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Thermal Comfort and Green Spaces: The Role of Temperature-Regulating Elements in Neighborhood Parks

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Abstract: According to current studies, the thermal effects of global warming will affect urban areas more intensely. In the face of this situation, strategies for the improvement and management of urban green spaces are becoming increasingly important in sustainable landscape design. These strategies promote social sustainability by positively affecting individuals' physical and psychological well-being, taking into consideration ecological sustainability. Projections regarding global warming emphasize that the density of hardscapes and green spaces, the selection of plant species, and the distribution of plants considered within the scope of this study should be taken into account. This research was conducted in the Görükle neighborhood of Bursa, focusing on the role of temperature-regulating elements in 14 neighborhood parks. Systematic temperature measurements were carried out in the research area on the 10th, 20th, and 30th of July and August, specifically between 12:00 and 13:00, during peak temperature hours. The presence of parks that are close to each other and relatively far away from each other in the study area was seen as advantageous to filter the effects of plant differences in similar conditions. Furthermore, evaluating these various factors together highlights the multifaceted nature of thermal comfort. Designated temperature measurement points included three points (hard surfaces and hard surfaces surrounded by vegetation and planted green spaces) in each park. An analysis utilizing SPSS and the RayMan program revealed that parks with a softscape to hardscape ratio of approximately two to one experienced temperature reductions of 2.5 to 3 °C. Furthermore, the findings indicate that coniferous trees have a more significant impact on thermal comfort compared to deciduous trees. The significant differences identified in this study underscore essential considerations for urban design processes aimed at achieving sustainability.

Keywords: landscape design; neighborhood parks; thermal comfort; plants; sustainability

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1. Introduction

Thermal environment and thermal comfort have a significant impact on human health [1–4]. In the 1980s, the term thermal comfort was added to the design criteria at the climatic comfort level. This term, which was initially used only for interior spaces, has become used almost exclusively for exterior spaces over time. Today, the term thermal comfort indicates that the majority of individuals must be at a certain comfort level in terms of climatic conditions such as temperature, humidity, and air flow while continuing their physical and mental activities indoors or outdoors. The factors influencing outdoor comfort are numerous and complex [5]. Research shows that if people's living environments do not have thermal comfort conditions, it first causes distress and then a very significant discomfort [6–9]. Thermal comfort is a critical factor for individuals in a particular region to live their lives in health and peace. If individuals in an open or closed space do not mention any thermally disturbing elements in that space, thermal comfort is provided [10,11].

Thermal comfort achieved in outdoor areas is fundamentally linked to sustainability. In sustainable landscape design, the strategic planning of green spaces in accordance with climatic conditions enhances users' thermal comfort while simultaneously reducing energy consumption. Elements such as plantation and shading play a crucial role in improving the microclimate, mitigating the urban heat island effect and thereby facilitating thermal comfort. Furthermore, the thermal comfort experienced in outdoor environments positively impacts individuals' physical and psychological well-being, fostering social interaction as the usage of these spaces increases. This increased engagement, in turn, promotes social sustainability. Consequently, ensuring thermal comfort in outdoor areas emerges as a strategy that provides both environmental and social benefits to urban settings.

Thermally disturbing effects will affect cities more intensely with global warming. In addition, the increase in the rate of urbanization will cause these effects to be felt more strongly [12]. Since the 1980s, every decade experienced has been warmer than the previous decade. This situation is emphasized in the report published by the IPCC 1st Working Group in August 2021. As emphasized in the report, climate change will show its adverse effects faster, more widely, and more severely in the upcoming period [13,14]. According to the future climate scenarios of the Turkish Ministry of Environment and Urbanization, it is predicted that temperatures in the western parts of Turkey will increase by 2 to 3 °C, especially in the summer months, and up to 6 °C. According to a projection study, a temperature increase of 2–3 degrees is predicted in the summer period between 2016 and 2040 and another 4 degrees between 2041 and 2070 in our research area [15]. These values were also confirmed in the study titled "Intercomparison of the expected change in the temperature and the precipitation retrieved from CMIP6 and CMIP5 climate projections: A Mediterranean hot spot case" by Bağçacı et al., using different projection scenarios [16].

The results obtained with the database and projection tool provided by the World Bank are given below (Figure 1) [17].

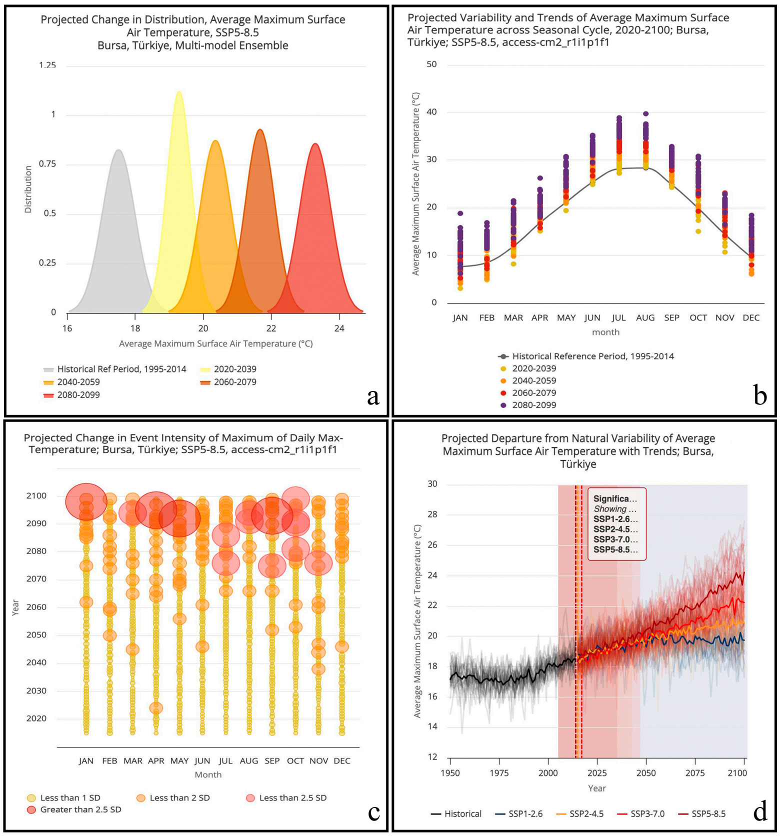

Figure 1. Temperature projections [17].

As can be seen from these projection data, the average maximum surface temperature will increase significantly over the years (Figure 1a). Especially considering the month of

August, it has been observed that the average surface temperature will not be below the reference previous years in any period in the future (Figure 1b). Again, starting from 2050, the daily maximum temperature level for August is predicted to increase by close to 2 SD compared to the reference years (Figure 1c). Considering four different generally accepted scenarios, it is predicted that the average maximum surface temperature for Bursa will increase by a minimum of 2 and a maximum of 6 degrees in the next 75 years, starting from 2025 (Figure 1d). Based on these projections, this situation should be taken into consideration in land use during the urban design process.

When urban design studies are examined, innovative suggestions have started to be presented by considering thermal comfort. During these studies, solution-oriented methods targeting sustainable and ecological cities are followed. In this solution process, natural and artificial landscape elements play a significant role in ensuring sustainability in urban studies, considering thermal dissipation and thermal conductivity [9,18–21]. The more perpendicularly the sun's rays come to a horizontal surface, the greater the absorption by the surface and therefore the higher the surface temperature. Thermal dissipation, thermal conductivity, and heat islands due to albedo in urban areas have the highest values compared to other land covers (Figure 2) [22,23]. Therefore, people in urban areas spend their leisure time in green spaces and especially parks.

Figure 2. Temperature varies and heat islands with land use [24].

Within the scope of green spaces, neighborhood parks are the places most used by urban users. It is known that neighborhood parks have essential effects on both reducing emerging problems and the climate [9,25,26]. To provide spatial comfort in the design process of neighborhood parks, climatic data and thermal comfort levels should be considered [27,28]. In urban green spaces where thermal comfort is provided, people can spend more extended time, and their stress levels can be reduced [28–30]. Urban green spaces offer a multitude of social and ecological benefits, promoting physical activity, social interaction, and recreational pursuits across different age groups. Consequently, they exhibit high exposure and vulnerability characteristics [31,32]. In order to reduce stress levels, designs should be made to prevent the formation of heat islands in urban areas or to alleviate them. In this direction, it is necessary to ensure the continuity of green space systems in cities with nature-based solutions. The importance of natural landscape elements emerges at this stage. Simultaneously, they offer extensive ecosystem services, including climate regulation, alleviation of urban heat islands, and enhancement of air quality, making them an indispensable and valuable resource within urban settings for sustainability [33,34]. However, Guo et al. note in their research that, at the human scale, the health risks to individuals are more significant due to the characteristics of green spaces, which tend to be more open, allowing for greater exposure to direct radiation on the ground. In this study, they found that the main risks for 33.3% of urban green areas and squares were hazards, exposure, and vulnerability [35].

Results similar to the above studies are also stated in The Sixth Assessment Report (AR6) of the United Nations (UN) Intergovernmental Panel on Climate Change (IPCC) (Figure 3) [36].

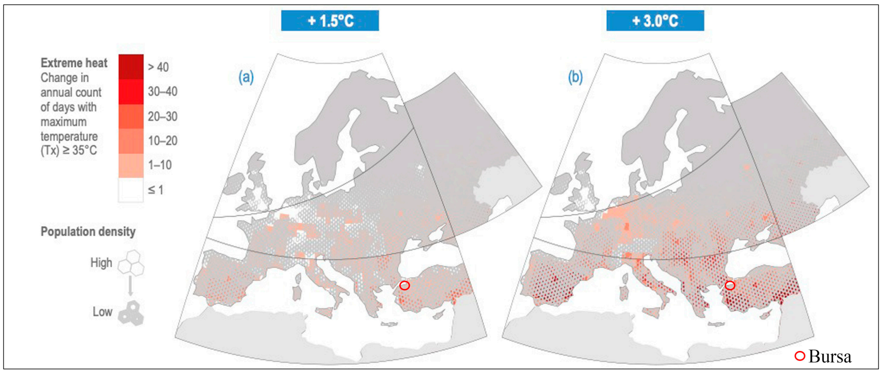

Figure 3. Extreme heat distribution [36].

In light of all these data, this research aims to determine the temperature-regulating elements in neighborhood parks in Görükle District and to reveal data that can increase thermal comfort. Although the selected area is relatively comfortable in terms of thermal comfort today, future projections show that there will be serious temperature increases in this region and similar regions. In this study, it is especially aimed to reveal the differences in the effects of plant choices on the thermal comfort level. In this research, surface material (hard ground density, green space density), and plantation and plant characteristics are taken as the basis for thermal comfort and stress levels. By evaluating these factors, it is aimed to create a basis for the preparation of datasets in regions with similar geographical characteristics. At the same time, it is aimed to determine the importance of plant characteristics in the processes to be carried out to reduce the effects of urban heat islands for sustainability.

In this context, the hypotheses of the study have been formulated as follows:

1. The balance between the density of impervious surfaces and the density of green spaces has either a positive or negative impact on thermal comfort levels in neighborhood parks.
2. The selection of different plant species can significantly alter the thermal comfort levels within neighborhood parks.
3. The distribution of plants can influence thermal stress levels, thereby enhancing users' comfort within neighborhood parks.

Examining these hypotheses together will contribute to understanding the importance of plant species, spatial/land use, and distributions in the design of neighborhood parks, providing valuable data for sustainable neighborhood park solutions.

2. Materials and Methods

2.1. Materials

The research area consists of neighborhood parks in the Görükle Neighborhood in the Nilüfer District of Bursa Province, which is located in the Marmara Region of Turkey. There are a total of 14 neighborhood parks in Görükle District and their locations are indicated on the Google Earth satellite image (Figure 4) [37].

The reason why Görükle was chosen as the study area is that it has an equally active young and old population. At the same time, having very close and relatively distant parks in the research area was considered an advantage in terms of filtering the effects of plant differences in areas with similar conditions. In addition, the city of Bursa, in terms of its geographical location, has features that can be an example for many similar cities with high populations in the same zone (Figure 5).

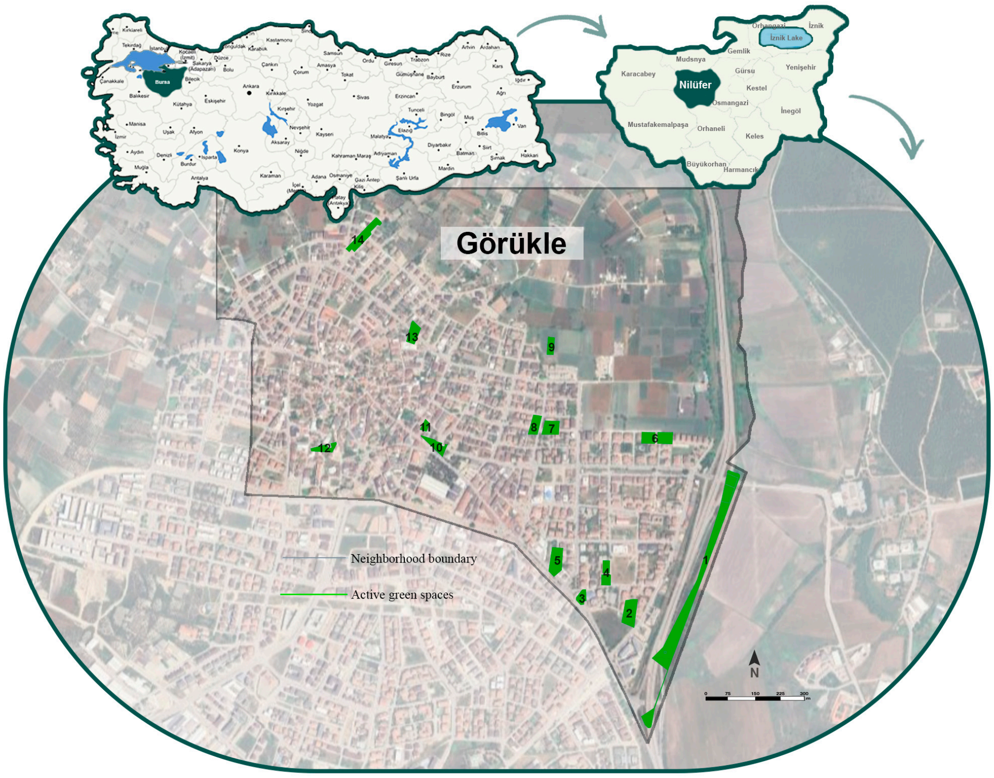

Figure 4. Locations of research area in Bursa/Nilüfer/Görükle [37]. Görükle Sport Park (1), Zambak Park (2), Necmi Yazıcıoğlu Park (3), Badem Park (4), 75. Yıl Park (5), Yıldız Park (6), Barış Park (7), Harmanlık Park (8), Çınar Park (9), Koca Park (10), Berrin Korkut Park (11), Taşpınar Park (12), Koza Park (13), and Esinti Park (14).

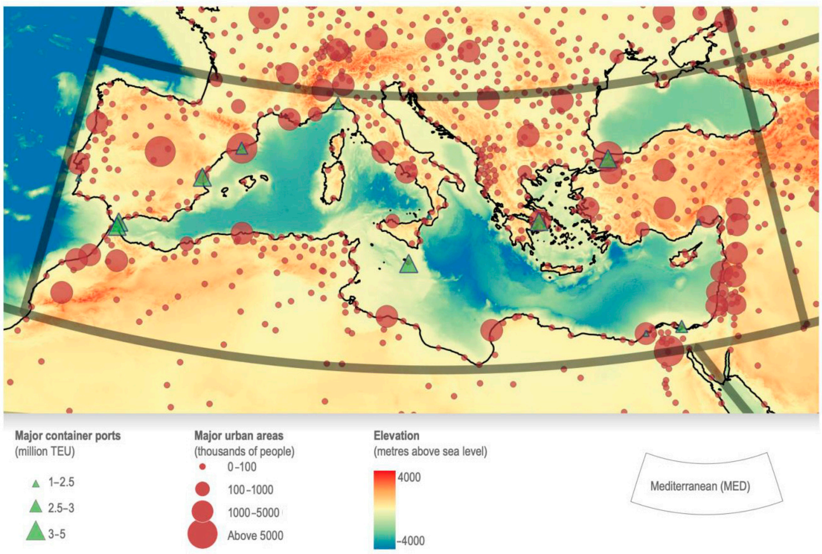

Figure 5. Cities located in the same zone as the research area [36].

2.2. Climate

Although the climate of the region is under the influence of the Marmara climate, it is very similar to the Mediterranean climate type. However, when compared to the Mediterranean climate, the average temperature of the Marmara region is lower, and the precipitation balance is more regular [38]. According to De Martonne's aridity index equation, summer months are dry, and autumn and spring months show less humid climate characteristics [39].

The annual average temperature in the region is 14.9 °C, and the average annual total precipitation is 719.1 mm. While the rainiest months of the year are December, January, February, and October, the driest months are July and August [40]. Summer wind blows from the southwest (Figure 6).

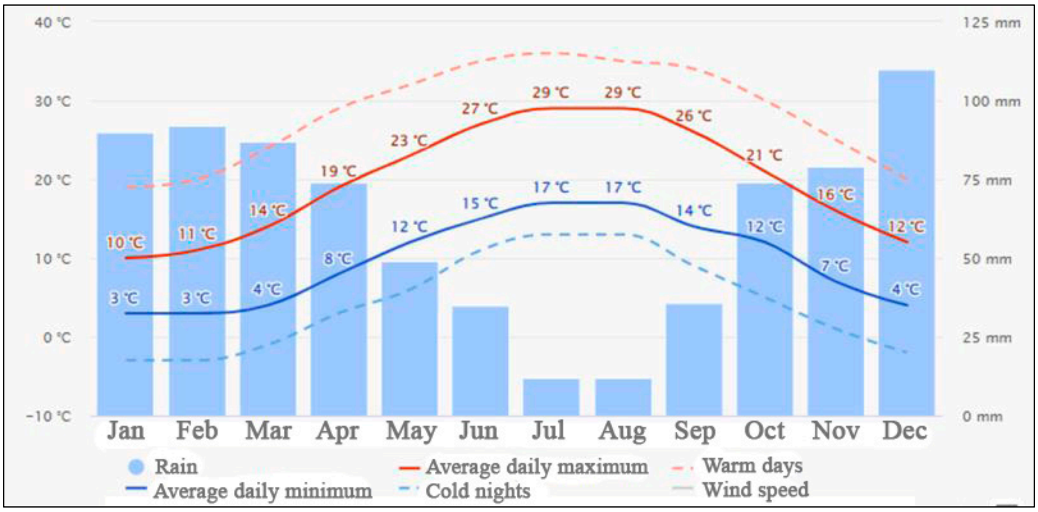

Figure 6. Average temperature and precipitation table for Görükle [40].

According to the data from the last 30 years in Görükle Neighborhood, the coldest month is January, and the hottest month is July and August (Figure 7) [41].

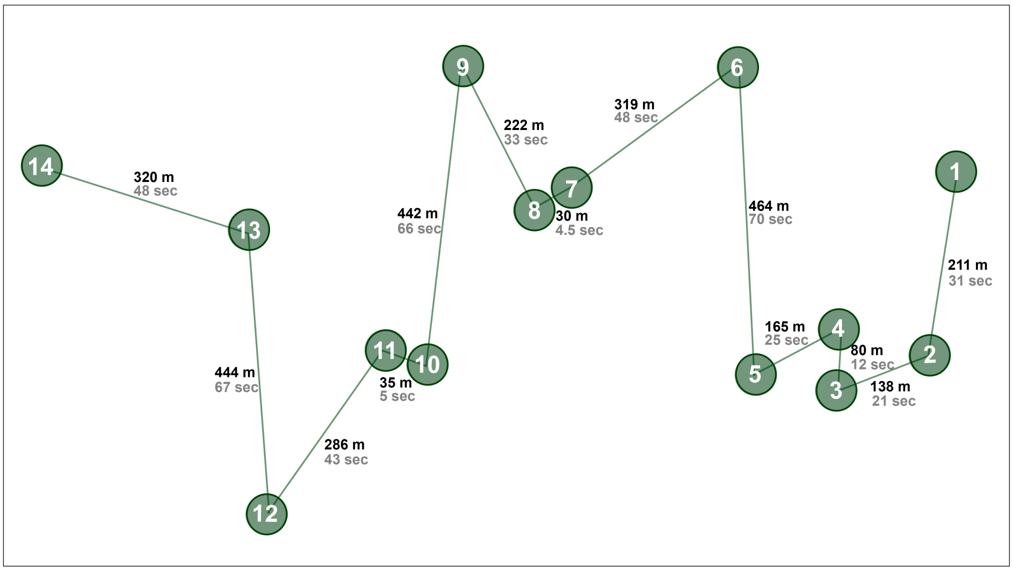

Figure 7. Distances between active green spaces in Görükle and measurement route.

2.3. Methods

In this study, the document analysis method and observation technique were used [42]. The document analysis method was preferred in this study to obtain the necessary qualitative and quantitative data to determine and detail the observations to be made. With this method, the necessary bases for observational studies were created. Within the scope of the document analysis method, studies on thermal comfort in parks [43–48] were examined and field observation forms were created. Among the many studies examined, particular attention was paid to those that most broadly covered the objectives of the research and included the variables planned to be examined. Then, fieldwork was carried out by the study team within the framework of the observation technique, which is a technique that records the researchers' observations without any changes. Fieldwork was carried out in two stages. The first stage is the measurement of temperatures in the parks. For this purpose, temperature measurements were carried out by visiting parks in July and August, when temperatures were high. The reason for choosing the periods with the highest temperatures is the results obtained in previous ministry projections. According to these results, periods with high temperatures appear to be the periods when possible temperature increases will be most intense. At the same time, it is thought that high-temperature periods will offer a broader perspective for researchers from different countries who will conduct thermal comfort studies outside the selected study area. Simultaneously, the potential for higher temperature variations within the research area will enhance the clarity with which the effects of the evaluated factors can be understood. Temperature measurements were systematically conducted on the 10, 20, and 30 of July and August, during peak temperature hours between 12:00 and 13:00. This timing was strategically chosen to capture the highest temperature readings. Measurements were taken on three distinct days at various predetermined locations, with the route illustrated in Figure 7 (according to the locations given in Figure 2), using a Triplett EM300 thermometer, with data meticulously recorded on standardized forms.

The designated temperature measurement points included (1) hard grounds, (2) hard grounds surrounded by plantations, and (3) planted green spaces. To accurately identify these locations, a preliminary assessment of active green spaces was performed in the field. Following this, sketches and three-dimensional representations of the area were created to facilitate a comprehensive understanding of the spatial layout. This process also involved calculating the types and quantities of plants, as well as assessing the extents of soft and hard ground areas.

During this phase, it was crucial to integrate specific criteria pertaining to the green spaces when determining the measurement points. Special attention was given to ensuring that the selected points were in close proximity to each other in each park, thereby allowing for a more coherent analysis of the thermal conditions across different surface types and vegetation arrangements. This methodological approach aims to provide a robust dataset that reflects the intricate relationships between landscape elements and thermal comfort.

The evaluation of hard grounds with similar materials alongside green spaces featuring comparable plant species is crucial in this study. This arrangement allows for meaningful comparisons regarding the urban heat island effect. Furthermore, the proximity of the parks is significant for conducting measurements during the hottest hours of the day, specifically between 12:00 and 13:00. For these reasons, the neighborhood parks in Görükle have been selected as the research area. This route was completed within 1 h by car on the 10th, 20th, and 30th days of July and August, and measurements were taken with a Triplett EM300 thermometer from 3 different points in 14 parks.

Criteria such as hard ground, soft ground, grass area, planted area, etc., have been kept as equivalent as possible. In measurements made in planted areas, care was taken to take measurements from the points where the plants were most dense. The second stage is the detection of existing plant material in the parks. To identify the plants, plant samples were taken and photographed by visiting parks twice a week, starting from the beginning of the spring vegetation period (March–April).

Content analysis was applied, which is based on defining the data obtained after the field study, bringing together and interpreting the data that were found to be similar and related to each other within the framework of certain concepts and themes. For this purpose, the RayMan model was used to determine the thermal comfort level of the parks according to the values obtained from temperature measurements. The PET index was used through the RayMan model, which is a widely used model that calculates many factors together to determine thermal comfort conditions. The PET (Physiological Equivalent Temperature) index [49–51] calculates human thermal comfort depending on body heat energy balance and meteorological conditions. The index takes into account all the effects of the thermal environment on humans (short- and long-wave solar radiation, air temperature, relative humidity, and wind speed) and the thermo-physiological conditions of the human body (clothing type and activity) as separate values [50,52,53]. In the calculation of the PET index, a 35-year-old, 175 cm tall, 75 kg male, healthy individual with 0.9 clothing load, and 80 W workload was taken into account. Spatial or temporal distributions of the values obtained as a result of PET can be easily made [54,55]. Before the PET index was selected for the study, different thermal indices such as UTCI, SET, PMV, PPD, and WBGT were evaluated. The data obtained were classified according to the study area and period [56–60]. As Zare et al. showed in their 12-month comparative study, all of the indices point to highly correlated results. This index was preferred because it was seen that the highest correlations among the studies for our study date ranges were in the PET index [61].

At this stage, the RayMan pro 2018 program was used in the analysis study. The program was provided by interviewing Matzarakis. With the user manual sent by Matzarakis, the thermal comfort level of Görükle Neighborhood (where neighborhood parks are located) was determined. While this study was being carried out, the climate data for 365 days of the year were processed into the RayMan program together with the data obtained by the General Directorate of Meteorology (GDM). Personal characteristics, clothing, and activity conditions were kept constant while processing in the RayMan program. However, the results were obtained by entering the date, temperature, relative humidity, and wind speed data separately for each day.

As a result of the calculation of the indexes in line with these studies, a single thermal comfort value emerges. This result changes as a result of the changes in the entered elements. A table has been prepared to evaluate this result. However, to evaluate the resulting index value, it is necessary to create a chart in which each data point is classified within itself (Table 1) [62].

Table 1. Thermal comfort levels of the data obtained in the RayMan program.

PMV (°C)	PET (°C)	Human Feeling	Thermal Stress Level
(−3.4)–(−2.5)	4.1–8.0	Cold	Strong cold stress
(−2.4)–(−1.5)	8.1–13.0	Cool	Moderate cold stress
(−1.4)–(−0.5)	13.1–18.0	Slightly cool	Mild cold stress
(−0.4)–0.5	18.1–23.0	Comfortable	No thermal stress
0.6–1.5	23.1–29.0	Mild temperate	Mild heat stress
1.6–2.5	29.1–35.0	Temperate	Moderate heat stress
2.6–3.5	35.1–41.0	Hot	Strong heat stress

Note: PMV: (Predicted Mean Vote), PET: (Physiologically Equivalent Temperature).

Accordingly, at this stage, thermal comfort levels were determined in the neighborhood parks.

In the final stage of the method, the points with intense heat stress were determined according to the thermal comfort levels in the neighborhood parks, and solution suggestions were developed. At this stage, statistical analyses were performed to evaluate thermal comfort between parks and to determine the effect of park plantings on thermal comfort.

Species identification for identifying plant species was carried out according to the studies [63–72] and Bursa Uludağ University Faculty of Science Herbarium (BULU). The identified plant species were examined under three groups: coniferous, deciduous, and shrubs.

2.4. Statistical Analysis

The statistical evaluation of the data was conducted using SPSS version 28 [73]. To compare the thermal comfort levels across different parks, a two-way analysis of variance (ANOVA) was employed. This method allowed for the assessment of interactions between the independent variables while controlling for other factors. Additionally, a one-way analysis of variance was utilized to examine the impact of various planted areas on thermal comfort levels, facilitating a focused analysis of single-factor effects.

The results of the variance analysis were interpreted at a significance level of $p \leq 0.05$, indicating the threshold for statistical significance. To further analyze the differences among the groups, the Duncan test was applied, which enabled the categorization of significantly different groups through the use of letter notation. This approach ensures a comprehensive understanding of the relationships between variables and their influence on thermal comfort within the neighborhood parks [74].

3. Results

As a result of the measurements made in the field, the sizes of the neighborhood parks and the amount of hard and softscape are given in Table 2.

Table 2. Sizes of neighborhood parks and amount of hard and softscape.

No	Neighborhood Park Name	Hardscape (m^2)	Softscape (m^2)	Total Area Size (m^2)
1	Görükle Sport Park	13,661.71	6737.89	20,399.60
2	Zambak Park	1837.24	873.43	2710.67
3	Necmi Yazıcıoğlu Park	358.39	780.20	1138.59
4	Badem Park	838.77	1076.55	1915.32
5	75. Yıl Park	1241.17	1735.19	2976.36
6	Yıldız Park	870.46	2578	3448.46
7	Barış Park	759.50	1208	1967.50
8	Harmanlık Park	582.93	990.26	1573.19
9	Çınar Park	300	774.21	1074.21
10	Koca Park	1397.51	567.56	1965.07
11	Berrin Korkut Park	590	9.25	599.25
12	Taşpınar Park	1352.03	314.45	1666.48
13	Koza Park	719	1427.81	2146.81
14	Esinti Park	1091.40	1902.37	2993.77

According to Table 2, the neighborhood park with the largest area size is Görükle Sport Park. The neighborhood park with the most softscape is also the Görükle Sport Park. The neighborhood park with the least softscape is Berrin Korkut Park. The neighborhood park with the most hardspace is Görükle Sport Park, and the least is Çınar Park. Soft and hardscape status in all parks are given in Figure 8.

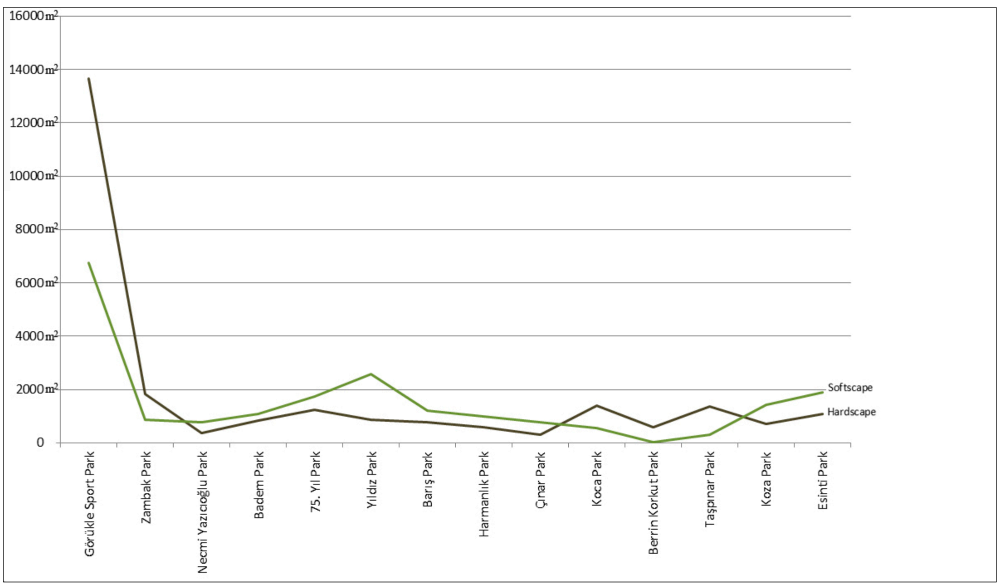

Figure 8. Soft and hardscape status in parks.

Considering the climate data from the research area, no average of a month is perceived as hot or very hot. However, this does not mean that this perception does not exist. On some days, the temperature value exceeded 40 °C, but this situation affected the degree of the average as a high value. Thermal stress levels of the Görükle Neighborhood were determined in the Rayman program with climate data (Table 3).

Table 3. Thermal comfort levels of Gorukle Neighborhood.

Months	PMV (°C)	PET (°C)	The Felt Temperature	Thermal Stress Level
Jan	−7.10	−2.6	Gelid	Extreme cold stress
Feb	−6.22	0.35	Gelid	Extreme cold stress
Mar	−6.81	0.58	Gelid	Extreme cold stress
Apr	−2.80	6.02	Cold	Strong cold stress
May	−0.72	13.8	Cool	Mild cold stress
Jun	0.25	18.20	In comfort	No thermal stress
Jul	2.3	31.17	Milder	Moderate heat stress
Aug	1.13	25.47	Mild	Mild heat stress
Sep	0.31	18.12	In comfort	No thermal stress
Oct	−1.82	12.45	Cool	Moderate cold stress
Nov	-3.30	7.77	Cold	Strong cold stress
Dec	-4.87	1.31	Gelid	Extreme cold stress

When 14 parks in Görükle District were evaluated in terms of thermal comfort, it was determined that the values found were significant at the $p \leq 0.05$ level. When the thermal stress level of the parks is evaluated, it is seen that all parks are in the medium temperature stress group, the highest value was measured in Berrin Korkut Park at 33.16 °C and the lowest values are 30.33 °C and 30.27 °C in Koza Park and Badem Park (Figure 9).

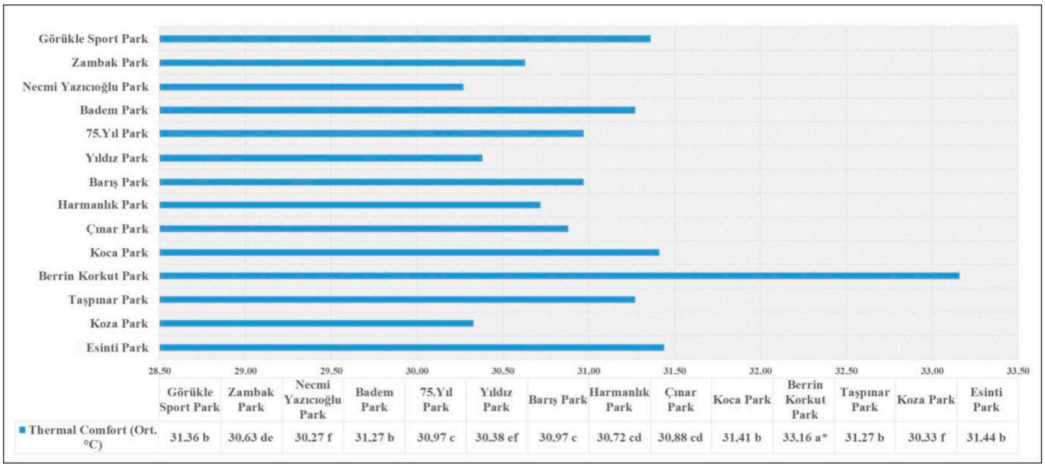

Figure 9. Comparison of thermal comfort in parks (* letters indicate different groups at $p \leq 0.05$ level).

However, it was determined that the measurement days and measurement locations were significant at the $p \leq 0.05$ level, while the months of measurement were not significant. When different measurement days were evaluated, the highest temperature value was measured on the 30th day with 32.89 °C, while the lowest temperature value was obtained on the 10th day with 28.89 °C. In terms of measurement location, the highest temperature value was obtained from measurements made on hard ground at 33.17 °C, while the lowest value was obtained from measurements made in planted green spaces at 29.74 °C (Table 4).

Table 4. Comparison of different days, months, and measurement locations.

Parameters		Temperature (Avg. °C)
Month	July	31.05
	August	31.09
Significance		n.s.
Day	10th	28.89 c
	20th	31.45 b
	30th	32.89 a*
Measurement location	Hard ground surrounded by plants	30.32 b
	Hard ground	33.17 a*
	Planted green spaces	29.74 c
Significance		*

(* Letters indicate different groups at $p \leq 0.05$ level).

The relationship between different measurement locations within the parks was found to be significant at the $p \leq 0.05$ level, and it was determined that the temperature measurements taken from the hard ground were at the highest values in terms of different measurement locations and thermal comfort decreased at these points. The highest value of 33.91 °C was obtained in Zambak Park. The lowest values were detected in planted green spaces and thermal comfort was observed to increase at these points. Accordingly, Yıldız Park, Koza Park, Necmi Yazıcıoğlu Park, and Zambak Park had the lowest values with 28.41 °C, 28.58 °C, 28.66 °C, and 28.75 °C. It was observed that a relatively thermal comfort level was achieved in hard ground areas surrounded by plants. While Koza Park received the lowest temperature of 29.16 °C, Berrin Korkut Park received the highest value of 33.33 °C (Figure 10).

Parks	Hard Ground Surrounded by Plants (Avg°C)		Hard Ground (Avg°C)		Planted Green Spaces (Avg°C)	
Görükle Sport Park	◑	30.66 cd	●	33.66 ab	◔	29.75 defgh
Zambak Park	○	29.25 defgh	●	33.91 a*	○	28.75 efgh
Necmi Yazıcıoğlu Park	◔	29.58 defgh	◕	32.66 ab	○	28.58 gh
Badem Park	◑	30.66 cd	●	32.83 ab	◔	30.33 de
75.Yıl Park	◔	30.16 defg	●	33.08 ab	◔	29.66 defgh
Yıldız Park	◔	29.58 defgh	●	33.16 ab	○	28.41 h
Barış Park	◔	29.75 defgh	●	33.75 ab	○	29.41 defgh
Harmanlık Park	◔	30.41 d	◕	32.25 bc	○	29.50 defgh
Çınar Park	◔	30.16 defg	◕	32.41 ab	◔	30.08 defgh
Koca Park	◔	30.58 d	●	33.41 ab	◔	30.25 def
Berrin Korkut Park	●	33.33 ab	●	33.50 ab	◕	32.66 ab
Taşpınar Park	◑	30.66 cd	●	33.16 ab	◔	30.00 defgh
Koza Park	○	29.16 defgh	●	33.16 ab	○	28.66 fgh
Esinti Park	◔	30.50 d	●	33.50 ab	◔	30.33 de

○ ◔ ◑ ◕ ●

Decreased Thermal Comfort →

Figure 10. Comparison of thermal comfort according to measurement locations (* letters indicate different groups at $p \leq 0.05$ level).

However, the relationship between different measurement days in different months was found to be significant at the $p \leq 0.05$ level, and when the measurements on different days in different months were evaluated, the highest temperature value was 34.30 °C, obtained from the measurement made on the 30th day of July, followed by 31.39 °C and the measurement made on the 20th day of July. The lowest value was determined to be 26.50, measured on the 10th day of July (Table 5).

Table 5. Comparison of measurements made in different months and days according to parks.

		Temperature (Avg. °C)
M × D		
July	10. Day	26.50 e
	20. Day	32.39 b
	30. Day	34.30 a*
August	10. Day	31.28 c
	20. Day	30.52 d
	30. Day	31.47 c
Significance		*

(* Letters indicate different groups at $p \leq 0.05$).

The Effect of the Presence of Planted Green Spaces in Parks on Thermal Comfort

One-way analysis of variance was used to determine the effect of planted green spaces on thermal comfort. The measurements made in planted green spaces in parks were considered and were found to be significant at the $p \leq 0.05$ level. The measurement values in planted green spaces and the plant taxa and numbers found around the measurement point are shown in Table 6. Accordingly, it was observed that the thermal comfort level was highest in Yıldız Park with a temperature value of 28.41 °C, and it was determined that there were especially coniferous taxa in this park and that there were three Pinus pinea and one Thuja occidentalis taxa. The lowest value in terms of thermal comfort was measured in Berrin Korkut Park at 32.66 °C, and there are only two Ailanthus altissima trees in this park. It can be said that it has a relative impact on the thermal comfort level, with values of 28.58–28.66–28.75–29.41 °C in Necmi Yazıcıoğlu, Koza, Zambak, and Barış parks. While the number of different taxa is high in Necmi Yazıcıoğlu and Koza parks, the presence of coniferous taxa in Zambak and Barış parks is noteworthy. In addition, it was determined that shrub taxa were used in Taşpınar, Çınar, and 75. Yıl parks, and this reduced thermal comfort (Figure 11).

Table 6. Measurements and taxa in planted green spaces.

Park	Temperature (Avg. °C)	Total Number of Plants (Pieces)	Taxa
Yıldız Park	28.41 d	5	*Pinus pinea* *Thuja occidentalis* *Robinia pseudoacacia*
Necmi Yazıcıoğlu Park	28.58 bc	5	*Prunus cerasifera* *Magnolia grandiflora* *Acer negundo* *Pistacia lentiscus*
Koza Park	28.66 bc	6	*Quercus cerris* *Robinia pseudoacacia* *Liquidambar orientalis* *Prunus domestica*
Zambak Park	28.75 bc	5	*Robinia pseudoacacia* *Juniperus horizontalis*
Barış Park	29.41 bc	4	*Acer negundo* *Prunus cerasifera* *Cupressus macrocarpa*
Harmanlık Park	29.50 bc	4	*Robinia pseudoacacia* *Prunus cerasifera*
75.Yıl Park	29.66 bc	3	*Ficus carica* *Euonymus japonica*

Table 6. *Cont.*

Park	Temperature (Avg. °C)	Total Number of Plants (Pieces)	Taxa
Görükle Sport Park	29.75 bc	3	*Robinia pseudoacacia* *Carpinus betulus*
Taşpınar Park	30.00 bc	3	*Ailanthus altissima* *Acer platanoides* *Yucca flamentosa*
Çınar Park	30.08 bc	3	*Populus nigra* *Euonymus japonica*
Koca Park	30.25 bc	2	*Robinia pseudoacacia* *Acer negundo*
Esinti Park	30.33 b	3	*Prunus cerasifera* *Liquidambar orientalis*
Badem Park	30.33 b	4	*Prunus cerasus*
Berrin Korkut Park	32.66 a*	2	*Ailanthus altissima*

(* Letters indicate different groups at $p \leq 0.05$).

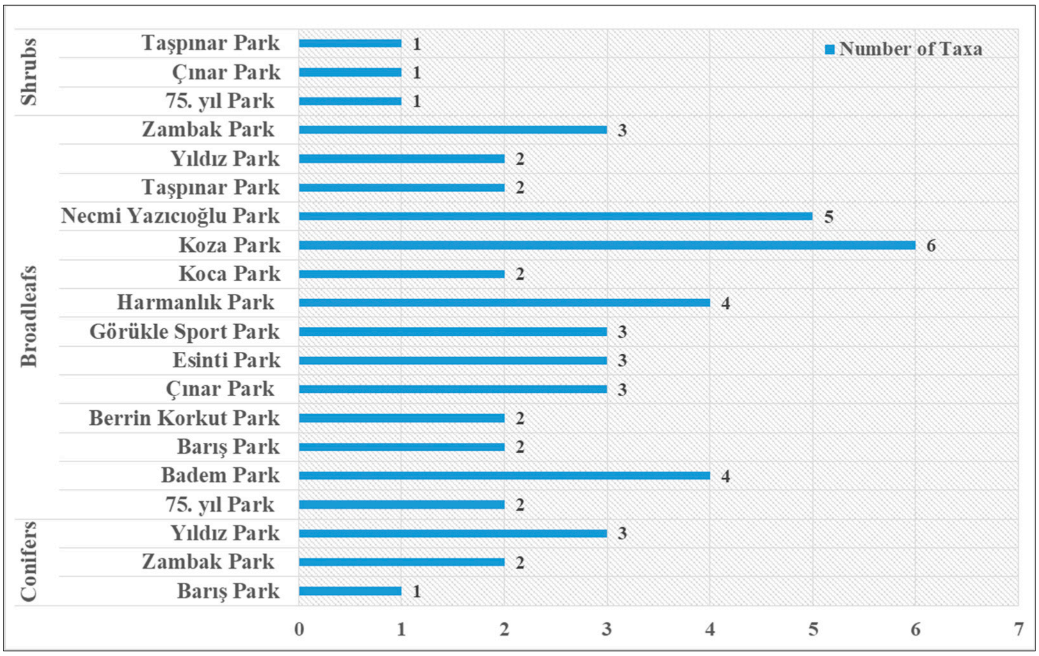

Figure 11. Distribution of taxa used in parks according to taxonomic groups.

4. Discussion

The effects of thermal discomfort are expected to become more pronounced in urban areas as global warming intensifies [34,75–77]. Based on the importance of these effects, in this research, temperature measurements were made in neighborhood parks in order to determine the elements regulating thermal comfort. Thermal comfort in green spaces is gaining significance in the context of climate change. Consequently, the specifics of planting and structural features within these green spaces will be increasingly crucial in the forthcoming period. In line with the measurements obtained, the thermal comfort level was determined with the data entered into the RayMan program, and the results obtained were evaluated statistically. This process is based on a systematic analysis process to increase the reliability of the data obtained.

As a result of the data obtained as a result of document analysis, temperature measurements were made between 12:00 and 13:00 (the hottest hours) on the specified days

(10th, 20th, and 30th days) in July and August 2021. These measurements were determined as a critical period for understanding the climatic impacts relevant to the research.

In the study conducted by Koçman (1991), it was stated that a temperature value between 17 and 24.9 °C is considered the appropriate temperature value in terms of comfort for countries in a mild temperate zone. In the study, results were obtained that confirm this information [78]. In this study, the comfort temperature values in the RayMan program are in the range of 18.1–23.0 °C while obtaining the data results. This provides concrete data supporting the effect of climatic conditions on thermal comfort.

According to Altunkasa (1990), a comfort zone is provided by optimum temperature and humidity conditions (21–27 °C temperature and 30–65% relative humidity). At the same time, it is easier to reach the thermal comfort level when the temperature and relative humidity are supported by the wind speed, especially in summer [79].

Yücekaya (2017), based on the thermal comfort evaluation study handled by Olgyay (1973) in the city of Gaziantep, revealed the seasonal differences in the thermal comfort balance that change throughout the year. In this study, it has been determined that the temperature data obtained from the field, the effects of the plant species used in the landscape design, and the amount of hard ground play essential roles in the thermal comfort balance. In line with this result, the data obtained by Yücekaya (2017) coincides with the data obtained in this study. In this study, it was determined that the temperature value of neighborhood parks with dense green spaces is closer to the comfort level. This result has similar characteristics to this study carried out in Görükle Neighborhood [80,81]. Such similarities underscore the critical role of plantations in moderating temperature and enhancing thermal comfort in urban environments.

In the study by Aksu et al. (2020), there is a linear relationship between green spaces and the decrease in air temperature. In another study, it was determined that the heating and cooling demands decrease with the increase in the number of trees near the structures. This research results support the results of Aksu et al. (2020). It has been determined that plants reduce the temperature during the summer months [82]. In this context, it is of significant importance from a sustainability perspective.

In the study conducted by Tzu-Ping et al. (2012), it was determined that the intensity of using neighborhood parks where shading elements are used is high. As a result of the observations and measurements made in this study, it has been determined that shading elements (trees, pergolas, etc.) increase the use of neighborhood parks, especially in hot times. Since the temperature reduction is achieved with the shading element, the thermal comfort level is approached. This function should also be taken into account in landscape design [83].

In the study by Aksu et al. (2020), the factors affecting people's thermal comfort balance were mentioned. They include environmental factors (air temperature, wind, relative humidity of the air, solar radiation), personal factors (metabolic heat, skin temperature, wetness, enveloping effect of clothing), and additional factors (climate acclimatization, body height/weight ratio, subcutaneous fat, presence of layers, age, and gender). In this study, personal and additional factors were kept constant [82].

The table showing the thermal stress level of PMV and PET indices, which Toy and Yılmaz (2008) included in their study, was also used for this study. These indices were derived following data processing with the RayMan program, thereby providing a robust framework for evaluating thermal comfort [62].

In the study by Gaspari and Fabri (2017), the difference between the average thermal sensation (ATS) index data was revealed by making comparisons in simulation models. In the study, ATS data and thermal comfort levels were hot (+1.50, +2.00), very hot (+3.50, +4.00), and ultrahot (+4.50). In this study, these ATS values were used to determine the thermal comfort level. Based on these values, thermal comfort levels were also determined in this study [84]. Therefore, the incorporation of these various factors and indices highlights the multifaceted nature of assessing thermal comfort.

5. Conclusions

According to the literature review, studies within this scope have primarily concentrated on assessing the thermal comfort conditions of specific spaces in relation to their environmental factors and contextual relationships, thereby making design recommendations that align with sustainability principles. Landscape design works should be progressed by considering the thermal comfort balance. Green space density, plant species, and characteristics of plant species should also be taken into account. All these factors should be evaluated considering user thermal comfort.

This research has established that hardscape areas retain significantly more heat compared to grass-covered regions. Consequently, it was concluded that the proportion of green spaces should exceed that of hardscape to effectively enhance thermal comfort. In neighborhood parks where the softscape-to-hardscape ratio approaches two to one, temperature values were found to be 2.5 to 3 °C lower than the overall ambient temperature. While similar design strategies are present in various neighborhood parks, this study indicates that those with a higher green space ratio experience more pronounced reductions in temperature compared to others. Furthermore, measurements taken at specific points within the neighborhood parks revealed that temperature values in areas dominated by hardscape were consistently higher than the average temperature readings. These findings underscore the necessity for landscape design studies in neighborhood parks to be informed by such data, highlighting the critical importance of integrating ample green spaces to mitigate heat retention and enhance thermal comfort.

In this study, it is seen that there is strong heat stress in the last days of July. To prevent strong heat stress, it is possible to approach the comfort level with landscape design studies. Reducing the strong heat stress will also be effective in terms of increasing the quality of urban life, reducing air pollution, providing balanced energy consumption, and establishing a cost balance by establishing a thermal comfort balance [85].

As a result of the analysis made in the RayMan program, when the climate data from 2021 is examined, no average of a month is perceived as very hot or ultrahot. However, this does not mean that this perception does not exist. Since the average of all days of the month was taken in the study, such a result could not be reached. However, on some days, the temperature value exceeded 40 °C, but this situation affected the degree of the average as a high value. However, it can be asserted that areas within planted green spaces in neighborhood parks offer a higher level of thermal comfort in comparison to hardscape environments.

The study revealed that the temperature difference between the GDM data and measurements taken exclusively from points with grass areas was −1.5 °C. In areas adjacent to grass areas and deciduous trees, the temperature difference ranged from −1 °C to −2.5 °C. For points located near grass areas and coniferous trees, the temperature difference varied between −1.5 °C and −3 °C. In locations adjacent to both evergreen coniferous and deciduous trees, the temperature difference ranged from −1.5 °C to −3 °C. Additionally, measurements obtained near grass areas and shrubs or deciduous trees exhibited temperature differences spanning from −2 °C to −3 °C. Based on these findings, it can be asserted that coniferous trees exert a more substantial influence on thermal comfort compared to deciduous trees. Nevertheless, when considering all plant types within the research area, it was concluded that during the hottest periods, taller plants provide a greater cooling effect than shorter plants. Moreover, the presence of broad-leaved trees contributes to an enhanced level of thermal comfort in comparison to shrubs.

All these meaningful differences were considered important in terms of landscape design. Landscape design, which is the intersection of art and functionality, has to offer solutions that will provide both aesthetics and comfort for users at the same time [86,87]. Furthermore, design solutions should be developed in alignment with the natural characteristics of the area in which they are to be implemented, as this approach promotes sustainability by minimizing environmental impact. The utilization of these plant species, which exhibit a broad range of applicability, in accordance with the data obtained from our research, will expand the options available to designers across various domains, particularly in enhancing thermal comfort.

Climate data plays a crucial role in urban planning and design studies; however, it is essential to maintain a balanced thermal comfort level to mitigate global warming and reduce the effects of urban heat islands. To support these sustainability goals, efforts should focus on monitoring temperature changes and providing a solid foundation for landscape design initiatives, as in this research.

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References

1. Wu, J.; Hou, Z.; Shen, J.; Lian, Z. Quantitative effect on work performance considering interactions among multiple indoor environmental factors. *Build. Environ.* **2020**, *185*, 107286. [CrossRef]
2. Xu, X.; Lan, L.; Shen, J.; Sun, Y.; Lian, Z. Five hypotheses concerned with bedroom environment and sleep quality: A questionnaire survey in Shanghai city, China. *Build. Environ.* **2021**, *205*, 108252. [CrossRef]
3. Du, H.; Lian, Z.; Lai, D.; Duanmu, L.; Zhai, Y.; Cao, B.; Hou, Z. Comparison of thermal comfort between radiant and convective systems using field test data from the Chinese Thermal Comfort Database. *Build. Environ.* **2022**, *209*, 108685. [CrossRef]
4. Liu, C.; Tang, L.; Yan, J.; Ouyang, J. Direct and indirect effects of multisensory modalities on visitor's thermal comfort in an urban park in a humid-hot climate. *Int. J. Sustain. Dev. World Ecol.* **2023**, *30*, 319–328. [CrossRef]
5. Cheng, C.Y.; Lin, T.P. Decision Tree Analysis of Thermal Comfort in the Courtyard of a Senior Residence in Hot and Humid Climate. *Sustain. Cities Soc.* **2024**, *101*, 105165. [CrossRef]
6. Toksoy, M. *Isıl Konfor*; TMMOB Makine Mühendisleri Odası Bildiriler Kitabı: Ankara, Türkiye, 1993.
7. Santamorius, M. *Energy and Climate in the Urban Built Environment*; James & James: London, UK, 2011.
8. Yeang, K. *Ekotasarım: Ekolojik Tasarım Rehberi*; YEM Yayın: İstanbul, Türkiye, 2012.
9. Altunkasa, C. Use of Outdoor Microclimate Maps in Design with Climate: A Case Study of Çukurova University Faculty of Architecture. Master's Thesis, Çukurova University Institute of Natural and Applied Sciences, Department of Landscape Architecture, Adana, Türkiye, 2020.
10. Özcan, U. Günümüz Mimarisinde Kullanılan HVAC Sistemleri, Mimariyle olan ilişkileri ve Hıgh Tech Yapılarda Uygulama Örnekleri. Ph.D. Thesis, Haliç Üniversitesi, İstanbul, Türkiye, 2008.
11. Eres, B. Turizm Yapılarında Hvac Sistemlerin Isıl Konfor ve İç Hava Kalitesi Bakımından Kullanıcı Sağlığı ile İlişkisinin İncelenmesi. Master's Thesis, Fatih Sultan Mehmet Vakıf Üniversitesi, İstanbul, Türkiye, 2019.
12. UN Revision of World Urbanization Prospects. Available online: https://www.un.org/development/desa/en/news/population/2018-revision-of-world-urbanization-prospects.html (accessed on 20 July 2024).
13. IPCC. Assessment Report 6-WGI Report. IPCC. 2021. Available online: https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_FullReport.pdf (accessed on 28 October 2024).
14. 2021 Joins Top 7 Warmest Years on Record: WMO. Available online: https://news.un.org/en/story/2022/01/1110022 (accessed on 21 January 2022).
15. Demircan, M.; Gürkan, H.; Eskioğlu, O.; Arabaci, H.; Coşkun, M. Climate Change Projections for Turkey: Three Models and Two Scenarios. *Turk. J. Water Sci. Manag.* **2017**, *1*, 22–43. [CrossRef]
16. Bağçaci, S.Ç.; Yücel, İ.; Düzenli, E.; Yılmaz, M.T. Intercomparison of the expected change in the temperature and the precipitation retrieved from CMIP6 and CMIP5 climate projections: A Mediterranean hot spot case, Turkey. *Atmos. Res.* **2021**, *256*, 105576. [CrossRef]
17. Climate Change Knowledge Portal. Available online: https://climateknowledgeportal.worldbank.org/country/test-country/trends-variability-projections (accessed on 20 July 2024).

18. Cohen, M. Habitat II and the Challenge of the Urban Environment: Bringing together the two Definitions of Habitat. *Int. Soc. Sci. J.* **1996**, *48*, 95–101. [CrossRef]
19. Gangloff, D. The Sustainable City. *Am. For.* **1996**, *101*, 30–36.
20. Willis, K.G.; Turner, R.K.; Bateman, I.J. *Urban Planning and Management*; Edward Elgar Publishing: New York, NY, USA, 2001.
21. Tosun, E.K. Sürdürülebilirlik Olgusu Ve Kentsel Yapiya Etkileri. *Parad. Ekon. Sosyol. Ve Polit. Derg.* **2009**, 14.
22. Tozam, İ.; Bulut Karaca, Ü. Kentsel Isı Adası Etkisi ve Serin Çatılar, 9. Ulusal Çatı & Cephe Konferansı, (pp.35-46). İstanbul, Turkey. 2018. Available online: https://www.b2bmedya.com/ekitap/pdf/9uncu-ulusal-cati-ve-cephe-konferansi-bildiriler-kitabi-2018.pdf (accessed on 20 July 2024).
23. Chen, L.; Mak, C.M.; Hang, J.; Dai, Y. Influence of elevated walkways on outdoor thermal comfort in hot-humid climates based on on-site measurement and CFD modeling. *Sustain. Cities Soc.* **2024**, *100*, 105048. [CrossRef]
24. Climate Central. Available online: https://www.climatecentral.org/climate-matters/urban-heat-islands-2023 (accessed on 20 July 2024).
25. Allegrini, J.; Dorer, V.; Carmeliet, J. Influence of the urban microclimate in street canyons on the energy demand for space cooling and heating of buildings. *Energy Build.* **2012**, *55*, 823–832. [CrossRef]
26. Boeri, A.; Gaspari, J. A multi-layer approach to urban re generation: Energy efficiency and comfort condition optimization. *TECHNE-J. Technol. Archit. Environ.* **2015**, *10*, 214–221. [CrossRef]
27. Algeciras, J.A.R.; Coch, H.; Pérez, G.; Yeras, M.C.; Matzarakis, A. Human thermal comfort conditions and urban planning in hot-humid climates—The case of Cuba. *Int. J. Biometeorol.* **2016**, *60*, 1151–1164. [CrossRef]
28. Demir, A.Ö.; Cengiz, C. Ilıman-Nemli İklim Bölgelerinde Kentsel Alanlarda Biyoklimatik. *Avrupa Bilim Ve Teknol. Derg.* **2021**, *32*, 1134–1139. [CrossRef]
29. Balogun, I.A.; Daramola, M.T. The outdoor thermal comfort assessment of different urban configurations within Akure City, Nigeria. *Urban. Clim.* **2019**, *29*, 100489. [CrossRef]
30. Chen, L.; Ng, E. Outdoor thermal comfort and outdoor activities: A review of research in the past decade. *Cities* **2012**, *29*, 118–125. [CrossRef]
31. Amani Beni, M.; Khalilnezhad, M.R.; Shen, Z.W. Iranian citizens' behaviors and attitudes on visitations and appreciation of the urban green space during the COVID-19 epidemic. *Acta Hortic.* **2023**, *1374*, 85–92. [CrossRef]
32. Khalilnezhad, M.R.; Amani Beni, M.; Shen, Z.W. Accessibility, visibility and connectivity between urbanites and edible landscape in the Persian gardens. *Acta Hortic.* **2023**, *1374*, 109–116. [CrossRef]
33. Dehghanifarsani, L.; Khalilnezhad, M.R.; Amani Beni, M. Book Review: Prominski et al. *River. Space. Design. Planning Strategies, Methods and Projects for Urban Rivers*, 3rd and Enlarged ed.; Birkhäuser: Basel, Switzerland. *Land* **2023**, *12*, 1483. [CrossRef]
34. Dong, J.; Guo, R.; Lin, M.; Guo, F.; Zheng, X. Multi-objective optimization of green roof spatial layout in high-density urban areas—A case study of Xiamen Island, China. *Sustain. Cities Soc.* **2024**, *115*, 105–827. [CrossRef]
35. Guo, R.; Guo, F.; Dong, J.; Wang, Z.; Zheng, R.; Zhang, H. Finer-scale urban health risk assessment based on the interaction perspective of thermal radiation, human, activity, and space. *Front. Archit. Res.* **2024**, *13*, 682–697. [CrossRef]
36. The Sixth Assessment Report (AR6) of the United Nations (UN) Intergovernmental Panel on Climate Change (IPCC). (IPCC 6. Assesment/Cross-Chapter Paper 4: Mediterranean Region). Available online: https://www.ipcc.ch/report/ar6/wg2/downloads/report/IPCC_AR6_WGII_SOD_CCP4.pdf (accessed on 19 March 2024).
37. Google earth 9.3.105.0. Görükle, Turkey. 40°13′41″N, 28°50′38″E, DigitalGlobe 2024. Available online: https://earth.google.com/web/ (accessed on 28 October 2024).
38. Korukçu, A.; Yazgan, S.; Gündoğdu, K. *Bursa ve yöresinde Su Kaynaklarına İlişkin Sorunlar*; Marmara Bölgesinde Tarımın Verimlilik Sorunları Sempozyumu: Bursa, Türkiye, 1989.
39. Sefa, S. *Bilecik, Bursa, Kütahya Yöresi Kuru ve Sulanabilir Şartlarda Kuru Soğanın Azotlu ve Fosforlu Gübre İsteği ile Olsen Fosfor Analiz Metodu'nun Kalibrasyonu*; Eskişehir Bölge Topraksu Araştırma Enstitüsü Müdürlüğü Yayınları: Eskişehir, Türkiye, 1983.
40. UI GreenMetric World University Rankings: Background of The Ranking. Available online: https://greenmetric.ui.ac.id/about/welcome (accessed on 20 July 2024).
41. Meteoblue Weather. Available online: https://www.meteoblue.com/tr/hava/historyclimate/climatemodelled/g%C3%B6r%C3%BCkle_t%C3%BCrkiye_746552 (accessed on 20 July 2024).
42. Baltacı, A. The qualitative research process: How to conduct a qualitative research? *Ahi Evran Univ. J. Soc. Sci. Inst. (AEÜSBED)* **2019**, *5*, 368–388.
43. Sayad, B.; Alkama, D.; Ahmad, H.; Baili, J.; Aljahdaly, N.H.; Menni, Y. Nature-based solutions to improve the summer thermal comfort outdoors. *Case Stud. Therm. Eng.* **2021**, *28*, 101399. [CrossRef]
44. Gioia, A.; Paolini, L.; Malizia, A.; Oltra-Carrió, R.; Sobrino, J.A. Size matters: Vegetation patch size and surface temperature relationship in foothills cities of northwestern Argentina. *Urban. Ecosyst.* **2014**, *17*, 1161–1174. [CrossRef]
45. Correa, E.; Ruiz, M.A.; Canton, A.; Lesino, G. Thermal comfort in forested urban canyons of low building density. An assessment for the city of Mendoza, Argentina. *Build. Environ.* **2012**, *58*, 219–230. [CrossRef]
46. Hami, A.; Abdi, B.; Zarehaghi, D.; Maulan, S. bin. Assessing the thermal comfort effects of green spaces: A systematic review of methods, parameters, and plants' attributes. *Sustain. Cities Soc.* **2019**, *49*, 101634. [CrossRef]
47. Matzarakis, A.; Amelung, B. Physiological equivalent temperature as indicator for impacts of climate change on thermal comfort of humans. In *Seasonal Forecasts, Climatic Change and Human Health*; Springer: Dordrecht, The Netherlands, 2008; pp. 161–172.

48. Hedquist, B.C.; Brazel, A.J.; Sabatino, S.D.; Carter, W.; Fernando, H.J.S. Phoenix Urban Heat Island Experiment: Micrometeorological Aspects. In Proceedings of the Eighth Conference on the Urban Environment, AMS 89th Annual Meeting, Phoenix, AZ, USA, 12 January 2009.
49. Höppe, P. Heat balance modelling. *Experientia* **1993**, *49*, 741–746. [CrossRef]
50. Höppe, P. The physiological equivalent temperature -a universal index for the biometeorological assessment of the thermal environment. *Int. J. Biomet* **1999**, *43*, 71–75. [CrossRef]
51. Matzarakis, A.; Mayer, H.; Iziomon, M.G. Applications of a universal thermal index: Physiological equivalent temperature. *Int. J. Biometeorol.* **1999**, *43*, 76–84. [CrossRef]
52. Matzarakis, A.; Rutz, F.; Meyer, H. Estimation and calculation of the mean radiant temperature within urban structures. In *Biometeorology and Urban Climatology at the Turn of the Millenium (ed. by R.J. de Dear, J.D.; Kalma, T.R. Oke, and A. Auliciems) Selected Papers from the Conference, Sydney*; University of Freiburg: Freiburg, Germany, 2000.
53. Gulyas, A.; Unger, J.; Matzarakis, A. Evaluation of microclimatic and human comfort conditions in a complex urban environment: Modeling and measurements. *Build. Environ.* **2006**, *41*, 1713–1722. [CrossRef]
54. Fanger, P.O. *Thermal Comfort: Analysis and Applications in Environmental Thermal Comfort: Analysis and Applications in Environmental Engineering*; Danish Technical Press: Copenhagen, Denmark, 1970.
55. Matzarakis, A.; Mayer, H. Heat stress in Greece. *Int. J. Biometeorol.* **1997**, *41*, 34–39. [CrossRef] [PubMed]
56. Blazejczyk, K.; Epstein, Y.; Jendritzky, G.; Staiger, H.; Tinz, B. Comparison of UTCI to selected thermal indices. *Int. J. Biometeorol.* **2012**, *56*, 515–535. [CrossRef] [PubMed]
57. Lai, D.; Guo, D.; Hou, Y.; Lin, C.; Chen, Q. Studies of outdoor thermal comfort in northern China. *Build. Environ.* **2014**, *77*, 110–118. [CrossRef]
58. Alfano, F.R.D.A.; Palella, B.I.; Riccio, G. Notes on the calculation of the PMV index by means of apps. *Energy Procedia* **2016**, *101*, 249–256. [CrossRef]
59. Budd, G.M. Wet-bulb globe temperature (WBGT)—Its history and its limitations. *J. Sci. Med. Sport.* **2008**, *11*, 20–32. [CrossRef]
60. Hyatt, O.M.; Lemke, B.; Kjellstrom, T. Regional maps of occupational heat exposure: Past, present, and potential future. *Glob. Health Action.* **2010**, *3*, 5715. [CrossRef]
61. Zare, S.; Hasheminejad, N.; Shirvan, H.; Hemmatjo, R.; Sarebanzadeh, K.; Ahmadi, S. Comparing Universal Thermal Climate Index (UTCI) with selected thermal indices/environmental parameters during 12 months of the year. *Weather Clim. Extrem.* **2018**, *19*, 49–57. [CrossRef]
62. Toy, S.; Yılmaz, S. Peyzaj Tasarımında Biyoklimatik Konfor ve Yaşam Mekanları İçin Önemi. *Ank. Üniversitesi Ziraat Fakültesi Derg.* **2009**, *40*, 133–139.
63. Davis, P.H. *Flora of Turkey and the East Aegean Islands*; Edinburgh University Press: Edinburgh, Scotland, 1970; Volume 3, p. 645.
64. Kayacık, H. *Orman ve Park Ağaçlarının özel Sistematiği, I. Cilt, Gymnospermae (Açık Tohumlar)*; İstanbul Üniversitesi Orman Fakültesi Yayınları: İstanbul, Türkiye, 1980.
65. Kayacık, H. *Orman ve Park Ağaçlarının özel Sistematiği, II. Cilt, Angiospermae (Kapalı Tohumlar)*; İstanbul Üniversitesi Orman Fakültesi Yayınları: İstanbul, Türkiye, 1981.
66. Kayacık, H. *Orman Park ve Ağaçlarının özel Sistematiği, III. Cilt, Angiospermae (Kapalı Tohumlular)*; İstanbul Üniversitesi Orman Fakültesi Yayınları: İstanbul, Türkiye, 1982.
67. Yaltırık, F. *Bazı Yapraklı Ağaç ve çalıların Kışın Tanınması (Uygulama Kılavuzu)*; Ormancılık Eğitim ve Kültür Vakfı: İstanbul, Türkiye, 1991.
68. Dirr, M.A. *Manual of Woody Landscape Plants: Their Identification, Ornamental Characteristics, Culture Propagation and Uses*; Varsity Press: London, UK, 1992.
69. Pamay, B. *Bitki Materyali I: Ağaçlar ve A0ğaççıklar*; Uycan Matbaası: İstanbul, Türkiye, 1992.
70. Yaltırık, F. *Dendrology Textbook II Angiospermae (Angiosperms)*; İstanbul University Publication: İstanbul, Türkiye, 1988.
71. Zencirkıran, M. Determination of native woody landscape plants in Bursa and Uludag. *Afr. J. Biotechnol.* **2009**, *8*, 5737–5746.
72. Ender Altay, E.; Zencirkiran, M. Contributions of native plants to the urban ecosystem: Bursa (Turkey) sample. *TeMA-J. Land. Use Mobil. Environ.* **2024**, 191–204.
73. IBM Corp. *IBM SPSS Statistics for Windows, Version 28.0*; IBM Corp.: Armonk, NY, USA, 2017.
74. Duncan, D.B. Multiple range and multiple F tests. *Biometrics* **1955**, *11*, 1–42. [CrossRef]
75. Lian, Z.; Liu, B.; Brown, R.D. Exploring the suitable assessment method and best performance of human energy budget models for outdoor thermal comfort in hot and humid climate area. *Sustain. Cities Soc.* **2020**, *63*, 102–423. [CrossRef]
76. Liang, C.; Zhang, R.C.; Zeng, J. Optimizing ecological and economic benefits in areas with complex land-use evolution based on spatial subdivisions. *Landsc. Urban. Plan.* **2023**, *236*, 104–782. [CrossRef]
77. Farina, G.; Le Cöent, P.; Neverre, N. Multi-objective optimization of rainwater infiltration infrastructures along an urban–rural gradient. *Landsc. Urban. Plan.* **2024**, *242*, 104–949. [CrossRef]
78. Koçman, A. İzmir'in kentsel gelişimini etkileyen doğal çevre faktörleri ve bunlara ilişkin sorunlar. *Coğrafya Araştırmaları Derg.* **1991**, *3*, 101.
79. Altunkasa, M.F. Adana'da İklimle Dengeli Kentsel Yeşil Alan Planlama İlkelerinin Belirlenmesi ve Çok Amaçlı Bir Yeşil Alan Örneğinde Geliştirilmesi. *Çukurova Üniversitesi Ziraat Fakültesi Derg.* **1990**, *5*, 39–54.

80. Yücekaya, M. Kentsel Açık Mekanların İklimle Dengeli Tasarımına Yönelik Analitik Bir Model Önerisi: Gaziantep Örneği. Ph.D. Thesis, Çukurova Üniversitesi, Adana, Türkiye, 2017.
81. Olgyay, V. *Design with Climate, Bioclimatic Approach to Architectural Regionalism*; Princeton University Press: Princeton, NJ, USA, 1973.
82. Aksu, A.; Yılmaz, S.; Mutlu, B.E.; Yılmaz, H. Ağaçların Bina ile Olan Mesafesinin Dış Mekan Termal Konfor Üzerine Etkisi: Erzurum Kenti Örneği. *Iğdır Üniversitesi Fen. Bilim. Enstitüsü Derg.* **2020**, *10*, 1298–1307. [CrossRef]
83. Elkamhawy, A.; El Eashy, A.; Elfiky, U. Comparative analysis of ten Neighborhood Sustainability Assessment (NSA) tools offering integrated criteria for urban development. *Int. J. Sustain. Dev. World Ecol.* **2024**, *31*, 71–88. [CrossRef]
84. Tzu-Ping, L.; Ting, T.K.; Chieng-Hung, T.; Lung, H.R.; Matzarakis, A. Quantification of the effect of thermal indices and sky view factor on park attendance. *Landsc. Urban. Plan.* **2012**, *107*, 137–146. [CrossRef]
85. Gaspari, J.; Fabri, K. A study on the use of outdoor microclimate map to address design solutions for urban regeneration. *Energy Procedia* **2017**, *111*, 500–509. [CrossRef]
86. Ender, E.; Batman, Z.P.; Şengül, S.; Yıldız, M.C. Kent Meydanları ve Tasarım Süreci: Şanlıurfa Kızılay Meydanı Örneği. *Mimar. Ve Yaşam* **2022**, *7*, 853–870. [CrossRef]
87. Ender Altay, E.; Pirselimoğlu Batman, Z.; Acaray, S. Urban Squares within the Framework of Urban Design: Kadıköy Square, Turkey. *Landsc. Archit. Art.* **2023**, *22*, 22. [CrossRef]