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ORIGINAL PAPER

Effect of the surface temperature of surface materials on thermal comfort: a case study of Iskenderun (Hatay, Turkey)

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Abstract

As a result of urbanization that started with the industrial revolution, high temperatures caused by surface materials in built areas cause the formation of urban heat islands. This situation adversely affects the livability of cities due to the thermal comfort or lack thereof. The surface temperatures of these widely used materials in a park located in the urban area of Iskenderun (Hatay, Turkey) were assessed in this study. The study was conducted in 3 stages in July 2019, one of the hottest months of the year in Iskenderun Community Park (the largest park on the borders of Iskenderun). The city itself is a coastal city with a Mediterranean climate. In the first stage, studies related to the subject were reviewed, and the points to be measured in the area were determined. It was taken into account that the measured points represented different surfaces in the park. In the second stage, the surface temperatures were measured 5 times in total during July using an infrared thermometer (TFA-ScanTemp330) from 12:00–13:00 with 3 repetitions from a height of 150 cm above the surface level. In the third stage, the data obtained was evaluated. The results of this study highlight the importance of the selection of surface materials in the development of healthy and livable cities. In regions where the Mediterranean climate prevails, the importance of increasing the presence of water bodies, grass areas, and plants (trees, bushes, and groundcover) due to their vital roles in reducing urban heat islands and increasing thermal comfort cannot be stressed enough.

Keywords Iskenderun-Hatay · Surface materials · Surface temperature · Thermal comfort

1 Introduction

As a result of urbanization, which started with the industrial revolution, heat islands began forming due to the environmental deterioration in the built areas. Urban heat islands affect the quality of life and the livability of cities (Aguiar et al. 2014; Adiguzel et al. 2020; Cetin 2019; Cetin 2020; Zeren Cetin and Sevik 2020; Zeren Cetin et al. 2020). There is a relationship

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between the morphology of residential areas, the textural characteristics of urban areas, and the size of the urban heat island effect (Oke 1981; Zhou et al. 2014; Irmak et al. 2017). Fragmented structures (scattered settlements) and open areas for development within a city play roles in the formation of urban heat islands. The ratio of open green areas and floor surface coverings is important (Zhou et al. 2014; Irmak et al. 2017). The built environment in urban areas generates or absorbs more heat. In areas with a high building density, the temperature is higher than that in open green areas, forest areas, and rural areas (Toy et al. 2007; Schwarz et al. 2012; Topay 2012; Feyisa et al. 2014; Dursun and Yavas 2016; Lehoczky et al. 2017; Cetin et al. 2019; Cetin 2019; Cetin 2020; Zeren Cetin and Sevik 2020; Zeren Cetin et al. 2020). High temperatures caused by floor coverings cause unhealthy thermal comfort areas in the urban parts of a city. The situation not only negatively affects people in terms of health but also impacts their happiness, economy, and recreation. However, the thermal stress generated outdoors cannot be controlled (Patz et al. 2005; Feyisa et al. 2014; Alkan et al. 2017). To provide thermal comfort, climate components must be within the appropriate value range for humans. In this context, thermal comfort is considered an important component of the usability of the urban landscape (Matzarakis and Endler 2010; Topay 2012; Cetin 2015; Cetin 2016; Cetin 2019; Cetin 2020; Zeren Cetin and Sevik 2020; Zeren Cetin et al. 2020). Individuals perform outdoor activities when the level of thermal comfort is the most appropriate. For this reason, the outdoor thermal environment is considered a factor directing the use of outdoor space (Lin et al. 2010).

The land surface temperature variation is affected by energy currents along the surface element. Except for the solar radiation current, all currents that change the energy of the surface element affect the temperature directly or indirectly. Heat is increasing both in the atmosphere and in the soil. Heat exchange makes it difficult to define the surface temperature for a canopy by overheating during the day and cooling at night (Grassl 1989).

One of the environmental problems that started with the settled life of human beings and increased as a result of technological developments is climate change. The heat emitted into the atmosphere is the result of intense solar radiation (Grassl 2011).

Observations of surface temperatures are made in both terrestrial and aquatic environments. While different methods can be used to determine the surface temperature formed by water surfaces, infrared sensors are also used. In these measurements, it was seen that wind and surface heat flow can change the mass-surface temperature difference between − 1.0 and 1.0 K (Schluessel et al. 1990).

Urban open and green areas minimize the anthropogenic impact in climate regulation. By reducing the heat island effect, they contribute to the creation of healthier and more comfortable living spaces. Planting trees in cities increases the thermal comfort by reducing the negative effect of the air temperature (Avissar 1996; Gómez et al. 2008; Topay 2012; Bozdogan and Sogut 2015; Estoque et al. 2017; Atwa et al. 2020). In increasing environmental comfort, the amount and quality of the green area and its distribution in the urban fabric are important (Gómez et al. 2008). The morphological features of the plants in an urban area directly affect the structure of an urban heat island. In particular, the use of grass and trees together increases the thermal comfort (Shashua-Bar et al. 2011). The increase in the plant density in urban green areas decreases the air temperature. It has been determined that plant-intensive city parks can be 4.8–6.9 °C cooler than their surrounding environment in the summer (Yan et al. 2018; Oliveira et al. 2011).

Surface coatings can play a part in the formation of heat islands by potentially increasing temperatures and thus affecting the comfort of life (Ikechukwu 2015; Estoque et al. 2017; Yan et al. 2018). Thermal comfort changes as the surface coating material changes (asphalt, concrete, tile, grass, etc.). Leuzingera et al. (2010) measured surface temperatures in their study. Their findings for the temperature values were 18 °C for water surfaces, 26 °C for vegetation, 37 °C for roads, and 45 °C for roofs in their study in the city of Basel. The surface temperatures and storage differ for different surfaces. The amount of heat generated on turf surfaces during the day is lower than that generated on asphalt. Asphalt causes a higher temperature increase than other surface coatings (concrete, lock parquet, and grass) (Yılmaz et al. 2008; Takebayashi and Moriyama 2009; Lin et al. 2010; Connors et al. 2013; Aguiar et al. 2014). Grass and travertine are the most suitable surface materials to reduce the urban heat island effect and increase the level of living comfort of people. Materials that reduce living comfort include impregnated wood, asphalt, and basalt, which absorb considerable heat (Irmak et al. 2017). The temperature difference between concrete and grass areas can reach approximately 4 °C due to the reflective properties of grass. Additionally, dark coating materials store more heat than lighter colored materials (Yılmaz et al. 2007). Berg and Quinn (1978) stated that white-painted roads have almost the same temperature as the environment, and Santamouris et al. (2001) reported that asphalt reached a temperature of approximately 63 °C (Yılmaz et al. 2008). Asphalt increases the heat much more than concrete and soil (Ikechukwu 2015; Chen et al. 2017). Hard floors and dark-colored surfaces cause thermal stress, especially in summer, due to their high heat loads (Gómez et al. 2013).

The aim of the study is to determine the effects of different floor coverings on thermal comfort in the summer. In this context, the effects of floor coverings, which are used extensively in parks in urban areas, on the surface temperature are shown using the example of the city of Iskenderun (Hatay). The data to be obtained from the study will set an example for other urban design/planning studies in which the Mediterranean climate prevails. It is forecasted that the results will form a base for similar future studies.

2 Materials and methods

2.1 Materials

The study was conducted in July 2019 in Iskenderun Community Park, which is the largest park located within the borders of Iskenderun (Hatay) district (Fig. 1). Covering an area of approximately 55,000 m^2, the park is located between 36° 35′ 17.862″ N–36° 35′ 11.6592″ E and 36° 9′ 48.8952″ N–36° 9′ 45.59044″ E. Iskenderun is a coastal city with a Mediterranean climate; summers are dry and hot, and winters are warm and rainy. The climate data of July, the month in which the study was conducted, include monthly, daily, and hourly data measured at İskenderun meteorology station. The daily and hourly data of the study period are given in Table 1. According to the data of the TSMS (Turkish State Meteorological Service) (2019), there were no stormy days in the city of İskenderun throughout July. The dominant wind direction in July was west, and it blew at an average speed of 2 m/s. On strong wind day 2, the highest wind speed was 11.3 m/s, and the direction was west-southwest. The highest monthly relative humidity was 97%, the lowest relative humidity was 16%, the average highest relative humidity was 78.9%, and the mean lowest relative humidity was 53.4%. The average temperature in this month was 28.5 °C, the highest temperature was 33.1 °C, and the lowest temperature was 21.5 °C. The average highest temperature was 31.4 °C, and the mean low temperature was 25.8 °C.

2.2 Methods

The study was conducted in 3 stages. In the first stage, studies related to the subject were reviewed. The second stage of the study is the stage in which the points to be measured in the area were determined and the surface temperatures were measured. In this stage, all the different floor coverings used in the park area within the scope of the study were evaluated, and the measurements were repeated. Thus, the surface temperature was measured made at 50 points in the study area. The measurement points consist of hard floors, a sitting unit (bench), a bridge, water surfaces, plant surfaces (shrub, groundcover, and grass), and under plant grass surfaces (group use and solitary use). Information about the measurement points and surface coatings is given in Table 2.

It is assumed that the data obtained using the infrared thermometer to measure the surface temperature of a plant crown or leaf are correct (Hackl et al. 2012; Yu et al. 2015). The measurements of plant surface temperatures in this study were based on the crown diameter (canopy). The temperature obtained from the crown of the plant consisting of branches, shoots, and leaves was accepted as the surface temperature. The plant species whose surface temperature was measured within the scope of the study are ground cover or bushes, and their coverage of soil surfaces is very high. For this reason, the surface temperature measurement was made at a right angle from the middle of the crown.

Information on the accuracy of the infrared thermometer used and its calibration is as follows. The temperature was calibrated with a PCE-IC 1 temperature calibrator, and we calibrated the Bosch PTD 1 laser thermometer using this device. In addition, on-site calibration was performed using this temperature calibrator. Table 3 shows the data.

Surface temperature measurements were conducted 5 times in total during July using an infrared thermometer (TFA-ScanTemp330) between the hours of 12:00 and 13:00 with 3 repetitions from a height of 150 cm from the surface. The third stage of the study is the stage in which the data obtained are evaluated. In this stage, the surface temperatures due to the ground materials were transferred to a geographic information system (GIS) using ArcGIS 10.5 software and then modeled using the Kriging interpolation method. The ground temperature map was created in July, and suggestions for increasing the thermal comfort in the urban area were presented.

There is no effect that distorts the temperature in these measurements (Fernicola et al. 2006). Due to some technical deficiencies of the infrared thermometer device we used in this study (such as the lack of calibration features), no correction was made for different surface emissions, and the radiation values emitted directly from the objects due to the temperatures of the objects were measured. However, knowing the emission coefficient values of different surfaces, which range from 0 to 1, gives an idea about the surface temperatures. For example, when the emission coefficient value of black bodies is 1, the emission values of other bodies under different temperature conditions are different from each other. In cases where the temperature value is 300 Kelvin (approximately 27 °C), the emission coefficients of asphalt surfaces are 0.85–0.93, those of wooden surfaces are 0.82–0.92, and those of water surfaces are 0.96. Again, this coefficient value varies on other surfaces (Incropera et al. 2007).

The surface skin temperatures need to be corrected due to emissivities lower than 1.0. This leads to corrections of several °C. Although the thermal measurement device conducts all temperature measurements considering an emissivity value of 1 for all ground materials, each temperature value has been corrected based on the specific emissivity coefficient of the material. Since raw thermal measurement data have already been updated before visualization and interpolation for more accurate results, all temperature values reported in the manuscript do not need to be updated.

3 Results

Within the scope of the study, the results of the surface temperature measurements made in July 2019 are given in Table 4. The surface temperatures of some materials in the area are shown in

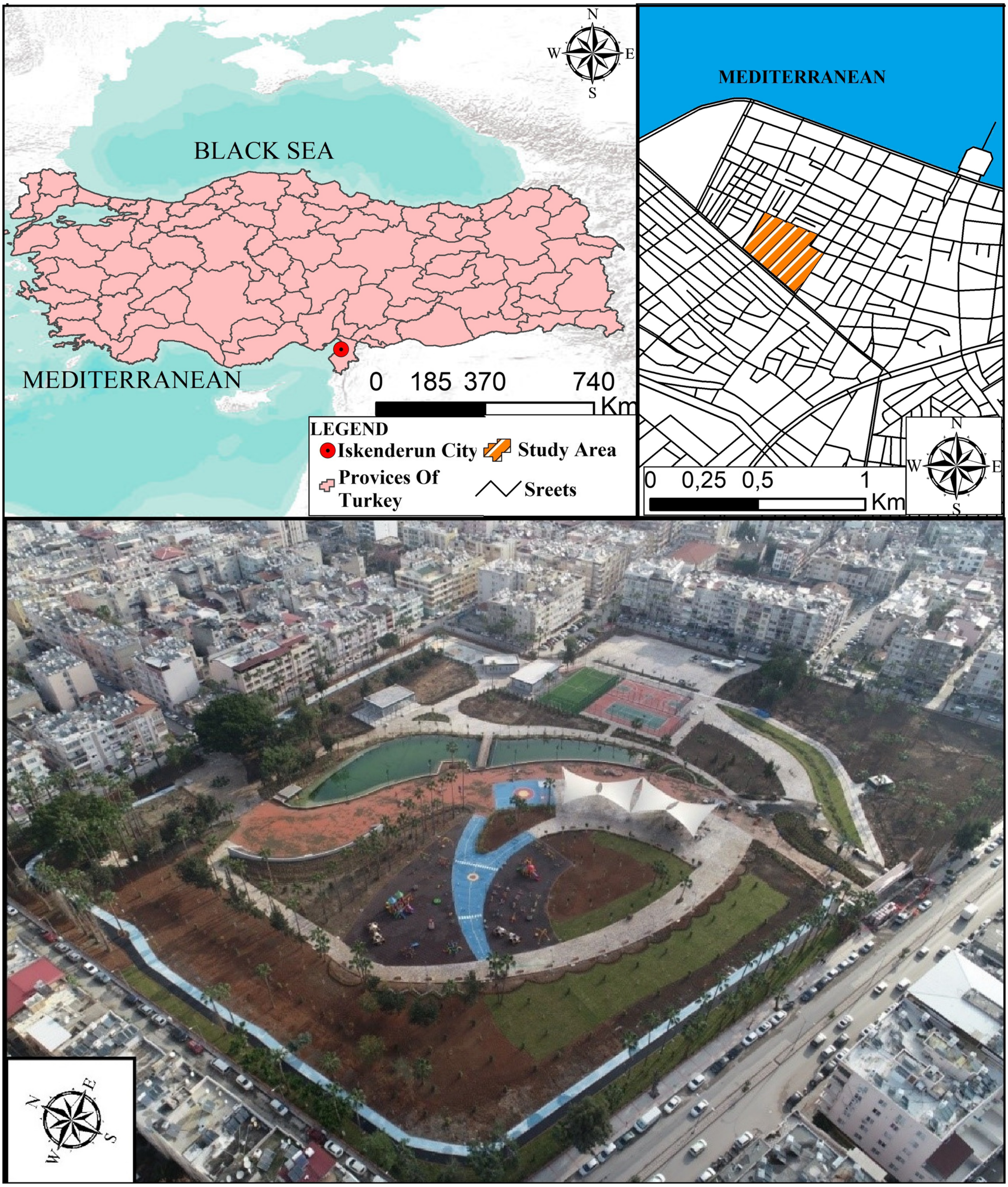

Fig. 1 The location of research area

Fig. 2. The monthly temperature map based on the obtained results is given in Fig. 3. In the study area, the measurement results of a total of 31 different surfaces, including hard floors, a sitting unit, a bridge, water surfaces, plant surfaces, and under tree grass surfaces, were evaluated. These surfaces are grouped as follows: hard floors (asphalt, blue-painted concrete, burgundy-painted concrete, green-painted concrete, cast rubber, rubber, sand parquet, sand parquet (shade), marble, ceramic, and

Table 1 Daily and hourly values of the climate parameters measured at the İskenderun Meteorology Measurement Station (TSMS, 2019)

	3 July 2019	10 July 2019	17 July 2019	24 July 2019	31 July 2019
Daily high temperature (°C)	30.4	31.0	31.3	32.3	32.1
Hourly peak temperature (°C)—hour: 12:00	30.0	30.8	31.2	32.3	31.9
Hourly peak temperature (°C)—hour: 13:00	29.6	30.8	31.3	31.2	31.2
Daily low temperature (°C)	24.3	26.8	25.2	26.1	26.5
Hourly low temperature (°C)—hour: 12:00	29.3	30.3	30.3	31.0	30.9
Hourly low temperature (°C)—hour: 13:00	29.1	30.0	30.7	30.6	30.7
Daily average temperature (°C)	27.8	28.8	28.4	29.1	29.1
Hourly temperature (°C)—hour: 12:00	29.8	30.8	30.6	32.1	31.7
Hourly temperature (°C)—hour: 13:00	29.3	30.6	31.2	31.0	31.1
Daily highest relative humidity (%)	68	81	73	79	79
Hourly highest relative humidity (%)—hour: 12:00	67	68	56	62	69
Hourly highest relative humidity (%)—hour: 13:00	68	71	55	69	69
Daily lowest relative humidity (%)	50	65	47	55	59
Hourly lowest relative humidity (%)—hour: 12:00	61	65	51	56	64
Hourly lowest relative humidity (%)—hour: 13:00	63	65	51	60	66
Daily average relative humidity (%)	60.3	72	61.5	67	71.5
Relative humidity per hour (%)—hour: 12:00	62	67	55	62	65
Relative humidity per hour (%)—hour: 13:00	66	68	51	61	67
Daily highest wind speed (m/s)	7.2	6.7	5.1	8.2	5.7
Hourly highest wind speed (m/s)—hour: 12:00	6.8	5.7	3.1	7.9	5.4
Hourly highest wind speed (m/s)—hour: 13:00	6.5	6.7	2.6	8.0	5.3
Daily average wind speed (m/s)	1.9	2.1	1.4	2.0	1.7
Hourly wind speed (m/s)—sat: 12:00	3.6	3.4	1.9	3.8	3.2
Hourly wind speed (m/s)—sat: 13:00	5.0	4.0	2.1	4.8	3.3
Hourly ground surface lowest temperature (°C)—hour: 12:00	39.6	43.5	43.4	42.1	42.4
Hourly ground surface lowest temperature (°C)—hour: 13:00	37.0	41.0	41.8	38.1	39.2

base brick), artificial grass, a seating unit (wood), a bridge (wood plastic composite), water surfaces, plant surfaces (bush: *Buxus microphylla*, *Berberis thunbergii* var. nana "Atropurpurea," *Callistemon citrinus*, *Cycas revoluta*, and *Nerium oleander* "Variegata") (groundcover: *Ruellia brittoniana*, *Sanvitalia procumbens*, and grass), and subgrass surfaces (group use: *Cupressus sempervirens* var. horizontalis: 4s group–3s group; *Washingtonia filifera*: 4s group–2s group; and W. *filifera-Casuarina equisetifolia*; solitary use: *Ficus elastica*, *F. retusa-nitida*, and *W. filifera*).

The lowest temperature was 23.27 °C on the grass surface under the *Ficus retusa-nitida* species. This value is far below the lowest temperature value (36.53 °C) obtained on the grass surface under direct sun. *F. retusa-nitida* can create this effect because it is a tree that can form dark shade and has a very large crown. When the plants were used as a group, the low under groundcover grass surface temperature was determined to be 23.79 °C in the sample of *W. filifera* and *Casuarina equisetifolia* species.

When the surface temperatures of shrubs and groundcover were evaluated, it was observed that *C. citrinus* registered the lowest temperature for shrubs (28.79 °C), and *R. brittoniana* had the lowest temperature for groundcover (29.23 °C). The highest temperature for grass surfaces was 38.30 °C. The highest surface temperature for hard floors was 71.64 °C for the rubber material used on children's playgrounds. Another surface material that follows was cast rubber. These results indicate that plastic-based materials increase the surface temperature by retaining heat. The lowest temperature was obtained for ceramic. The most striking temperature compared to other surfaces was that for the water surface. The temperature of the water surface was 27.23 °C. The wood used in the sitting unit was 52.84 °C, the wooden plastic composite used in the bridge was 60.17 °C, and the temperature of the artificial grass surface used on the football field was 66.77 °C.

When all the data obtained are compared with the hourly climate data of July, the differences between hard floors, grass surfaces, and vegetation grass surfaces are quite clear. Accordingly, the lowest soil surface temperature value obtained by TSMS (2019) at 12:00 on the measured days

Table 2 Information about the measurement points and surface coatings

No.	Point name	Surface material	No.	Point name	Surface material	No.	Point name	Surface material
1	Entrance	Sandy hardwood	18	Bridge	Wood plastic composite	35	Grass field	Grass surface
2	Walkway	Cast rubber	19	Flooring	Base brick	36	*Cupressus sempervirens* var. *horizontalis*-group of 3	Subplant on grass surface
3	Bicycle path	Blue-painted concrete	20	Grass field	Grass surface	37	Children's play area	Rubber
4	Grass field	Grass surface	21	*Washingtonia filifera*-soliter	Subplant on grass surface	38	*Sanvitalia procumbens*	Plant surface
5	*Buxus microphylla*	Grass surface	22	*Cycas revoluta*	Grass surface	39	Grass field	Grass surface
6	*Berberis thunbergii* var. *nana* "Atropurpurea"	Grass surface	23	Flooring	Sandy hardwood	40	*Washingtonia filifera*-soliter	Subplant on grass surface
7	Flooring	Sandy hardwood	24	*Ficus retusa-nitida*-soliter	Subplant on grass surface	41	*Washingtonia filifera-Casuarina equisetifolia*	Subplant on grass surface
8	Sitting bench	Wooden	25	Flooring	Ceramic	42	*Ficus retusa-nitida*-soliter	Subplant on grass surface
9	*Nerium oleander* "Variegata"	Grass surface	26	Vehicle road	Asphalt	43	Parking lot	Sandy hardwood
10	*Ruellia brittoniana*	Grass surface	27	*Ficus elastica*-soliter	Subplant on grass surface	44	Vehicle road	Asphalt
11	Children's play area	Rubber	28	Walking path	Cast rubber	45	Parking lot	Sandy hardwood
12	*Washingtonia filifera*-group of 4	Subplant on grass surface	29	Bicycle path	Blue-painted concrete	46	Walkway	Cast rubber
13	*Callistemon citrinus*	Grass surface	30	*Ficus retusa-nitida*-soliter	Subplant on grass surface	47	Bicycle path	Blue-painted concrete
14	Under a canopy	Sandy hardwood	31	*Cupressus sempervirens* var. *horizontalis*-group of 4	Subplant on grass surface	48	Football field	Artificial grass
15	Flooring	Base brick	32	*Cupressus sempervirens* var. *horizontalis* -group of 4	Subplant on grass surface	49	Basketball court	Burgundy-painted concrete
16	Pool cooping	Marble	33	*Washingtonia filifera*-group of 2	Subplant on grass surface	50	Tennis court	Green-painted concrete
17	Pool	Water surface	34	*Buxus microphylla*	Plant surface			

Table 3 Technical specifications of the calibration device

Measuring range	35 °C/50 °C ... 35 °C (for calibration after 35 °C, the ambient temperature of the room where the calibrator is located should not exceed 25 °C)
Sensitivity	± 0.5 °C ... 100 °C
	± 1.0 °C ... 200 °C
	± 1.5 °C ... 350 °C
Emissions factor of the black body	0.95
Diameter of the black body	58 mm
Warm-up time	30 min up to the maximum temperature
Cooldown time	30 min to 100 °C
Power source	230 V
Dimensions (width × height × depth)	180 × 114 × 233 mm
Weight	3000 gr.

Table 4 Surface temperature values of the surface coatings in the İskenderun Community Park in July 2019

No.	Surface material	Temperature value (°C)	No.	Surface material	Temperature value (°C)	No.	Surface material	Temperature value (°C)
1	Sandy hardwood	51.14	18	Wood plastic composite	60.17	35	Grass surface	36.64
2	Cast rubber	57.67	19	Base brick	48.67	36	Subplant on grass surface (*C. sempervirens* var. *horizontalis*-group of 3)	25.74
3	Blue-painted concrete	52.48	20	Grass surface	38.30	37	Rubber	71.64
4	Grass surface	36.53	21	Subplant on grass surface (*W. filifera*-soliter)	23.70	38	Plant surface (*S. procumbens*)	31.08
5	Plant surface (*B. microphylla*)	32.83	22	Plant surface (*C. revoluta)*	33.70	39	Çim yüzeyi	36.63
6	Plant surface (*B. thunbergii* var. *nana* "Atropurpurea")	33.16	23	Sandy hardwood	45.15	40	Subplant on grass surface (*W. filifera*-soliter)	27.42
7	Sandy hardwood	47.62	24	Subplant on grass surface (*F. retusa-nitida*)	23.38	41	Subplant on grass surface (*W. filifera-C. equisetifolia*)	23.79
8	Wooden	52.84	25	Ceramic	26.95	42	Subplant on grass surface (*F. retusa-nitida*)	23.27
9	Plant surface (*N. oleander* "Variegata")	32.35	26	Asphalt	48.51	43	Sandy hardwood	53.13
10	Plant surface (*R. brittoniana*)	29.23	27	Subplant on grass surface (*Ficus elastica*-soliter)	24.41	44	Asphalt	50.94
11	Rubber	70.85	28	Cast rubber	59.73	45	Sandy hardwood	52.68
12	Subplant on grass surface (*W. filifera*-group of 4)	25.41	29	Blue-painted concrete	50.82	46	Cast rubber	58.37
13	Plant surface (*C. citrinus*)	28.79	30	Subplant on grass surface (*Ficus retusa-nitida*-soliter)	24.99	47	Blue-painted concrete	57.62
14	Sandy hardwood (shadow)	32.91	31	Subplant on grass surface (*C. sempervirens* var. *horizontalis*-group of 4)	26.03	48	Artificial grass	66.77
15	Base brick	49.56	32	Subplant on grass surface (*C. sempervirens* var. *horizontalis*-group of 4)	24.85	49	Burgundy-painted concrete	55.90
16	Marble	43.36	33	Subplant on grass surface (*W. filifera*-group of 2)	25.38	50	Green-painted concrete	55.89
17	Water surface	27.23	34	Plant surface (*B. microphylla*)	29.56			

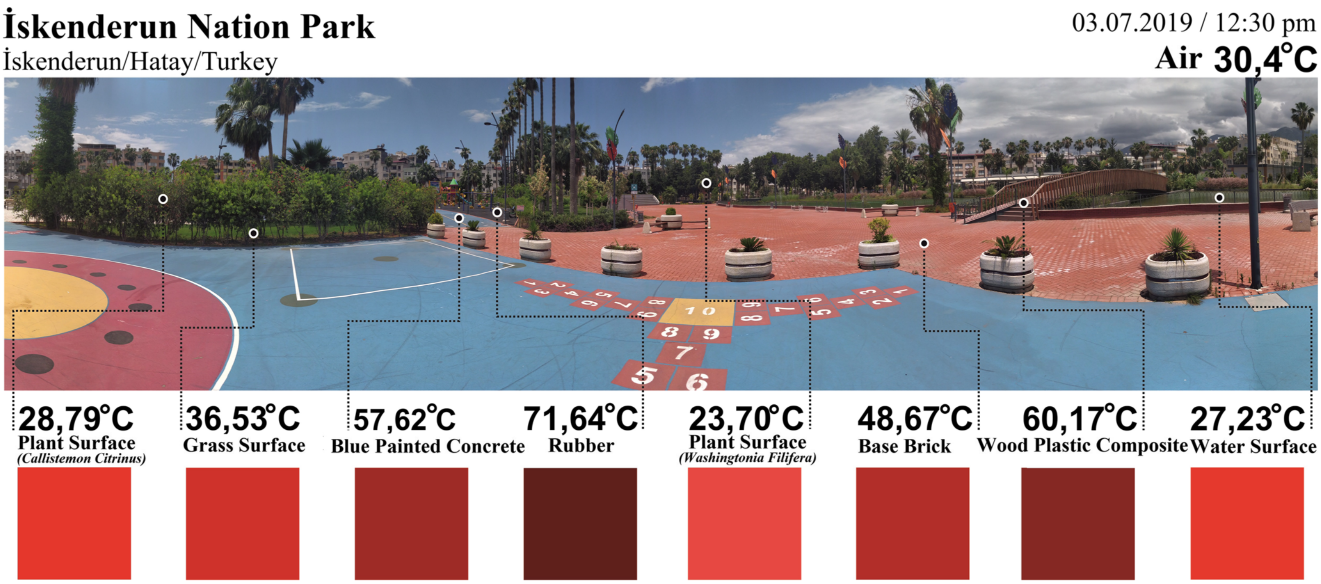

Fig. 2 Temperature values created by some surface materials used in the area in July

was 4.2–8.3 °C higher than the surface temperature of the grass surface at 12:00. Additionally, the temperatures of under grass surfaces have always been below these values. The surface temperatures of hard floor coverings obtained in the study were higher than the lowest temperatures at 12:00.

4 Discussions

Increased levels of thermal comfort (asphalt, concrete, parquet, etc.) of cities are related to the thermal comfort level, roads, buildings, etc.; however, thermal comfort decreases as green areas decrease. Hard surfaces store heat and cause the surface temperature to increase (Alkan et al. 2017). When the temperatures formed by 31 different surfaces in our study were evaluated, the temperature created by hard floors, especially artificial materials, reached 71.64 °C for the rubber material used on children's playgrounds at 12:00 noon in July. The artificial grass used in football fields in recent years has also become the second hottest material with a temperature of 66.77 °C. The lowest surface temperature among other hard surfaces was 26.95 °C for ceramics. The surface temperature was determined to be 32.91 °C for sandy parquets in shaded areas. These values follow asphalt at 50.94 °C. All these data reveal the high temperatures created by hard floors.

In the study conducted in the Erzurum city center in July, the impregnated wooden surface temperature was at the highest level, and turf was at the lowest level. Asphalt also increased the surface temperature to a high level (Irmak et al. 2017). Although these data are not similar to the data obtained in our study in terms of temperatures, it is seen that both materials are materials that can increase the surface temperature to a high level compared to other materials. The surface temperature of asphalt reached a high of 50.94 °C, and the wood composite was 60.17 °C.

Human thermal comfort increases with the amount of green space. Urban green areas are important to the thermal comfort of cities and the formation of thermal comfort areas (Gómez et al. 2008; Gómez et al. 2013; Atwa et al. 2020). Within the scope of our study, the data obtained from the measurements on the grass, under grass surfaces, and plant surfaces support this conclusion. Thermal comfort increases to a high level due to the temperature created by subgrass surfaces. The temperature of the grass surface for the *Ficus retusa-nitida* species was 23.27 °C. The plant surface of *Callistemon citrinus* reaches 28.79 °C, and the temperature of the grass surface also reaches 38.30 °C. These values are far below the values obtained for hard surfaces. In other words, herbal material increases the thermal comfort by reducing the surface temperature. Water surfaces are among the most important materials that contribute to increasing the thermal comfort in urban areas (Radhi et al. 2013). This situation was also demonstrated by the data obtained in our study, where the temperature of the water surface was 27.23 °C.

Therefore, it was determined that the surface temperatures of 31 different surface coatings used in Iskenderun Nation Park in July are different from each other. There is a temperature difference of approximately 48 °C (23.27–71.64 °C) among the surface materials. This situation varies according to the density of the plant communities.

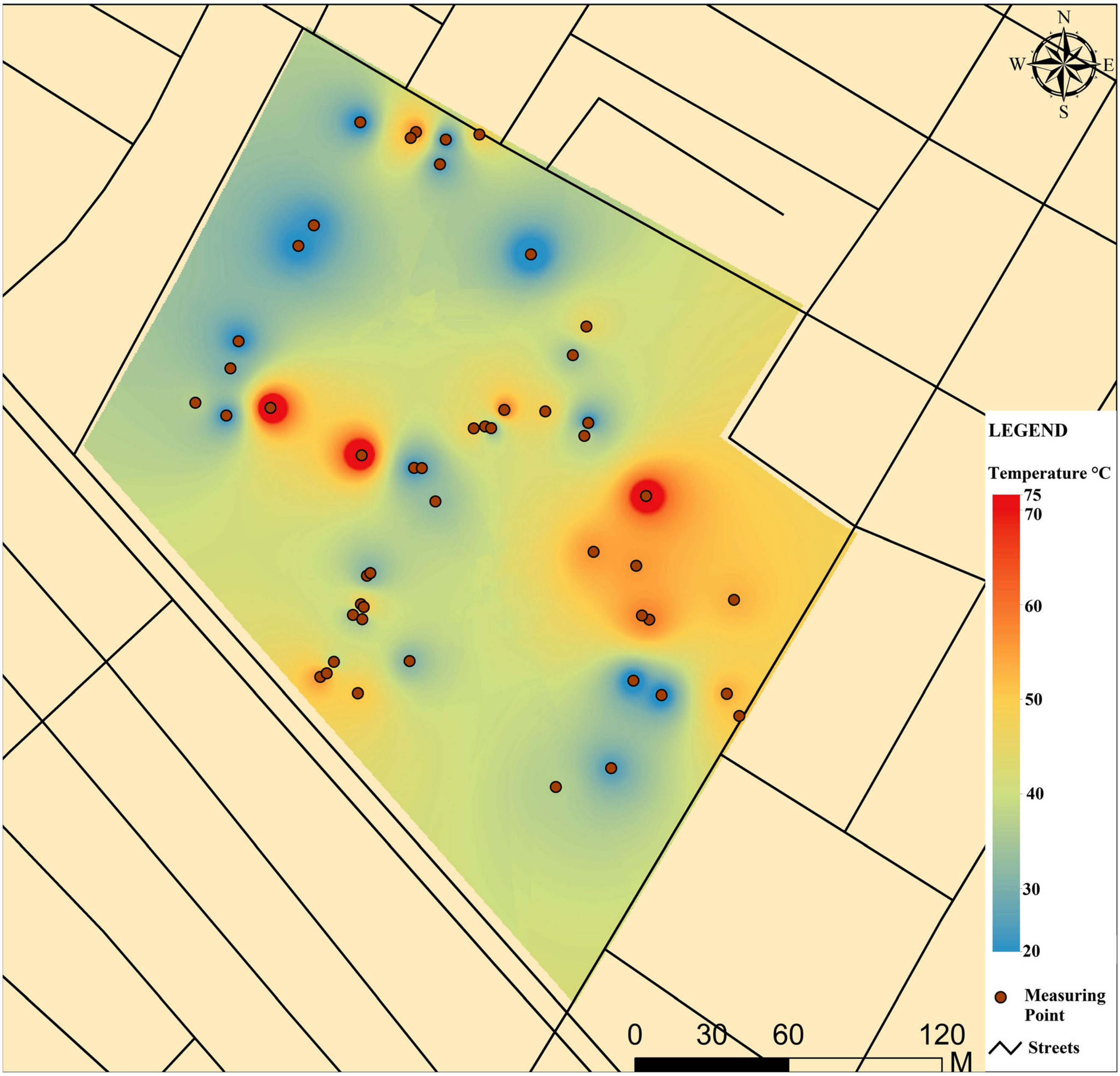

Fig. 3 The temperature level map created by the floor coverings in the study area in July

5 Conclusions

This study found that trees (solitary or in groups), water surfaces, grass areas, and plant surfaces (shrub and perennial herbaceous groundcover) increase thermal comfort in urban areas. Conversely, plastic-based surface coatings (rubber, cast rubber, and artificial grass) have very high thermal comfort. Hard floors such as concrete, asphalt, and parquet also reduce the thermal comfort. In particular, rubber, which is the flooring used on children's playgrounds and running tracks, has a rapid heating feature, thus negatively affecting bioclimatic conditions. Despite their aesthetic appearance, these areas reach very high temperatures during the day.

In light of all these data obtained, the importance of surface material selection in terms of bioclimatic conditions and thermal comfort becomes evident in urban open and green space design. The surface coatings of all the elements forming the built environment should be designed from the building scale to the finer details on the texture scale considering the hierarchical thermal comfort properties. The selection of surface material to be used in all areas should be an important design criterion in the formation of healthy, livable cities. In the regions where the Mediterranean climate prevails, in order to reduce the urban heat island effect and increase the thermal comfort, the presence of water surfaces, grass areas, and trees in the urban area should be increased. Conversely, the use of rubber/derivatives and plastic surface materials such as artificial grass should be avoided in parks that people use intensely during the day as they minimize thermal comfort.

Authors' contributions EBS, EK, FA, SG, IZC, YD, and MC designed the study and performed the experiments; EBS, EK, FA, and MC performed the experiments, analyzed the data, and wrote the manuscript

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Compliance with ethical standards

We declare that the appropriate permissions were received from the responsible authorities before conducting the study in "Iskenderun Community Park." The statements are provided in the manuscript and added to the appendix. All permissions are made and provided by the Iskenderun Municipality Garden. There is a clear statement on nonfinancial conflicts of interest during the research.

Conflict of interest The authors declare that they have no conflicts of interest.

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