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Evaluation of thermal climatic region areas in terms of building density in urban management and planning for Burdur, Turkey

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Abstract

The main aim of this research is to investigate the bioclimatic conditions of Burdur city center in different terrain areas by taking measurements at 20 different points in the same time zone over the city. In order to investigate the bioclimatic comfort properties of Burdur City by taking into consideration the number of floors in Burdur city center, on 17 February 2018 between 16.00 and 16.30 h, temperature and relative humidity measurements were made with two Benetech GM8910 devices from 20 different locations with different characteristics. In addition to the parameters taken from 20 points, the physiological equivalent temperature (PET) index which includes the human energy balance was used. Thermal detection values of 20 stations were calculated. Multiple linear regression models were used for spatial distribution of the obtained values. According to the analysis, urban high building density areas have higher PET values in most of the day than in other terrestrial areas. Between these areas and open areas was a difference of 0.4–1.2 °C, between parks 2.2–3 °C, between locations 1.4–2.2 °C, and between rural areas 1.7–2.5 °C per day. There are mean PET differences.

Keywords Burdur · GIS (geographic information system) · Measurements · Regions · Thermal climate · Urban management and plan

Introduction

The increase in urban population in almost all of our cities compels the government, municipalities, and urban planners to accommodate these imposing changes, thus reshaping the structure of cities. The expectations of present-day residents from their habitats are changing, with more and more criteria now playing a big role in where people relocate. Social facilities, activity facilities, proximity to nature, and the quality of air are some of these criteria. Climatic conditions of a region are one of the factors that are taken into account nowadays. People feel more dynamic and healthier when the best conditions of climatic affects such as precipitation, temperature, wind, and humidity are favorable. These effective values are briefly called climatic comfort scales. When the effect of climatic comfort is not in the appropriate value range, it leads people to feel uncomfortable in that area and potentially drives them away (Artis and Carnahan 1982; Cetin et al. 2010, 2017, 2018a; Olgyay 2015; Milne 2013; Cetin 2015a, 2016a, b, c; Barsi et al. 2007; Attia and Herde 2009; Chander and Markham 2003; Cetin and Zeren 2016; Kim et al. 2017; Insaf et al. 2013;Cetin and Sevik 2016; Li et al. 2019; Kaya et al. 2018).

In many developing countries, in addition to the rapid urbanization and ecological concerns, unplanned urbanization has led to the creation of dysfunctional and esthetically unattractive cities. Ecological planning will prevent these concerns from turning into important environmental problems in the future. Because, although terms such as ecological balance, clean environment, and comfort conditions are not very important for people at first, these factors come to the forefront with increasing income levels, and they can be the most important factors for people to choose the cities they will live in (Li et al. 2012; Cetin et al., 2010, 2018a, b, c; Streutker 2002; Kim et al. 2017; Cetin 2016a, b, c; Sobrino et al. 2004; Insaf

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et al. 2013;Cetin and Sevik 2016; Li et al. 2019; Cetin and Zeren 2016; Matzarakis et al. 1999; Kaya et al. 2018).

Perhaps the most important component of ecological planning is climate. The climate and air have a significant effect on people's physiological and behavior status. Making human performance and climate comfort can be affected by climate change. The condition of climatic or thermal comfort refers to healthy and dynamic weather conditions and therefore human satisfaction (Artis and Carnahan 1982; Cetin and Zeren 2016; Chander and Markham 2003;Topay 2013; Milne 2013; Cetin 2015a, b, c, 2016a; Chung and Kim 2019; Kim et al. 2017; Insaf et al. 2013; Li et al. 2019; Cetin et al. 2018a, b; Kaya et al. 2018).

The factors of climatic conditions have six important parameters in landscape planning and management. These parameters are associated with climatic conditions such as average temperature, relative humidity, and average wind speed (Steadman 1979; Synnefa et al. 2007; Cetin 2015a, 2016a; Cetin et al. 2017, 2018b; Sobrino et al. 2004). People tend to be healthy and lively in situations where environmental factors such as humidity, temperature, wind, and precipitation are at regular intervals. If these climatic values are in the proper range for people, then it is called bioclimatic comfort. In the middle latitudes where our country is located, the sensed temperature value, which is considered suitable for climatic comfort range, is between 24.9 and 17 °C depending on the wind and humidity (Kocman 1991; Cetin et al. 2010; Cetin 2015a; Sobrino et al. 2004). Cetin et al. 2010, Cetin 2015a, 2016a mentioned that 21–27 °C temperature and 30–65% relative humidity create a combination of comfort conditions if all other conditions are normal. Under or above these conditions, in order to achieve bioclimatic comfort, either shade or radiation energy or heat, specific humidity, and wind are required. However, it is very important to determine these negativities in the planning studies and to serve the purpose of landscaping arrangements (Cetin 2015a, 2016b; Sobrino et al. 2004; Cetin et al. 2010, 2018a, b; Matzarakis et al. 1999).

Planned urbanization is one of the main indicators of development in physical and socioeconomic terms. However, the more sensitive and diverse the data or criteria that are based on planning, the higher the success achieved in planning (Cetin 2015a, b, c, 2016a, b, c Chung and Kim 2019; Kim et al. 2017; Cetin and Zeren 2016; Insaf et al. 2013; Cetin and Sevik 2016; Li et al. 2019; Cetin et al. 2017, 2018a, b, c).

In our life cycle, our goals, our settlements, our lifestyle, and many other issues that we cannot count are kept under control of the climate (Kocman 1991). Climatic, geographic environment that determines the viability of the natural processes and process of cultural and sociocultural is in a position to integrate. Therefore, it is the first degree in the formation of both sociocultural and natural environment. Therefore, people living in climate conditions where they feel more comfortable contribute significantly to their happiness and health (Li et al. 2012; Cetin et al. 2010, 2018a, b, c; Streutker 2002; Kim et al. 2017; Cetin 2016a, b, c; Sobrino et al. 2004; Insaf et al. 2013;Cetin and Sevik 2016; Li et al. 2019; Cetin and Zeren 2016; Matzarakis et al. 1999; Kaya et al. 2018).

Determining areas where climate parameters exist where people feel comfortable and taking these areas into account are the most important stages of modern urban planning. Therefore, many researches have been conducted to determine the lower and upper limits of the climatic conditions that provide bioclimatic comfort and some values that differ slightly from each other have been obtained. However, the bioclimatic comfort approach of Olgyay (1973), which was developed in order to determine the climatic comfort requirements of all people living outside the equator and Arctic areas, is of particular importance in this regard. Olgyay (1973) determines the conditions of climatic providing bioclimatic comfort by means of a coordinate system. The climate data in any area can be processed on this coordinate system called bioclimatic values, and the climatic values required to achieve bioclimatic comfort in this area can be revealed (Altunkasa 1990; Li et al. 2012; Cetin et al. 2010, 2018a, b, c; Streutker 2002; Kim et al. 2017; Cetin 2016a, b, c; Sobrino et al. 2004; Insaf et al. 2013;Cetin and Sevik 2016; Li et al. 2019; Cetin and Zeren 2016).

Cetin et al. (2010) stated that the searches conducted in our country about the evaluation of the comfort zone for climatic and its reflection on the landscape management and planning process started to be seen in the late 1960s. Kocman, in his study in 1991, found effective temperature range values for our country to be between 24.9 and 17.0 °C (Cetin et al. 2010, 2018a, b, c; Streutker 2002; Kim et al. 2017; Cetin 2016a, b, c; Sobrino et al. 2004; Insaf et al. 2013;Cetin and Sevik 2016; Li et al. 2019; Cetin and Zeren 2016).

Cinar (1999) revealed the bioclimatic structure of the town of Fethiye and established a balanced criterion with the climate that could be included in the planning process. Cinar (2004) later carried out a search on the effectiveness of climatic comfort measures in the landscape planning and management process on the Muğla-Karabağlar Plateau. Cetin et al. 2010 worked out a research on the possibilities to utilize GIS (geographic information systems) for the determination and mapping of suitable regions with climatic comfort and prepared the climatic comfort maps for the first time.

After this date, a large number of studies have been conducted on biocomfort mapping, especially with the use of GIS. Cetin and Zeren (2016) Kastamonu Inebolu in Turkey; Gumus (2012) in Ankara; Cetin et al. (2010) in Kutahya; Topay (2013) in Isparta; Cetin (2015a) Kastamonu in Turkey; Kestane and Ulgen (2013) in Izmir Province; Cetin (2016a) in Kastamonu Cide in Turkey; Cetin et al. (2018b) in Elazig; Cetin et al. (2017) in Kastamonu Doganyurt in Turkey; Topay and Parladir (2015) in Isparta Province in Turkey; Demir et al. (2014) in Aras basin; and Cetin et al. (2018a) in Aydin made studies on bioclimatic comfort for suitable planning and management making bioclimatic maps.

Numerous studies have been conducted in the world on bioclimatic comfort. Roshan et al. (2017) in Iran, Kamoutsis et al. (2013) in Greece, Mahmoodi and Iravani (2012) in the Sirjan Desert, and Safaeipoor et al. (2013) studies in Shiraz can be given as an example.

The climatic comfort maps generated within the aim of this research, which makes enabling the status of climatic comfort regions to be evaluated locally because of the climatic regions of characteristics of Burdur city center, can be determined to use as a basic for the planning of physical processes of the region basin. Approaching urban design with traditional management and planning, the determined climatic region comfort is not made to create or ignored due to use of inputting only climate data. Thus with these requirements, as a main base data that it can be generated in the plan and management of physical urban plans to be make created with, it is proposed to reveal the urban region of climatic comfort situation of Burdur city center.

Thermal sequences are needed to understand the reactions of people to meteorological variables in their environment and to explain the bioclimatic conditions in a concrete way. The directories that are prepared to reveal the reactions of people against the atmospheric events are called thermal indexes or thermal comfort directories (Li et al. 2012; Cetin et al. 2010, 2018a, b, c; Chander and Markham 2003; Topay 2012, 2013; Olgyay 2015; Cetin 2015a, 2016a, b; Streutker 2002; Cetin and Zeren 2016; Topay and Parladir 2015; Matzarakis et al. 1999). In this study, physiological equivalent temperature (PET), which is one of the directories that has wide usage in the world, is used to evaluate the response of thermoregulators providing human heat balance due to meteorological climatic parameters such as humidity, air temperature, wind speed, and average radiation temperature.

Materials and methods

Burdur City is where a material in this research is located in southwest Turkey in the Mediterranean region. The research area where the measurements points were taken is shown in Fig. 1. The device used to take the measurements

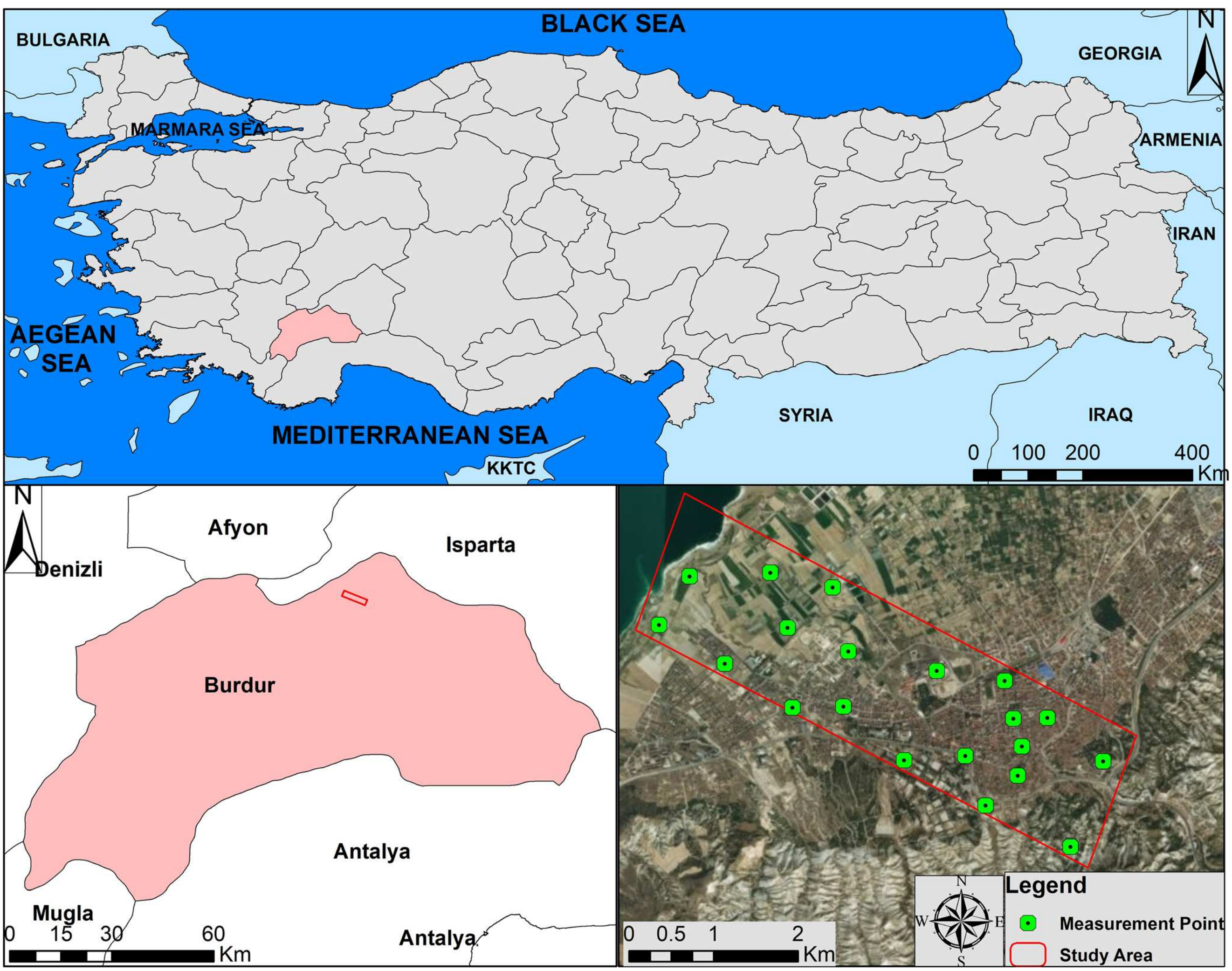

Fig. 1 Location of the research area showing the measured points

Fig. 2 The measurement device and how to take the measurements by the researcher

and the researcher showing how to take measurements with the devices are shown in Fig. 2. In order to examine the climatic comfort characteristics of Burdur City, relative humidity and air temperature measurements were made with two Benetech GM8910 brand devices from 20 different locations between 16.00 and 16.30 on February 17, 2018. The technical specifications of the device are given in Table 1. The building data and the profile map of the city center are given in Figs. 3 and 4.

Temperature data were measured in 20 different locations by the cokriging method. Cokriging method is as follows:

$$Z_1\ (S) = \mu_1 + \varepsilon_1\ (S)$$

$Z_2\ (S) = \mu_2 + \varepsilon_2\ (S)$ is calculated with the formula.

Relative humidity data collected from the field were mapped by the kriging method. The basic equation of the kriging technique is as follows:

$$Z^{\mathrm{p}} = \sum_{i=1}^{n} W_i\, Z_i$$

In this equation,

Z^{p} The desired corrugation value of point P.
W_i The weight values corresponding to each Z_i used in the calculation of Z^{p}.
Z^{p} Correction values of points used in the calculation of Z^{p}
N The number of points used in the calculation of Z (Tural 2011)

Temperature-humidity index was obtained/derived from air temperature and relative humidity measurements by E. C. Thom. Thom's index is as follows:

$$\mathrm{DI} = T - (0.55\text{–}0.0055 \times \mathrm{RH}) \times (T\text{–}14.5)$$

Here,

DI Temperature-humidity index (discomfort indices)
T Monthly average temperature (°C)
RH Relative humidity (%)

In order to determine the climatic comfort classes of the sensed temperature values, physiological equivalent temperature (PET) created by Basansenot, in other words, temperature equivalent psychology (TEP), classification table is used in Table 2. PET classification was defined by Mayer and Höppe in 1987 (Guclu 2010; Toroglu et al. 2015).

The PET values obtained from the stations were analyzed by using ArcGis software and by using multiline regression analysis with land use values, and constant and independent coefficient was calculated for each hour. Regression formula was applied to raster data using ArcGis software. A raster map was obtained

Table 1 Benetech GM8910 technical properties

Item of measuring	Range of measuring	Resolution	Accuracy	Time of response (s)
Temperature (°C)	− 20.0~60.0 °C	0.1 °C	± 1.0 °C	1
Humidity (%)	0~100.0% RH	0.1% RH	± 5% RH	1
Wind (°C)	− 40.0~10.0 °C	0.1 °C	± 2.0 °C	1
Dew point (°C)	− 40.0~60.0 °C	0.1 °C	± 2.0 °C	1
Speed of wind (m/s)	0.7~30.0 m/s	0.1 m/s	± 3% ± 0.3 m/s	1
Pressure of barometric (hPa)	300~1100 hPa	0.1 hPa	± 1.0 hPa	1
Altitude (m)	500~900 m	1 m	–	1
Illumination (Lx)	0~55000 Lx	1 Lx	± 3%	1
Size	48 × 21.2 × 122 mm			

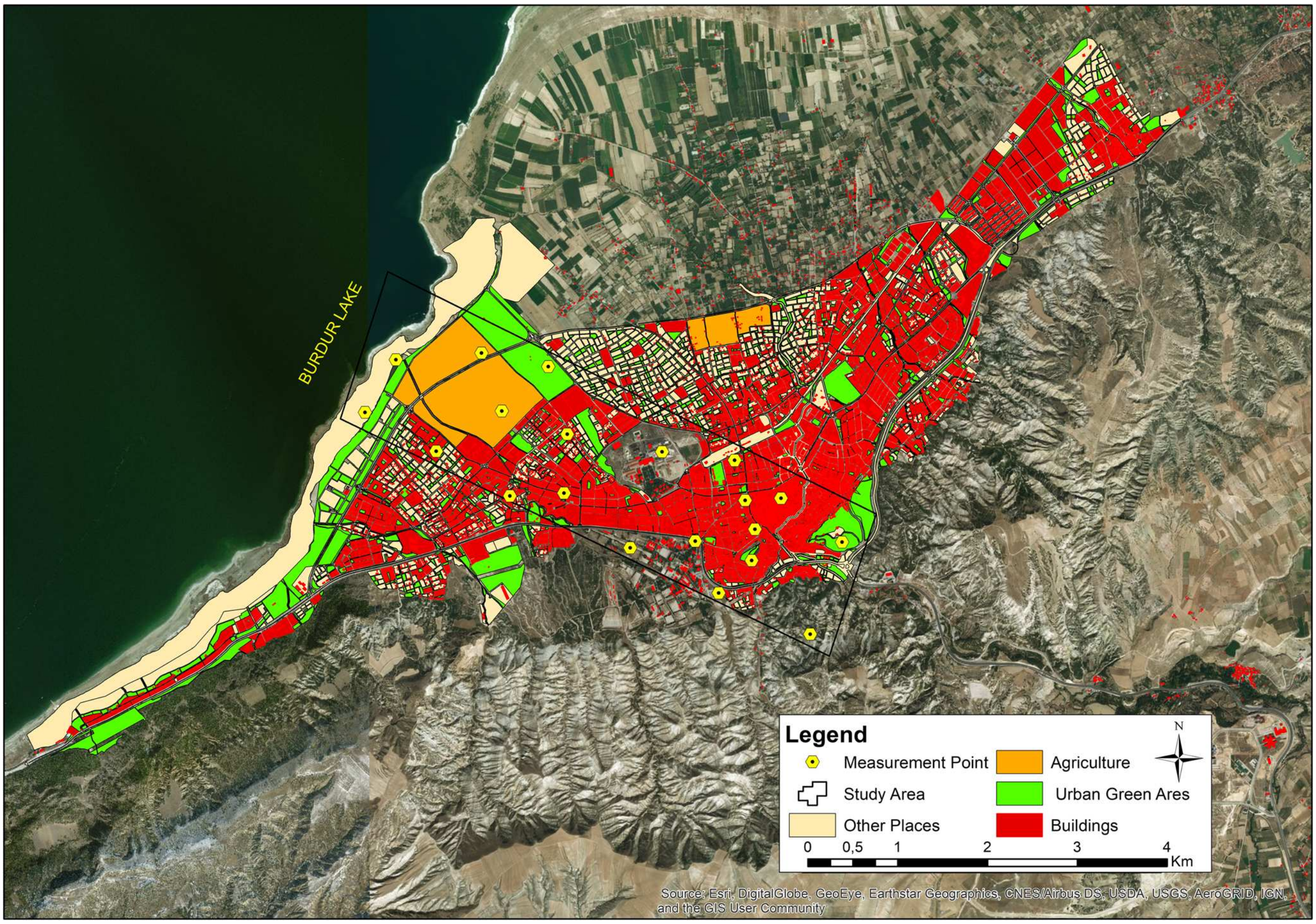

Fig. 3 The land use of Burdur city center

using the digital elevation model (DEM) for the elevation variable. For land use, Corine land classification was reduced to 12 steps. A raster numerical land use map is obtained through Bowen rates projected for each step. The map algebraic module in the spatial analysis tools of the ArcGis software can be used to calculate raster data. In this way, when the data for the independent variables are placed in the regression estimation equation, a raster PET map of the work area is obtained. The difference between the PET values of the stations and the actual values in the maps varies between 0.002 and 0.01 °C. The differences between the estimated value and the actual value are reasonable.

Results and discussion

The most negative bioclimatic conditions in Burdur city center are in the northern and southern regions. The main reason for the occurrence of the lowest levels of thermal detection is the lack of heat energy. There is a PET difference between 1.5 and 7 °C depending on the elevation between high building density areas and rural areas in the city center. According to the averages, the city heat is the strongest at 16:00 h. High building density areas' air temperature is 1.8–1.9 °C and urban forest open areas and PET values 2.2–2.4 °C higher than in rural areas. It is compatible

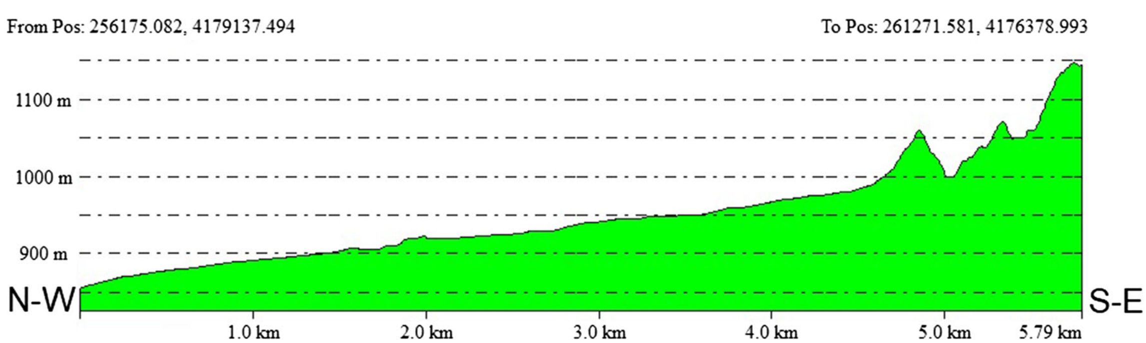

Fig. 4 Burdur city center's profile map

Table 2 Basansenot classification scheme

Index values (DI)	Thermal comfort classifications for people
< − 40.0	Extremely ice
− 39.9 to − 20	Freezing cold
− 19.9 to − 10	Extremely cold
− 9.9 to − 1.8	Very cold
− 1.7 to + 12.9	Cold
13.0 to + 14.9	Cool
15.0 to + 19.9	Comfortable
20.0 to + 26.4	Hot
26.5 to + 29.9	Very hot
> + 30.0	Extremely hot

with the fact that high building density areas in the city center have higher thermal sensing values than other areas. According to this, freezing cold in high areas in the north and southeast of Burdur and extreme cold thermal perceptions in other areas are dominant (Figs. 5, 6, and 7).

PET values are increasing according to an average of 16:30 h. The highest increase in PET values is in the east and west. This is because the surface area is large. Therefore, short-wave radiation from the sun is absorbed by more space. Accordingly, the long-wave radiation flow occurs at high rates, increasing the mean radiant temperature.

Atmospheric heat islands are formed in sections of high building density areas with high number of floors and in areas with less green areas. PETs of areas with high building density are 0.8–2.7 °C higher than rural areas. This difference increases to 6 °C depending on the increase in the elevation. Cold to the south and low areas of the city center, cold to the north of this area, and cold and high rural areas have extreme cold thermal perceptions.

In Burdur city center, there are different areas in terms of elevation, topography, maintenance, and land use. These differences lead to changes in the thermal sensing values during the day. Although the interaction between the abovementioned parameters and PET values has different rates and trends, the main factor determining the bioclimatic conditions is land use.

Within the different land use areas in the city center, the open spaces in the urban park are distinguished by distinct differences in thermal comfort conditions. This is caused by long-wave radiation and heat transfer. This can be seen from the trend of PET values throughout the day. The thermal

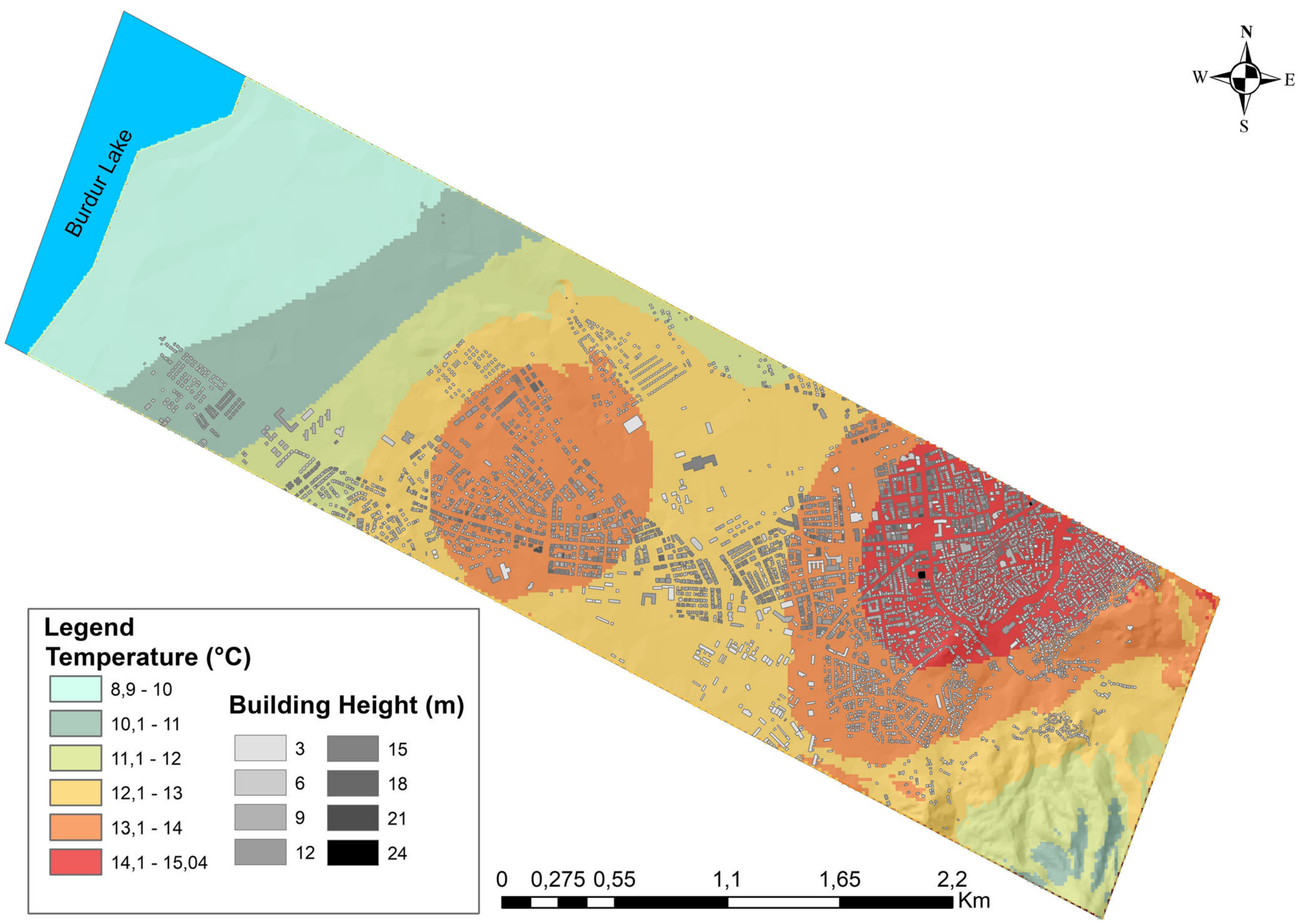

Fig. 5 The temperature map

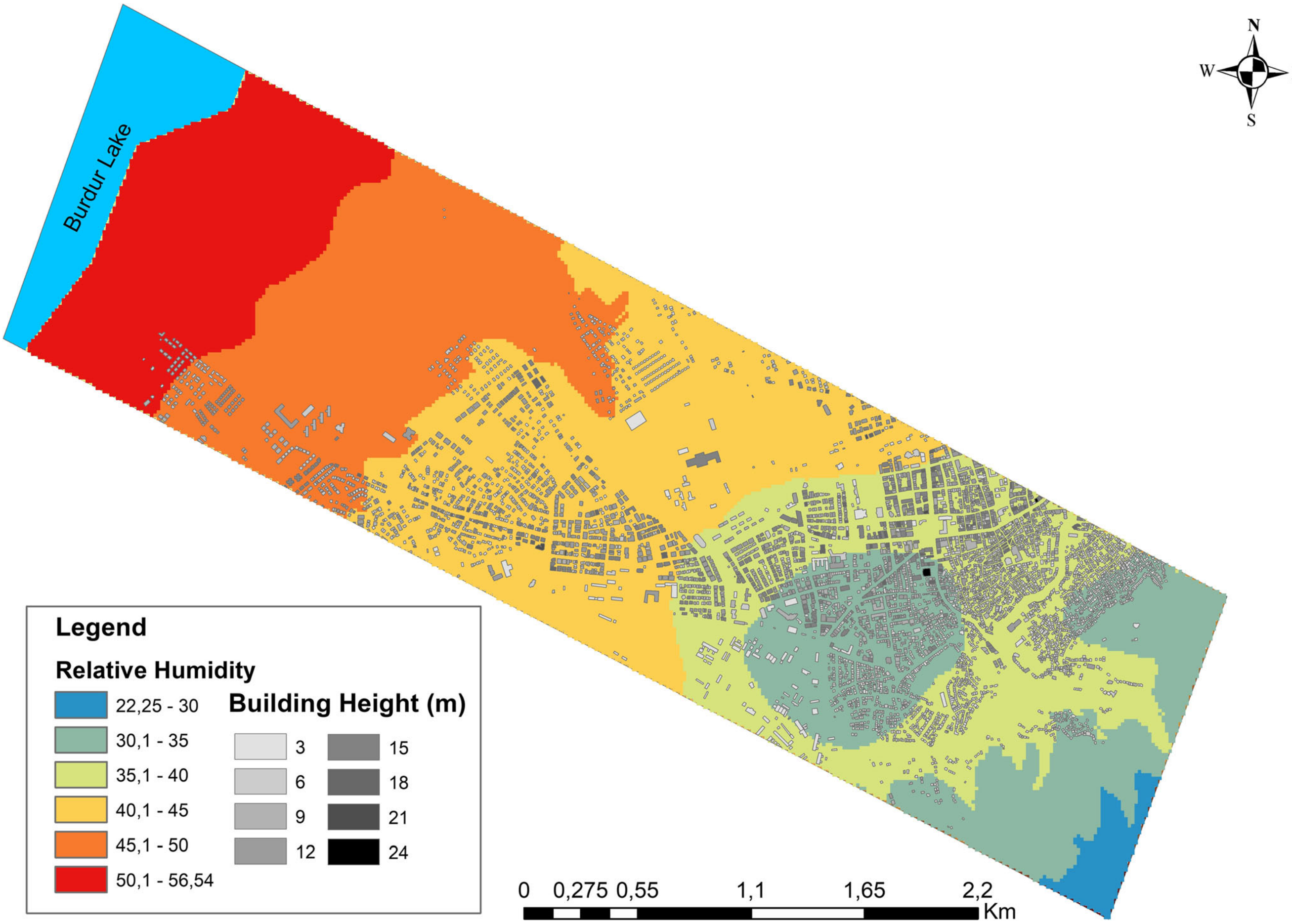

Fig. 6 Relative humanity map

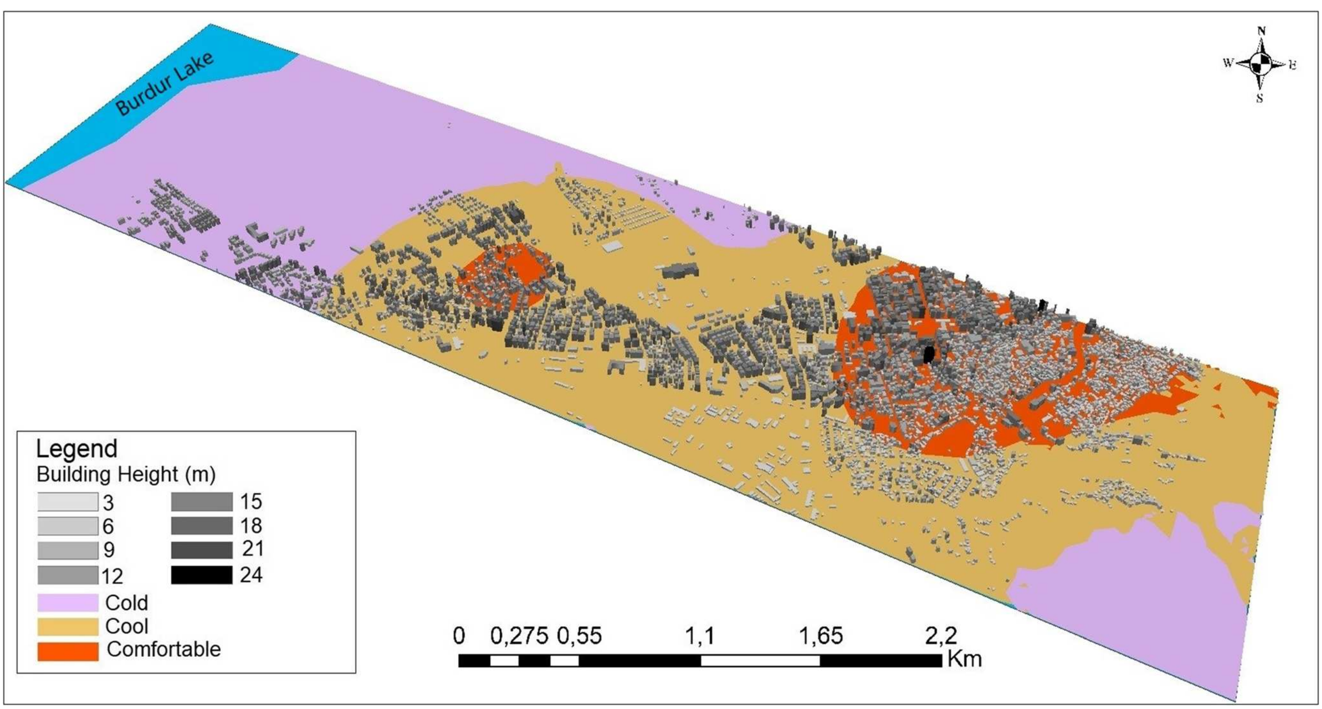

Fig. 7 Biocomfort area depends on the results of Thom-Besancenot

detection values of urban park are higher than the surrounding rural areas and most of the areas with high building density as long as the sun is in the sky. The cover formed by the trees provides the flow of long-wave radiation using more surfaces. Further radiation flow also results in an increase in the average radiant temperature. The average radiant temperature in the city at 1600 h may be 15 °C higher than the surrounding environment. It is observed that the city park is able to maintain higher PET values for a period of time when short-wave radiation starts to decrease. Looking at the received points, if the source of radiation is removed shortly after the decrease in PET values, it reaches the highest level (Fig. 7).

Conclusions

The most unfavorable conditions in terms of comfort in the city center of Burdur are large areas. In the center, buildings with green areas and medium-height buildings show positive thermal sensing values. In Burdur city center, high building density is seen as a warm island. The warm cliffs of the warmer island are slightly sloping to the west and east, and it is steeper in the south. Cities are changing depending on the density of the buildings, energy transfer, thermal conditions, humidity conditions, and air circulation. As a result, bioclimatic conditions are shaped differently in areas with natural materials and patterns. Their reactions to energy at an equal rate change. In Burdur city center, even though the solar radiation is the same, higher PET values are formed in the high building density areas during the night. The green areas in the city give similar reactions to the urban texture and rural texture. The influence of the positive bioclimatic conditions provided by urbanization in the west of the area is evident when compared with the north. It has lower PET values in rural and urban areas, which are higher in north area. In the north where long-wave radiation, transport and transmission occurs, it has the reaction of areas with high building density under bioclimatic conditions. It is observed that rural characters evolved into urbanization during the night.

It is noteworthy that urban green areas are affected by a hybrid effect. According to the points taken in Burdur, cold thermal perceptions are dominant in different levels. Therefore, bioclimatic conditions in Burdur are not suitable for living without urbanization. Urbanization brought about the change of energy transfer, thermal, humidity, and wind conditions. Alterations in areas with high building density with the current situation reduce the cold pressures that dominate most of the year. Between these regions and open areas 1.2–0.4 °C, between parks 3–2.2 °C, between locations 2.2–1.4 °C, and between rural areas 2.5–1.7 °C, there are average PET differences. Therefore, less energy is used in rural areas than in rural areas in order to increase thermal conditions and to make them suitable for human life. At the end of July and early August, when PET values were high, extreme heat detections occurred in areas with high building density. In short, the buildings that people make to protect from the cold are at risk of becoming a heat trap in the hot period. In such cases, urban green areas serve as refrigerators and soften the urban climate. The primary condition for the creation of comfortable cities is enough green space. Therefore, taking into account climatic conditions in management and planning will be effective in the creation of more sustainable and comfortable cities.

Compliance with ethical standards

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

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