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RESEARCH ARTICLE

# Analysing daytime summer thermal comfort conditions for Turkey's third largest tourism destination

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**Abstract**
Tourism is one of the most vulnerable sectors to climate change since outdoor leisure activities are only possible in appropriate climate conditions for them. Among several climate or weather–related factors effective on tourist satisfaction, the concept of outdoor thermal comfort conditions gains importance with climate change because it is the combined effect of all atmospheric conditions on human body. Therefore, tourism–climate indices to reflect the favourability of destinations begin to include this parameter as a component. Mediterranean basin harbours world famous summer and cultural tourism destinations among others and climate change is expected to impact the region which covers the third largest primary destination of Turkey. The aim of this study is to analyse human thermal comfort conditions in the southwest part of Turkey, world–famous summer tourism region using Physiologically Equivalent Temperature (PET) and Mean Radiant Temperature (Tmrt) values and Geographic Information System (GIS) as a tool to show their spatial distribution as a component of tourism climate indices. As the result of the study, the most influential factors on human thermal comfort conditions in the region are mean radiant temperature, moisture content, air movement and increasing dense urbanisation in 12 districts, where meteorological measurements were taken. As the result of the study, suggestions were proposed to reduce the effect of higher PET and Tmrt values on tourists in the study.

**Keywords** Climate change · Tourism · Adaptation · Tourism climatology

## Introduction

Humans have adapted their daily activities, routines, behaviours, traditions, architecture, clothes and many other characteristics to the prevalent climate conditions in their surroundings due to their impacts on human health and well-being (WMO 1999; Matzarakis and Mayer 2000). Apart from the individual effects of each climatic parameter, thermal effect on human body refers to the combined effect of all climatic elements, like temperature, relative humidity, wind and solar radiation (Jendritzky et al. 1990; VDI 1998; Matzarakis 2000). Human thermal comfort is defined as the "..condition of mind which expresses satisfaction with the thermal environment" i.e. ambient thermal conditions (ANSI/ASHRAE Standard 55–2004; ISO 1995), which means that human body feels no discomfort with the air conditions and requires minimum energy to adjust its physical and emotional conditions. Human thermal comfort conditions vary depending on the environmental factors such as climatic elements; air temperature (Ta), wind velocity (Wv), relative humidity (RH) and solar radiation (as mean radiant temperature; Tmrt) and personal characteristics, e.g. clothing and activity types (Thorsson et al. 2014).

Tourism is a vital sector all over the world for its contribution to local, regional and national economies. According to UNWTO (2021), the sector accounts for 10.3, 6.8, 28.3 and 4.3% of global GDP, total exports, service exports total investment, respectively. Europe and Mediterranean basin including Turkey is one of the key

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regions for travels and tourism receipts. Turkey has still experienced an increase trend since the beginning of 2000s in both tourist number and revenues and adopted concrete targets in national development plans and strategies. However, the area is predicted to be under significant effect of climate change (EUROCONTROL 2021), which shows itself as weather and climate extremes, heatwaves, heavy precipitation, droughts, and tropical cyclones (IPCC 2021). Various tourism–climate indices have been developed (Mieczkowski 1985; Lin and Matzarakis 2008; Demiroglu et al. 2020) and used to make conclusion about existing and possible tourism attractiveness in a destination and compare these potentials. These indices, like the Tourism Climate Index (TCI; Mieczkowski 1985) and Holiday Climate Index (HCI; Scott et al. 2016; Rutty et al. 2020), Climate-Tourism-Information-Scheme (CTIS; Matzarakis 2014) evaluate the destinations in a fragmented approach involving meteorological elements expected to be effective on experience/pleasure, i.e. temperature, humidity, precipitation, cloud cover, and wind speed as well as thermal comfort, which is the combined effect of all these parameters on visitors. In this respect, it is important to determine temporal and spatial distribution of thermal comfort conditions as one of the components of tourism climate indices.

Because human thermal comfort conditions are important for a wide range of social and economic human activities and people have raised awareness towards climate change, the quality and quantity of studies in related literature have increased since the pioneering study of Haldane (1905). A great number of approaches and indices have been developed to define the components of human thermal comfort conditions with varying weights like solar radiation (Kenny et al. 2008) and calculate a concrete indicator value representing thermal comfort as temperature using different indices. For instance, Olgyay (1973) defines the outdoor human thermal comfort as the condition where relative humidity is between 30 and 65%, temperature between 21 and 27.5 °C, and wind speed up to 5 m/s. In addition, there are many other human thermal comfort calculation indices like Predicted Mean Vote (PMV; ANSI/ASHREA 2004) working in built environment, Standard Effective Temperature (SET), Universal Thermal Climate Index (UTCI 2009) and Physiological Equivalent Temperature (PET, Höppe 1999). Human thermal comfort conditions can show spatial and temporal variations depending on the topography, land-use types, ambient meteorological conditions and seasonal differences.

Climate can play significant roles as source (De Freitas et al. 2008) causing sometimes tourism assets while hinder the existent potentials by threatening the natural and cultural values or tourist satisfaction. Due to the keen competition between the tourism destinations analysing present and future climate conditions using real-time monitored data, indices, scenarios and thermal comfort values (Demiroglu et al. 2020; Şensoy 2020) to reveal their (dis)advantages for both visitors and investors.

The aim of this study is to evaluate spatial and temporal distribution of human thermal comfort conditions as a suitability component of south west Mediterranean Region of Turkey for tourism, which is among the most important parts of the country for sea–sun–sand tourism using one of the most widely used thermal comfort calculation indices, PET and Tmrt values and Rayman software 3.2 to make suggestions for the development of tourism sector.

## Study area and methodology

The study area covers the province of Muğla and a small part of Antalya located in the farthest south–west part of Turkey (36°03′–37°00N and 28°12′–29°25′E; Fig. 1). The area shelters world famous summer beach tourism resorts and also ancient city of Lycian with a recorded history dating back to fifth century BC at east Mediterranean. Total number of tourists visiting the area is 3,266,650 in 2019.

Meteorological data was obtained from the meteorological stations in Table 1, which have been operated by the official meteorology authority, Turkish State Meteorological Service and established in the settlements (districts) of Fethiye (3 m MSL), Dalaman (6 m MSL), Koycegiz (4 m MSL), Marmaris (16 m MSL), Bodrum (26 m MSL), Datca (30 m MSL), Seydikemer (124 m MSL), Kas (153 m MSL), Mugla-Mentese (646 m MSL), Yatagan (650 m MSL) and Elmalı (1050 m MSL).

The study area has Mediterranean climate characteristics (Table 2), where very hot, dry and long summers with an average annual temperature 34 °C, cool and wet winters with an average annual temperature of 17 °C are prevalent. The coldest month is January and the warmest month is July in the study area. Annual rainfall changes between 750 and 1200 mm in the area while relative humidity is around 75% all year and sunshine duration is 140 h in winter and 360 h in summer period. The prevailing wind direction is West during daytime and East at night from sea and land respectively. Average wind velocity is about 3.5 m/s. Geography of the study area is diverse causing different types of nature landscapes covering mountains which run perpendicularly to the sea coast and valleys open to the sea winds.

## Method

At the first stage of the study, all related meteorological data, i.e. Ta (°C), RH (%), wind velocity (m/s) were obtained from the meteorological measurement stations at

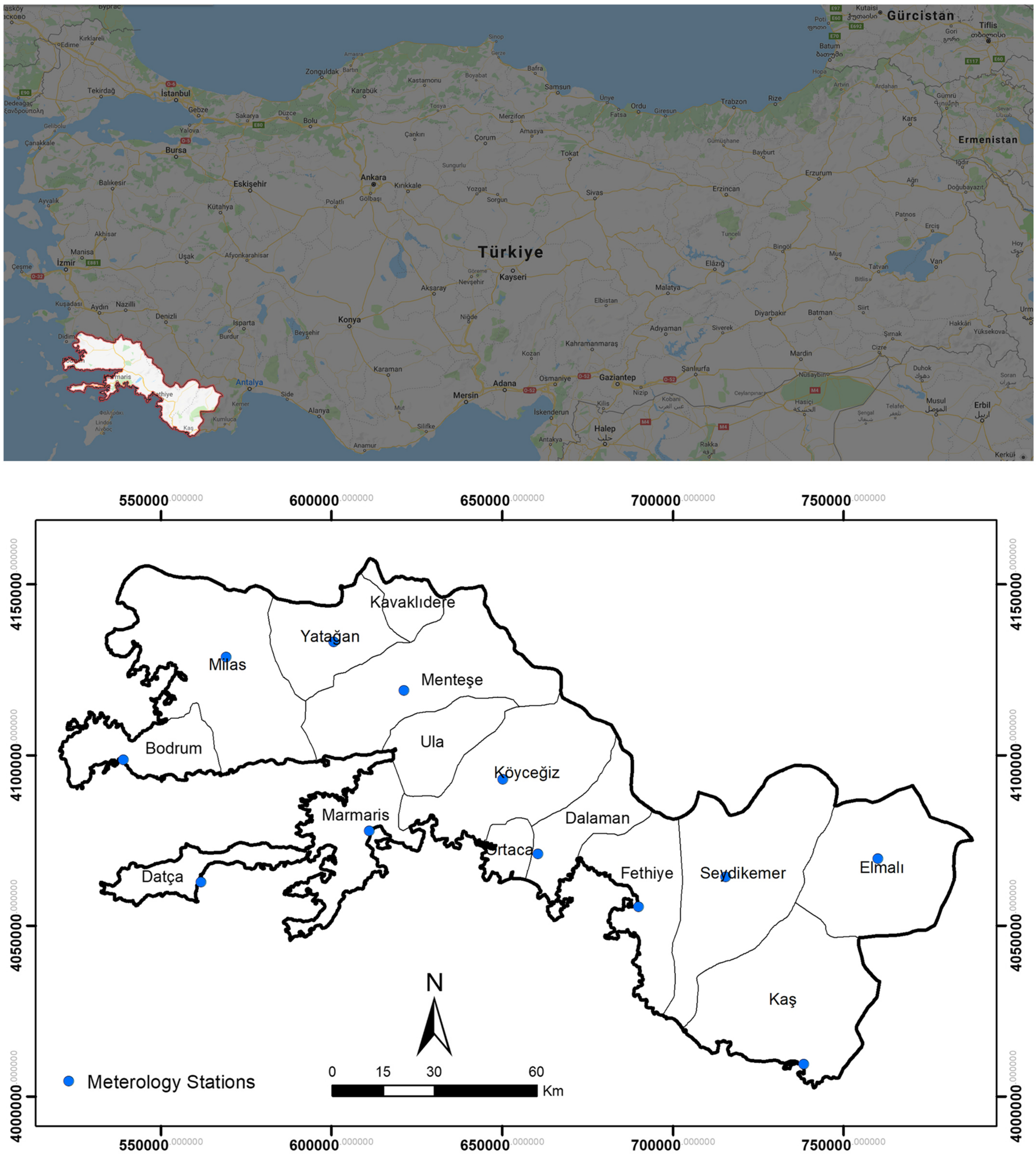


**Fig. 1** Location of study area in Turkey and east Mediterranean basin

12 sites on hourly basis over 10 years (between 2010 and 2020) in the hottest period of the year between May and October. Mean radiant temperature (Tmrt; °C) and PET (°C) values were calculated through the software, Rayman 3.2 (Matzarakis et al. 2010), which can estimate radiation fluxes considering microclimatological modifications of different outdoor environments. While evaluating the PET and Tmrt, different elevations were also considered in the study. In addition to the obtained meteorological values mentioned above, parameters of clothing (set to 0.9 clo in

**Table 1** List of meteorological stations from which the data was obtained

| Stations | Coordinates | Elevation (m, AMSL) |
|---|---|---|
| Fethiye | 36°37′36.5″N 29°07′26.0″E | 3 m |
| Dalaman | 36°46′18.8″N 28°47′55.0″E | 6 m |
| Koycegiz | 36°58′12.0″N 28°41′12.8″E | 4 m |
| Marmaris | 36°50′22.2″N 28°14′42.7″E | 16 m |
| Bodrum | 37°01′58.1″N 27°26′23.3″E | 26 m |
| Datca | 36°42′28.1″N 27°41′30.1″E | 30 m |
| Seydikemer | 36°38′57.1″N 29°21′14.0″E | 124 m |
| Kas | 36°12′00.7″N 29°39′00.7″E | 153 m |
| Mugla-Mentese | 37°12′34.2″N 28°22′00.5″E | 646 m |
| Yatagan | 37°20′22.2″N 28°08′12.8″E | 650 m |
| Elmalı | 36°44′13.9″N 29°54′43.6″E | 1050 m |

https://mgm.gov.tr/kurumsal/istasyonlarimiz.aspx?il=Mu%C4%9Fla
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summer and 1.0 clo in winter), activity (set to 80 w) and global radiation (Gr) were set in the Rayman to calculate PET and Tmrt values.

Tmrt which is defined as the 'uniform temperature of an imaginary enclosure in which the radiant heat transfer from the human body equals the radiant heat transfer in the actual non-uniform enclosure has been widely adopted for urban thermal comfort studies (Masmoudi and Mazouz 2004; Thorsson et al. 2014; Emmanuel et al. 2007). Tmrt better describes the spatial thermal pattern within complex urban environment than the air temperature and it also indicates the heat stress and heat related mortality better in clear and warm conditions with high solar irradiance in especially summer season (Winslow et al. 1936; Clark and Edholm 1985; Koichi 1996; Matzarakis 2000; Thorsson et al. 2014; Kenny et al. 2008; Vanos et al. 2010). Tmrt is affected by shadows generated by vegetation cover, buildings, topography and surface materials therefore urban green spaces offer advantages for Tmrt against UHI or for the moderation of urban climatic conditions (Lucchese et al. 2016; Rodríguez-Algeciras et al. 2016; Xi et al. 2012; Zhang et al. 2018).

Before the calculation of PET and Tmrt, wind data was adjusted to those at 1.1 m according to the generally adopted empirical formula for human biometeorology (Troen and Petersen 1989).

$W_{1.1.} = w_{10}(^{1.1.}/_{10})^{(0.12z_0+0.18)}$; where $W_{1.1}$ is the estimated wind velocity at 1.1 m, $W_{10}$ is the wind velocity measured at 10 m, and zo is the surface roughness depending on the characteristics of the study area.

A dataset including PET and Tmrt values was used to prepare coloured graphics and then transformed to GIS software, ArcGis 9.3 to determine the spatial distribution of human thermal comfort conditions calculated. With the help of ArcGis 9.3 software, measurement points were digitized considering national coordinate system. Inverse distance weighted (IDW) belonging to spatial analysis module in ArcGis 9.3 software was applied for the distribution of PET and Tmrt in the study area. IDW interpolation determines cell values using linear weighted combination set of same points (Chang et al. 2006; Yang et al. 2008). The weight is a function of inverse distance. The surface being interpolated is location–dependent variable. The use of IDW provides control over the points with known values to estimate the interpolation values based on their distances from the source point. The IDW function offers 2 options; a fixed search Radius type and a variable search radius type. With a fixed radius, the radius of the circle used to find input points is the same for each interpolated cell. A higher power puts much emphasis on the nearest point, creating a surface that has more details but is less smooth. A lower power gives much influence to surrounding points that are farther away, creating a

**Table 2** Some meteorological parameters in the area

| MUGLA | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Measurement period (1928–2020) | | | | | | | | | | | | | |
| Mean temperature (°C) | 5.3 | 6.1 | 8.5 | 12.7 | 17.7 | 22.8 | 26.4 | 26.2 | 21.9 | 16.2 | 10.8 | 7.0 | 15.1 |
| Mean max. temp. (°C) | 9.8 | 10.9 | 14.2 | 18.8 | 24.3 | 29.6 | 33.4 | 33.5 | 29.2 | 23.1 | 16.6 | 11.5 | 21.2 |
| Mean min. temp. (°C) | 1.6 | 1.9 | 3.6 | 7.0 | 11.4 | 16.1 | 19.7 | 19.6 | 15.3 | 10.3 | 5.9 | 3.2 | 9.6 |
| Mean sunshine duration (hour) | 3.5 | 4.5 | 5.8 | 7.3 | 8.7 | 10.6 | 11.4 | 11.0 | 9.5 | 6.9 | 4.8 | 3.4 | 7.3 |
| Mean wet days | 15.5 | 13.2 | 11.5 | 9.7 | 8.5 | 4.1 | 2.0 | 1.7 | 2.9 | 7.2 | 9.9 | 14.7 | 100.9 |
| Total rainfall (mm) | 241.4 | 178.6 | 123.1 | 64.7 | 50.9 | 24.5 | 11.7 | 14.7 | 23.3 | 73.4 | 136.5 | 265.5 | 1208.3 |
| Measurement period (1928–2020) | | | | | | | | | | | | | |
| Record maximum temp. (°C) | 20.9 | 25.5 | 28.8 | 31.2 | 39.4 | 40.8 | 42.1 | 41.2 | 39.2 | 36.8 | 29.0 | 23.8 | 42.1 |
| Record minimum temp (°C) | −12.6 | −9.9 | −8.5 | −3.6 | 1.0 | 6.7 | 10.5 | 9.0 | 5.6 | 0.1 | −7.0 | −9.0 | −12.6 |

smooth surface. It makes search radius variable for each interpolated cell depending upon how far it has to stretch to obtain specified number of input points. It determines a maximum distance to limit the potential size of the radius of the circle.

For the interpolation of temperature values according to elevation, the following formula was used to calculate temperature values;

$$Tr = Ti \pm (hi * 0.005)$$

Tr Reduced temperature with height;
Ti Station mean temperature;
hi Station height (Demircan et al. 2011).

The rates of adiabatic heating and cooling in the atmosphere are described as lapse rates and are expressed as the change of temperature with elevation. The adiabatic lapse rate for dry air is very close to 1 °C per 100 m. If vapour condensation occurs in the air parcel, latent heat is released, thereby modifying the rate of temperature change. This retarded rate is called the pseudo-adiabatic lapse rate; it is not a constant for its value depends on the temperature at which the process takes place and the amount of water vapour in the air mass. However, for general descriptive purposes, it is assumed as 0.5 °C per 100 m (Oliver and Fairbridge 2005).

Even though 24-h calculation of PET and Tmrt was performed, only daytime values were analysed in the study in order to determine the situation to which the locals and visitors are exposed in the most disadvantageous period for human thermal comfort. For the categorisation of PET values into thermal stress levels, the ranges given in Table 3 were used.

**Table 3** Human thermal sensation and stress ranges for PET (Matzarakis and Mayer 1996; Matzarakis et al. 1999; Höppe 1999; Matzarakis et al. 2007)

| PET [°C] | Thermal sensation | Level of thermal stress |
|---|---|---|
| <4 °C | Very cold | Extreme cold stress |
| 4.1–8 °C | Cold | Strong cold stress |
| 8.1–13 °C | Cool | Moderate cold stress |
| 13.1–18 °C | Slightly cool | Slight cold stress |
| 18.1–23 °C | Neutral (comfortable) | No thermal stress |
| 23.1–29 °C | Slightly warm | Slight heat stress |
| 29.1–35 °C | Warm | Moderate heat stress |
| 35.1–41 °C | Hot | Strong heat stress |
| 41 °C> | Very hot | Extreme heat stress |

## Results and discussion

This study provides an analysis of human thermal comfort conditions using the interpolated distribution of values in the study area. Results of the spatial analysis of PET values in the study area is presented in Fig. 2. This distribution shows variations in different parts of the study area and months.

It is seen from the daytime distribution of PET in May that majority of study area is in comfortable range except for Fethiye and Köycegiz city centres and their close proximity, where the elevation and dense urban settlements are effective. Other observation sites (districts) seem to be in comfortable range during May while in Elmalı and Menteşe-Muğla stations, cool range is prevalent in this month as a result of their high altitudes as expected from positive lapse-rate (i.e. cooling 0.5 °C per 100 m).

In June, heat stress is the most dominant in Köyceğiz depending possibly on the wind velocity and direction from the sea supplying humidity. The north of the city is covered with high mountains blocking the air movement to pass through the site. Prevailing wind direction causes high moisture accumulation in the area from the sea surface causing inevitably heat stress during day time at this location. As can be seen from the figure again, warm comfort range is prevalent in a significant part of the area from Köyceğiz in the west to Kaş in the east being centred around Fethiye city centre in the middle part of the study area. Another interesting distribution during June is in Bodrum, which is warm in contrast to the stations in its close proximity. Reason for this situation can again rely on densely urbanised city parts and lower elevation. Elmalı is the only station to show slightly cool characteristics in the area in this month depending on its higher elevation.

In July, heat stress is prevalent all over the area ranging from slightly warm to very hot, which is around Fethiye and Köyceğiz locations. Slightly warm condition shows an elevation–dependent distribution like in Datça, Ortaca, Menteşe and Elmalı together with less urbanisation and sea breezes.

The conditions slightly close to comfortable ranges are dominant around Muğla, Elmalı district in August. The same heat stress conditions in July are also valid in August by covering nearly all over the study area. In and around Fethiye and Köyceğiz, very hot and hot ranges are prevalent. Slightly warm range dominates around Muğla and Elmalı in August. Except for hot and slightly warm ranges, the area is under the effect of warm range. In September, prevalent range changes all over the area which diversifies as hot, warm, slightly warm, comfortable and slightly cool both heat and cold stress can be seen in the area depending on elevation differences together with maritime effect. In October, the area where heat stress is prevalent shrinks considerably and comfortable and cool

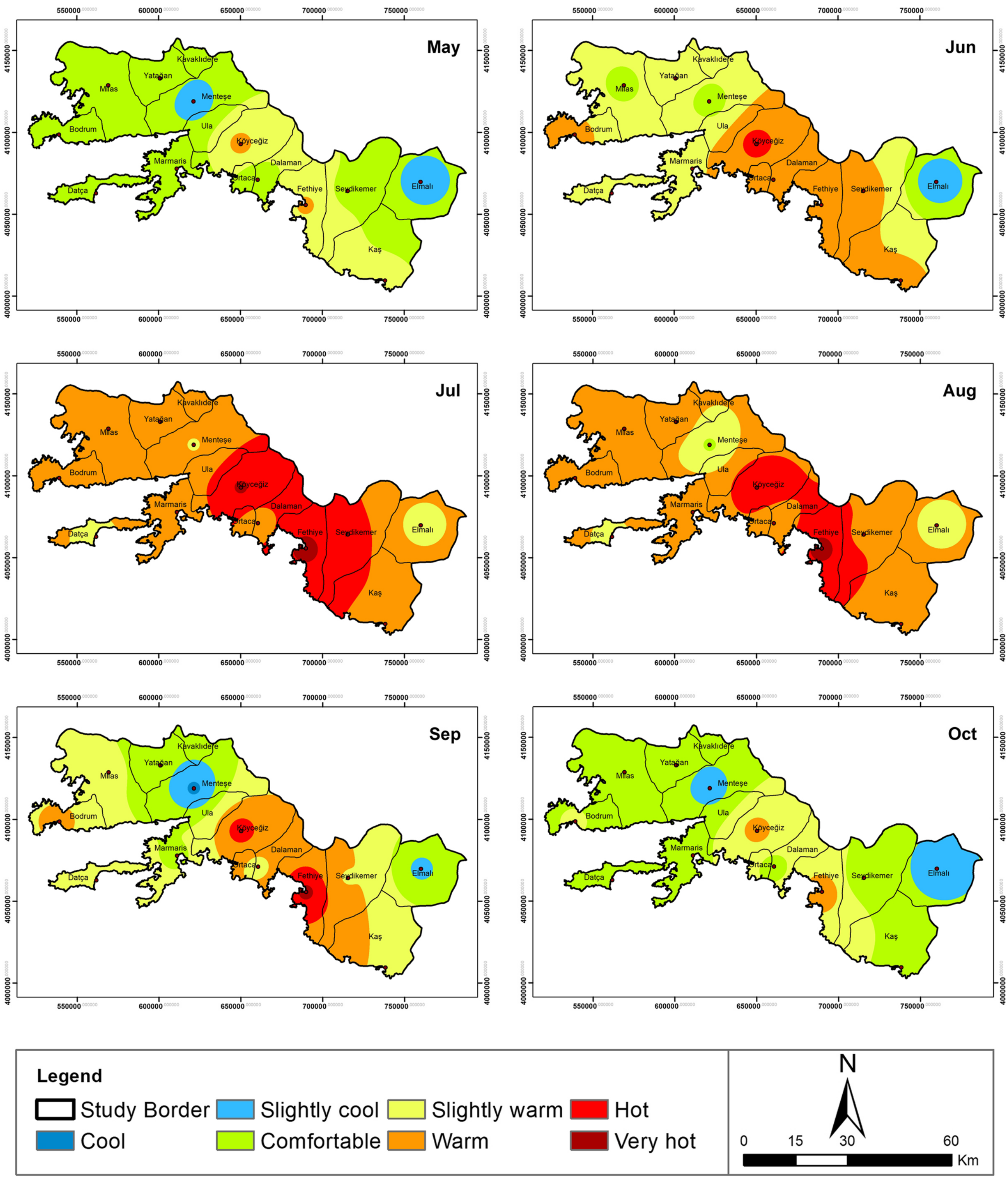



**Fig. 2** Distribution of PET values in the study area

ranges expand in the study area. It can be stated from the spatial analysis of PET values that heat and cold stress are seen in the study area partially depending on the seasonality, elevation, maritime and urbanisation effects.

Tmrt represents the spatial thermal pattern within complex urban environment better than the air temperature and it also indicates the heat stress all over the study area. Tmrt distribution in the area is given in Fig. 3. It is observed from

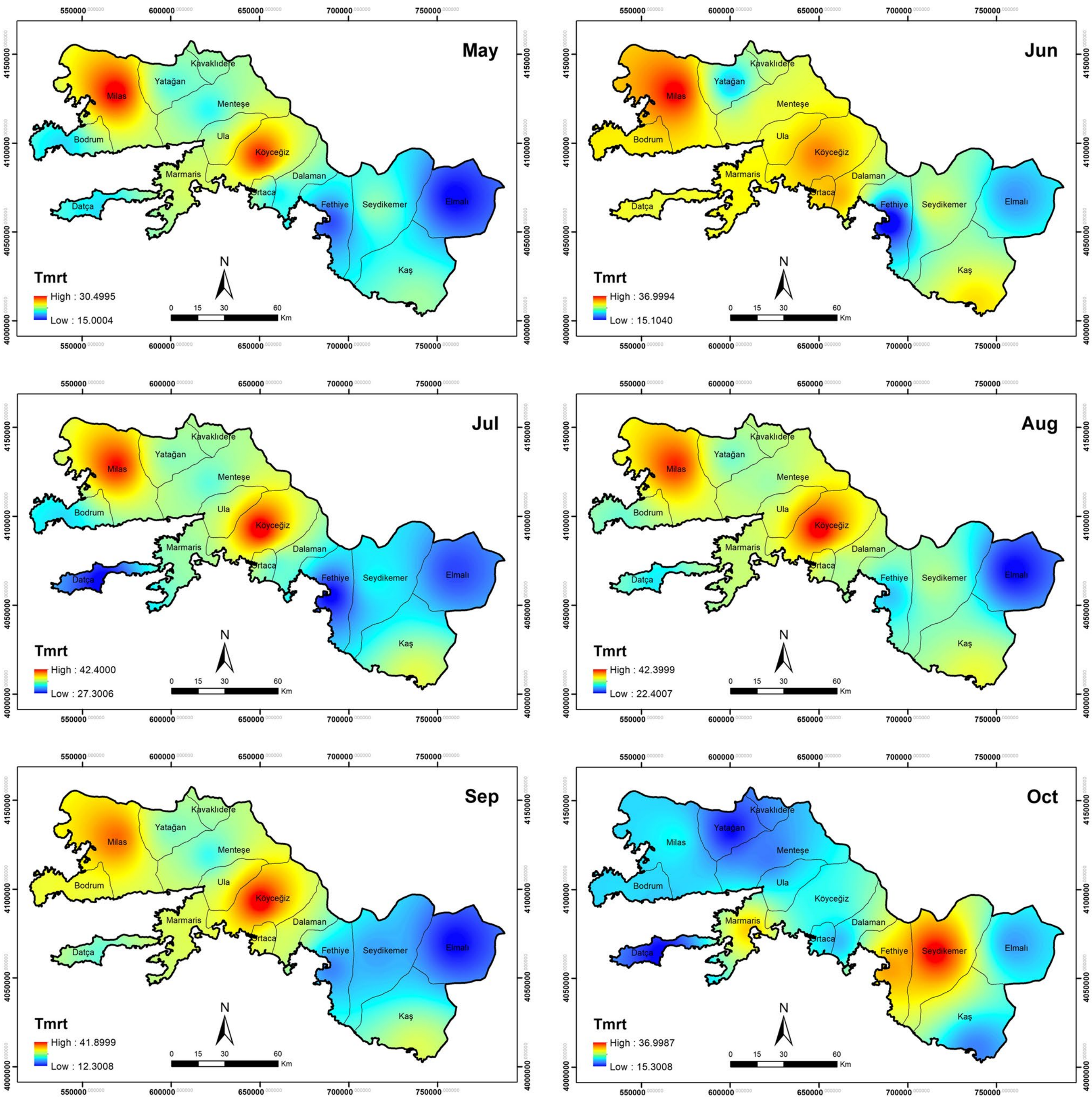



**Fig. 3** Tmrt distribution in the study area

the figure that PET and Tmrt values show similar distribution characteristics. Milas and Köycegiz districts represent higher Tmrt rates in May showing greater radiation insolation compared to other locations in the area while Elmalı district at the highest elevation is expected to have lower insolation value and so lowest Tmrt rate. Elmalı, Fethiye and Yatağan have higher Tmrt values depending upon the radiation insolation in June. Tmrt distribution reveals that a considerably large part of the study area represents low Tmrt values except for Milas and Köyceğiz in July. The East part of the area is represented by lower Tmrt values in August and September as the result of lower radiation characteristics. In October, Seydikemer and Marmaris stations have higher values while the others have lower Tmrt values.

In some studies related to human thermal comfort, temporal results are presented through tables showing the mean daily, decadal or monthly index values as it is in Fig. 4. In this study, comfort ranges are presented in monthly averages. Monthly means of daytime PET values in the stations are seen to be in different ranges. The highest

| PET($^0$C) | May | Jun | Jul | Aug | Sep | Oct |
|---|---|---|---|---|---|---|
| FETHİYE | 30 | 34 | 42 | 42 | 42 | 32 |
| BODRUM | 19 | 30 | 32 | 30 | 30 | 23 |
| S.KEMER | 20 | 26 | 30 | 28 | 25 | 18 |
| MUĞLA | 15 | 20 | 29 | 22 | 12 | 16 |
| DALAMAN | 20 | 32 | 33 | 32 | 28 | 22 |
| DATÇA | 38 | 45 | 45 | 45 | 41 | 39 |
| MARMARİS | 20 | 29 | 33 | 31 | 22 | 23 |
| MİLAS | 21 | 22 | 34 | 30 | 24 | 19 |
| YATAĞAN | 22 | 28 | 32 | 32 | 18 | 19 |
| ELMALI | 17 | 15 | 28 | 28 | 17 | 15 |
| KÖYCEĞİZ | 31 | 37 | 42 | 41 | 37 | 31 |
| KAS | 24 | 30 | 34 | 33 | 29 | 23 |
| Max. | 38 | 45 | 45 | 45 | 41 | 39 |
| Min. | 15 | 15 | 28 | 22 | 12 | 15 |

PET≥41 Extremely hot
35≤PET<41 Hot
29≤PET<35 Warm
23≤PET<29 Slightly warm
18≤PET<23 Comfortable
13≤PET<18 Slightly cool
8≤PET<13 Cool

**Fig. 4** Mean monthly PET values

mean PET values are observed in the far southwest part of the area, Datça station throughout the period, possibly due to the effect of elevation and higher relative humidity while the lowest values are seen at the higher elevations like in Menteşe and Elmalı.

It is seen when the relationship between Ta, Tmrt and PET in °C is considered in Fig. 5 that Tmrt corresponds higher values as it is the result of radiation temperature. In some districts, PET and Ta are seen to be very close to each other due to different wind velocity and direction and elevations. In Fethiye, 3 parameters follow a parallel trend and Tmrt represents the highest values while PET values are higher than Ta since the area is exposed to moist sea breezes and so PET is higher than Ta due to the high humidity content. In Bodrum district, sea breezes are also effective but in the morning wind blows from land and reduces the humidity content of air. In Seydikemer, in the morning and evening Ta is equal to PET, since the city is located in some distance to maritime effect

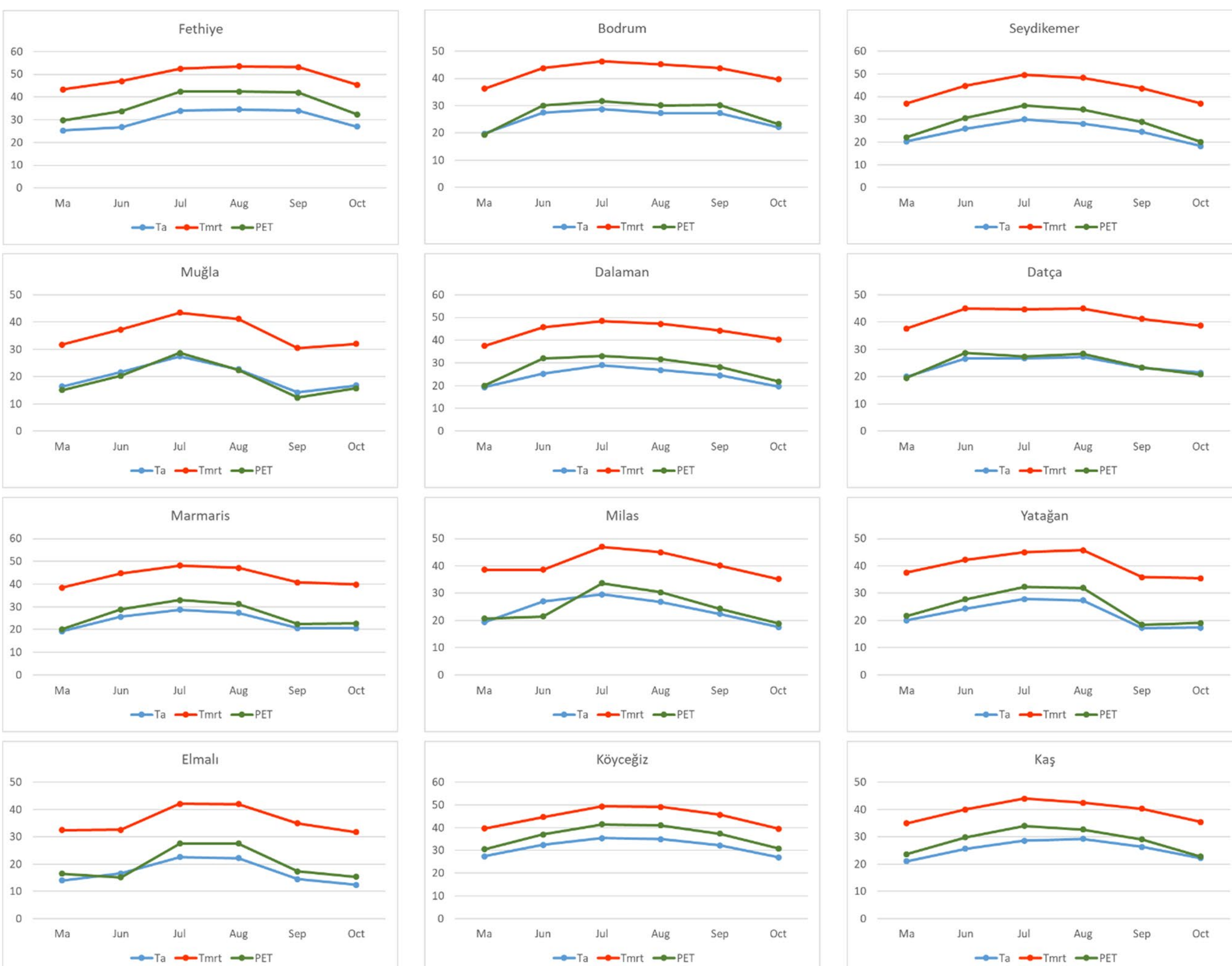
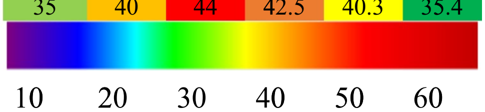



**Fig. 5** Trends in Ta, Tmrt and PET in the study period

and exposed to wind from mountains with low moisture content. Menteşe is at an elevation of about 600 m, and Ta shows a trend equal to PET and away from the maritime effect therefore due to the lack of moisture it is one of the most comfortable settlements in the study area especially in the middle of summer. Dalaman seems to represent a normal trend line for each parameter while in Datca, PET and Ta show nearly the same values and trend during the study period depending on the humidity supplied by winds from sea to land. In Marmaris, wind from the sea is also effective and causes close values for PET and Ta during daytime while in Milas, PET is lower than Ta in the morning resulting from the wind chill due to sea breezes in the midday. In Yatağan district, parameters follow a normal trend, PET is nearly equal to Ta in the morning and evening time but in the middle of the day while in Elmalı, PET is higher than Ta as the result of a 1000 – m elevation from sea level. In Köycegiz, trend of parameters is in normal order but PET is closer to Tmrt and much higher than Ta showing a strong heat stress while in Kaş, PET and Ta values are close to each other in the morning and evening.

Monthly mean values of Tmrt are presented in Fig. 6. The highest mean Tmrt values are observed in Fethiye and Datça in July and August while the lowest ones are in Muğla and Elmalı depending on the elevation.

| $Tmrt(^0C)$ | May | Jun | Jul | Aug | Sep | Oct |
|---|---|---|---|---|---|---|
| FETHİYE | 43.3 | 47 | 52.5 | 53.5 | 45 | 45.4 |
| BODRUM | 36.2 | 43.8 | 46.2 | 45.2 | 43.8 | 39.7 |
| S.KEMER | 37 | 44.7 | 49.5 | 48.3 | 43.6 | 37 |
| MUĞLA | 31.7 | 37.2 | 43.4 | 41.1 | 30.5 | 32 |
| DALAMAN | 37.5 | 45.7 | 48.5 | 47.2 | 44.2 | 40.4 |
| DATÇA | 37.6 | 45 | 44.7 | 45 | 41.1 | 38.7 |
| MARMARİS | 38.5 | 44.7 | 48.2 | 47.2 | 40.8 | 39.8 |
| MİLAS | 37.6 | 42.2 | 45 | 45.8 | 35.9 | 35.5 |
| YATAĞAN | 37.6 | 42.2 | 45 | 45.8 | 35.9 | 35.5 |
| ELMALI | 32.5 | 32.6 | 42 | 42 | 35 | 31.7 |
| KÖYCEĞİZ | 39.7 | 44.7 | 49.4 | 49.1 | 45.7 | 39.6 |
| KAS | 35 | 40 | 44 | 42.5 | 40.3 | 35.4 |




| | | | | | | |
|---|---|---|---|---|---|---|
| Max | 43.3 | 47.0 | 52.5 | 53.5 | 45.7 | 45.4 |
| Min | 31.7 | 32.6 | 42.0 | 41.1 | 30.5 | 31.7 |

**Fig. 6** Mean Tmrt values of the area

Mapping human thermal comfort conditions is helpful to show the distribution of ideal conditions in a defined area in the desired periods for the work fields like spatial planning and design. It is also possible to combine relevant/effective parameters with thermal comfort like topography, plant cover, water surface. Previous studies (Zengin et al. 2010; Toy et al. 2018) using IDW for spatial distribution were generally based on the interpolation of air temperature, humidity and wind speed. This study contains the distribution of thermal comfort using PET and Tmrt values and interpolation method.

In the present study, surface morphology (density of built environment) is an effective factor in the study area where the meteorological values were taken from city centres. Even though the study area is covered with native plant species, cities have transformed such surfaces causing UHI, intensity of which increases in the combination of moisture supply from the sea breezes.

## Conclusion

This study is aimed to determine the spatial and temporal distribution of human thermal comfort conditions in the hottest and most humid west part of the Mediterranean region (Southwest Anatolia), which harbours the world-famous summer tourism centres. Human thermal comfort is represented in the study by PET and Tmrt values calculated for the hottest daytime and period of the year (five hottest months). Results show that, except for the first and last month (May and October), the study area is majorly exposed to uncomfortable ranges dominating heat stress. Therefore, such a condition should be evaluated from the perspective of tourism sector to increase tourist satisfaction and revenue.

Since locals and tourists gather in the city centres, thermal comfort levels of cities in the study area should be increased using short- and long-term measurements.

From the results of the study, it is suggested that lower temperature and greater wind velocity can create neutral thermal environment (comfortable conditions) by removing the effect of heat stress in summer. It is well known that solar radiation is among the most influential parameters on human thermal comfort, however in the study, meteorological parameters were taken from shadowy environment as a measurement standard all over the world. For that reason, Tmrt is expected to have the highest influence on comfort conditions under clear sky. From this point of view, wind plays the most important role in providing comfortable conditions not only with its velocity but also direction. An additional measure can be the use of open water surfaces to cool the micro environment.

The use of different calculation, statistical and mapping tools like GIS for the analysis of human thermal comfort conditions makes important contributions to the spatial planning and design process of an area since they enable to perform different types of analysis in various approaches. In this study, detailed maps were created for human thermal comfort conditions (ranges) using GIS instruments to combine various parameters (like topography) with thermal comfort data to obtain more precise results to take accurate measures.

In the scope of the study, 24-h thermal comfort analyses were also conducted, but only daytime results are given. However, in the future studies, hourly index values can be used to evaluate thermal conditions in a more detailed manner.

**Author contribution** All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Ismail Çınar, Nihat Karakuş. The first draft of the manuscript was written by Süleyman Toy and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

**Data availability** The temperature data used in this paper come from the Turkish Meteorological Data Network (http://mgm.gov.tr).

## Declarations

**Ethics approval and consent to participate** Not applicable

**Consent for publication** Not applicable

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