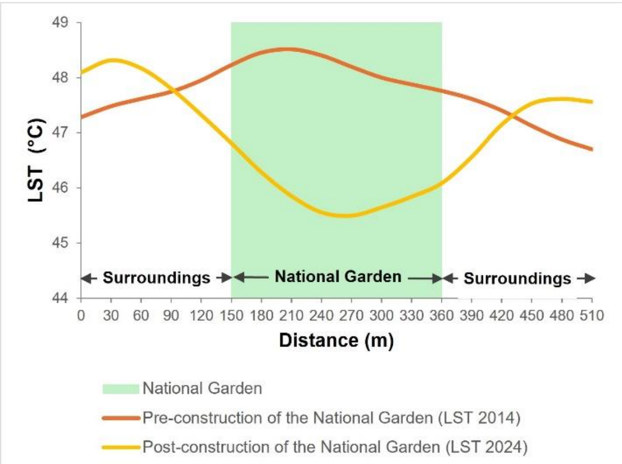

Figure 3. LST change of Serik National Garden before construction (LST 2014) and after construction (LST 2024)

4. Discussion and Conclusion

Analyses of LST in Serik National Garden for the pre-construction (2014) and post-construction (2024) periods demonstrate that green space management significantly impacts micro-scale thermal comfort. A periodic comparison within the confines of Serik National Garden indicated that post-construction land surface temperature readings declined by –1.7±0.6 °C relative to pre-construction levels. This reduction illustrates a notable cooling effect at the garden resulting from the proposed landscaping design and execution. Research in the literature corroborates this fact. Comparable research indicates that urban green spaces have an average daily cooling effect between 0.3 to 2.4 °C (Bowler et al., 2010). Some studies indicate a temperature reduction of 2–3 °C within parks (Grilo et al., 2020; Amani-Beni et al., 2021; Akarsu Varşak and Ender Altay, 2024), while others suggest that this variation may be more pronounced depending on specific factors and environmental conditions present in the park (Feyisa et al., 2014; Gao et al., 2023). Research demonstrates that the spatial extent of the cooling effect caused by parks is constrained, influenced by the proximity of the park to adjacent areas, the size of the park, the species and composition of vegetation, and the density of surrounding structures. Prior research indicates that park cooling is typically confined to several hundred meters, and the existence of dense urban structures and concrete/asphalt surfaces may diminish the extent of this phenomenon (Aram et al., 2019; Blachowski and Hajnrych, 2021; Gao et al., 2023; Verma et al., 2024). This aligns with the modest average shift of –0.3 °C recorded in the environmental zone of Serik National Garden. The restricted environmental cooling impact in Serik National Garden is attributable to its recent establishment, resulting in low vegetation height and limited crown development. The restricted shade ability of juvenile plants and their reduced evapotranspiration rates, relative to adult trees, inherently diminish the spatial extent of the microclimatic cooling impact caused by green spaces (Pattnaik et al., 2024; Zhang et al., 2020). Literature indicates that in initial landscaping applications, a significant cooling effect is not observed until vegetation matures, and that cooling efficacy improves with the expansion of shade area, leaf area index, and crown volume over time (Rahman et al., 2020; Yin et al., 2024). Skelhorn et al. (2014) indicated that a 5% rise in mature tree cover decreases surface temperature by roughly 1 °C, but the same increase with young tree saplings results in a cooling effect of about 0.5 °C. The restricted environmental cooling effect at Serik National Garden aligns with an urban surface temperature modeling work by Skelhorn et al. (2014) in Manchester.

In conclusion, despite Serik National Garden being newly established and displaying early-stage vegetation traits such as diminished height and crown development, it has been found to significantly reduce surface temperatures in its vicinity compared to pre-construction levels, albeit with a limited cooling effect on its surroundings. Remote sensing assessments should be performed at five-year intervals to evaluate the changes in the thermal regulation capacity of the National Garden as vegetation matures. The study concentrated on the temperature effects during the peak summer time. Consequently, analyzing surface temperature variations in different seasons helps elucidate the thermal influence of the National Garden annually.

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