Chapter 33
Evaluating the Spatial Distribution of Thermal Comfort Conditions in a High, Elevated Lakeside City, Van

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Abstract Thermal comfort can be defined as the state of people feeling comfortable/happy in their environment. This study is aimed to explain the distribution of thermal comfort conditions in the city of Van, which is a historical city with a high altitude established on the shores of Lake Van. In the study, the data of three meteorology stations was evaluated according to the physiological equivalent temperature (PET) index, and their spatial distribution was explained by taking into account many variables related to the field with Geographic Information Systems (GIS). As a result of the study, cold stress perceptions were dominant in the city from November to March, and "slightly warm" and "warm" stresses were dominant in the summer season. During the transition seasons, "slightly cool" stress and "comfortable" conditions are effective. Due to urbanisation, it has been observed that city centres have different thermal comfort conditions compared to the rural and semi-rural areas around them, and the thermal conditions of the city have slightly milder characteristics than the effect of Lake Van. For sustainable urbanisation, it is necessary to make urban design and planning with a geographical perspective that takes into account human, ecological and physical conditions.

Keywords Thermal comfort · Urban climate · Lakeside city · PET · Van

Introduction

Climate, which is the most important composition of the natural environment, has an impact on all human activities. Distribution of world population, economic activities, transportation, tourism, health, culture, architecture, settlement, etc. activities are under the control of the climate. Within the settlements, cities are the places where inventions that change the age of humanity are developed, socio-economic progress is recorded, and cultural interactions accelerate. Thanks to these features, cities are universal heritage areas of human history with their intangible and tangible cultural

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features (Author, 2006). However, the migration from rural to urban areas, which gained momentum with the industrial revolution, caused the number of cities to increase and their areas to expand. As a result of this situation, urban areas have been covered with impermeable surfaces such as asphalt and concrete, green areas in the city have been destroyed, and the air quality of the cities has deteriorated with the use of motor vehicles, industrial and domestic wastes. Due to all these factors, cities have had different climatic conditions from the semi-rural and rural areas around them. This situation has been demonstrated in many studies conducted in different parts of the world (Lerner 1964; Oke 1973; Mayer 1993; Unger 1999; Çiçek and Doğan 2005; Charalampopoulos et al. 2013; Türkeş and Erlat 2017).

With the increasing level of knowledge and technological developments, many studies have begun to study thermal comfort conditions, which are the state of feeling the common effect of all climate elements, according to the specific climatic conditions of each city. In the most general sense, thermal comfort can be defined as the state of feeling comfortable or comfortable/happy in the thermal environment (air temperature, relative humidity, wind, solar radiation, mean radiant temperature, etc.) (Olgyay 1973; Sungur 1980). It can also be expressed as a state of thermally undisturbed or neutral discomfort between uncomfortable heat and uncomfortable cold (Parsons 2003). In uncomfortable conditions, there are many social, economic and physical negativities such as decrease in people's welfare and happiness, health problems and increase in energy use, decrease in work efficiency (Anderson and Bell 2009; Nastos and Matzarakis 2011; Scherber et al. 2014; Huang et al. al. 2015; Błażejczyk et al. 2018; Fallah and Mayvaneh 2012; Aboubakri et al. 2020). The first studies started in the early 1900s (Haldane 1905) in order to present the thermal comfort conditions in a concrete way, and it has become an important issue with the methods developed day by day. Today, more than 100 thermal comfort indices have been developed, and bibliographic studies have been conducted on them (Landsberg 1972; Driscoll 1992; Epstein and Moran 2006; Parsons 2014; de Freitas and Grigorieva 2015). Thermal comfort indices, which were started to be developed to increase the work efficiency of the employees, are used in areas such as the outdoor conditions of cities, tourism-climate relations, human health, climate change and energy consumption, especially in the temperate zone. Among these indices, the physiological equivalent temperature (PET) index, which is widely used to determine the outdoor thermal conditions, especially in urban areas. In addition, PET index is an ideal tool for calculating human thermal comfort in different climate types (Toy 2010). The PET index is the latitude, longitude, elevation, etc. of the studied area. The radiation model, which can be entered in information and works in all computer operating systems, is calculated with RayMan software (Matzarakis et al. 2000). Therefore, the PET index was used in the study.

With the increase in urban areas, energy transfer, specific heat, albedo, humidity, evaporation, precipitation, air pollution, anthropogenic heat, impermeability of surfaces, thermal properties of materials used on surfaces and surface geometry change the thermal comfort conditions of cities (Oke 1981). Urban areas have more burning, suffocating and suffocating thermal conditions than the surrounding rural areas. Clarke and Bach (1971) stated that the suburbs in the city of Cincinnati, Ohio, USA, are more comfortable than the city centre, and this difference is most visible in the evening hours. Mayer (1993) found that wooded environments in Munich, Germany, are more comfortable than treeless environments. It has also been revealed in Szeged, Hungary (Unger 1999), a central European city where urban areas are more uncomfortable than rural areas, and Warsaw and Łodz, Poland (Blażejczyk et al. 2016). Çiçek (2003) stated that in the capital city of Turkey, Ankara, higher temperature stresses are experienced in the urban area during the summer season. In another study conducted in Ankara, it was stated that different thermal conditions were experienced according to the land texture of the city, and these differences were more pronounced at night (Türkoğlu et al. 2011). Such unfavourable comfort conditions due to urbanisation are located in Erzurum (Toy) in the northeast of Turkey.

Location and Properties of Study Area

The city of Van is located in Eastern Turkey, in the Middle East Anatolian Region (TRB2 Level 2 Region), on the Iranian border. The city was established between latitudes 38° 36′ N—38° 25′ N and longitudes 43° 29′ E—43° 18′ E, at an altitude of 1627–2000 m, and on the shores of Lake Van, Turkey's largest lake (Fig. 33.1). Lake Van ranks fourth among the closed lakes in the world and has the distinction of being the largest soda lake in the world (Koyuncu and Karakılçık 2019).

Van city, BC, it became the capital of the Urartians between 850 and 585 years and therefore has a historical texture that reflects the Urartian heritage (Eriçok 2019). Van, which has been an important city since the past, has had a dense population due to the urbanisation movements experienced all over the world after the industrial revolution. The city of Van has metropolitan status and consists of Tusba, İpekyolu and Edremit district centres. According to the 2021 Turkey Static Institution (TSI) data, the total population is 631,827, with 163.320 people in Tusba district, 339.952 people in İpekyolu district and 128.555 people in Edremit district.

According to Köppen-Geiger (Csa) in the city of Van, which has a high altitude on the shores of Lake Van, the climate is mild in winter, very hot in summer and dry, according to De Martone; steppe—semi-humid and according to Thornthwaite; (C1) semi-arid—less humid, according to Erinç; semi-humid climatic conditions are experienced (Bölük 2016).

In the city where continental climate conditions are experienced, the annual average temperature is 9.4 °C, the maximum average temperature is 28.5 °C in August, and the minimum average temperature is −7.6 °C in January, according to long term (1960–2020) averages. The total annual precipitation is 392.8 mm, the highest precipitation falls in the spring and autumn seasons, and the least precipitation falls in the summer season. The annual average relative humidity is 57%, the annual average wind speed is 2.3 (m/s), and the annual average cloud cover is 3.7 (octa) (Table 33.1 and Fig. 33.2). Due to the high elevation in the east of the city and the presence of Lake Van in the west, east–west winds are effective. In addition,

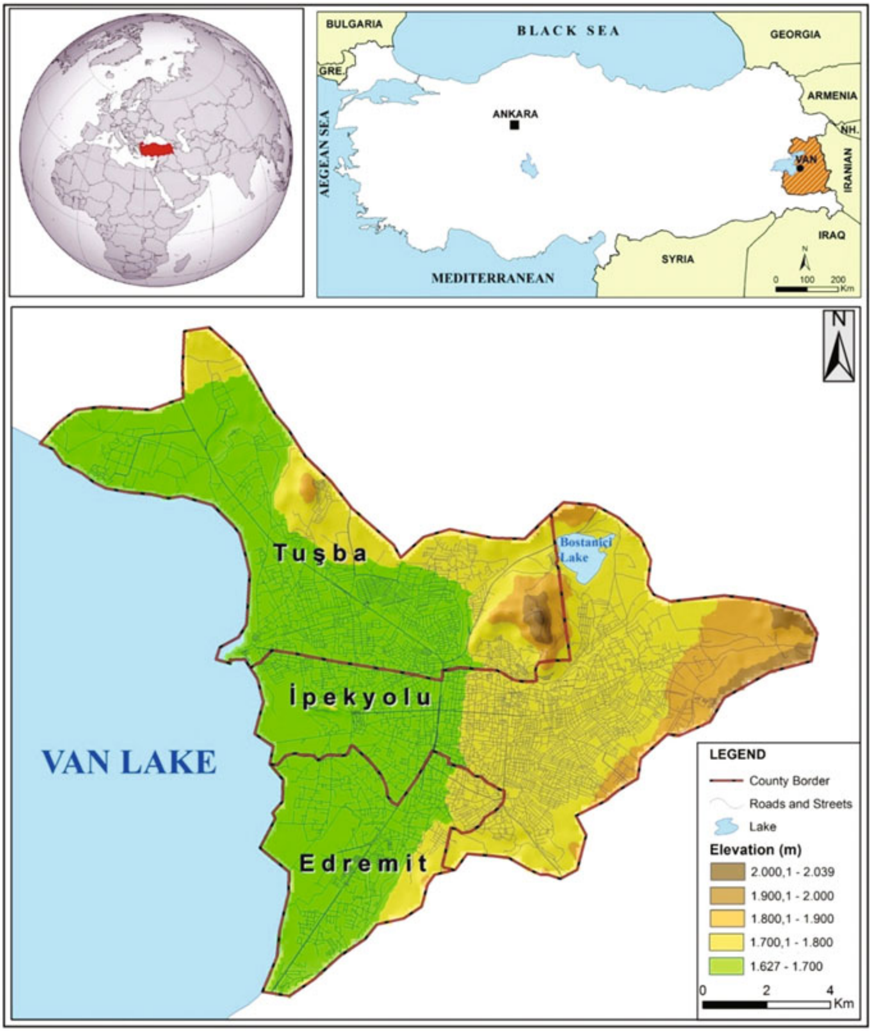

Fig. 33.1 Location map of the Van city

northeast winds from the hilly areas in the northeast of the city towards the city are also effective (Fig. 33.2).

According to the annual average values, in the city of Van, the mean temperature ranges between 7.5 and 9.6 ˚C, the maximum temperature ranges between 13.5 and 15.6 ˚C, and the minimum temperature ranges between 1.9 and 3.9 ˚C. While the highest values are observed along the coast of Lake Van, the values decrease with the increase in altitude from the coast to the interior. The total annual precipitation in the city ranges between 379 and 602 mm. While precipitation decreases along the coast of Lake Van, precipitation increases from the coast towards the interior. The

Table 33.1 Average and extreme meteorological values of the city of Van (1960–2020)

Months	Mean temperature (°C)	Maximum temperature (°C)	Minimum temperature (°C)	Precipitation (mm)	Relative humidity (%)	Wind velocity (m/s)	Cloud cover (octa)
1	−3.1	2.0	−7.6	35.3	68.0	2.0	5.3
2	−2.5	2.7	−7.1	32.7	68.0	2.0	5.2
3	1.6	6.6	−2.8	46.6	68.0	2.0	5.2
4	7.8	12.9	2.6	55.1	61.0	2.5	5.1
5	13.2	18.6	7.1	45.4	56.0	2.3	4.2
6	18.3	24.0	10.9	18.6	49.0	2.3	2.2
7	22.3	28.3	14.7	6.3	45.0	2.4	1.7
8	22.2	28.5	14.6	5.8	43.0	2.4	1.2
9	17.8	24.4	10.8	15.5	45.0	2.5	1.4
10	11.3	17.4	5.7	46.5	59.0	2.3	3.6
11	4.9	10.3	0.4	47.1	66.0	2.2	4.5
12	−0.4	4.5	−4.6	37.9	67.0	2.1	5.3
Annual	9.4	15.0	3.7	392.8	57.0	2.3	3.7

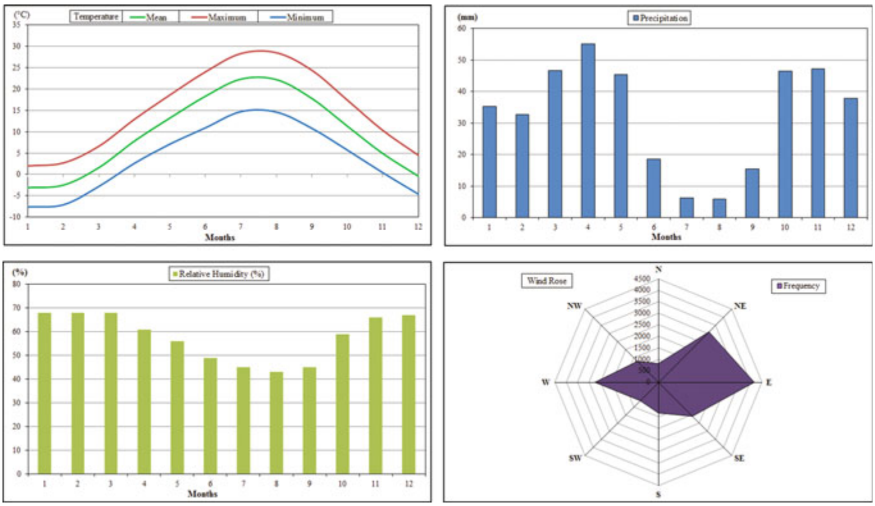

Fig. 33.2 Diagrams showing the climatic characteristics of the city of Van (1960–2020)

mean relative humidity is between 57 and 69%, while the relative humidity values are low in the urban area, and it increases in the urban peripheries. Mean wind velocity is between 0.8 and 3.6 (m/s). While the wind velocity is low due to the effect of buildings in the urban area, it increases in the city peripheries and the high areas to the southwest of the Bostaniçi Pond (Fig. 33.3).

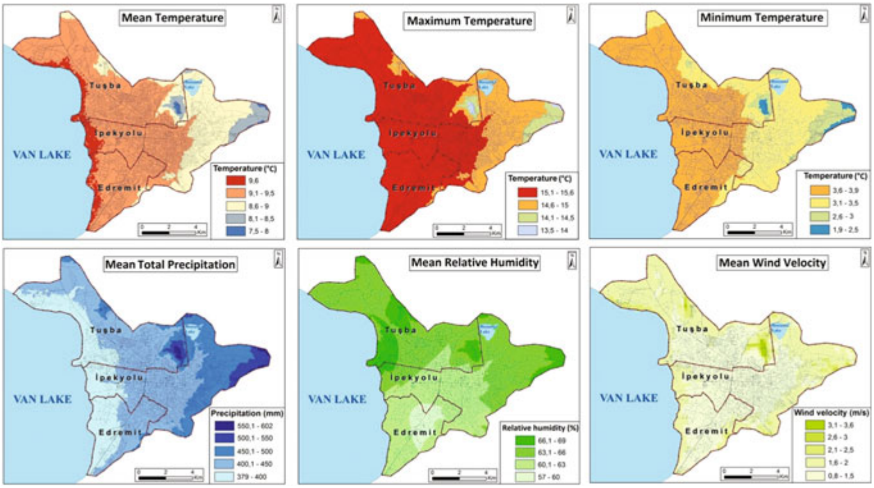

Fig. 33.3 Maps showing the climatic characteristics of the city of Van (1960–2020)

Materials and Methods

In the study, between 2015 and 2021 (7 years), hourly, temperature, relative humidity, wind speed and cloudiness data were used. Meteorology station 17170 is located at an altitude of 1665 m in the open area at Ferit Melen Airport, at an altitude of 1675 m in the urban area consisting of surfaces with built surfaces of meteorology station 17172, and meteorological station 17482 is at an altitude of 1647 m on the shore of Lake Van. Meteorology stations are located at close elevations and on different terrains (Table 33.2 and Fig. 33.4).

The first scientific approach to thermal comfort was formed by Heberden (1826) and noticed that humidity affects the temperature felt by humans as well as air temperature. But the first serious work was done by Haldane (1905). The first bioclimatic comfort index was the effective temperature index developed by Houghton and Yagloglou (1923). More than 100 indices have been developed to determine thermal comfort conditions, and bibliographic studies have been conducted on them (Landsberg 1972; Epstein and Moran 2006; de Freitas and Grigorieva 2015). Examples of indices used in thermal comfort studies are given in Table 33.3 according to their historical development.

Table 33.2 Meteorology stations used in the study

Station code	Latitude	Longitude	Altitude (m)	Surface
17170	38° 28′ 08.4" N	43° 20′ 13.2" E	1665	No structure
17172	38° 28′ 09.5" N	43° 20′ 45.6" E	1675	Structured area
17482	38° 30′ 46.0" N	43° 18′ 22.0" E	1647	Lake shore

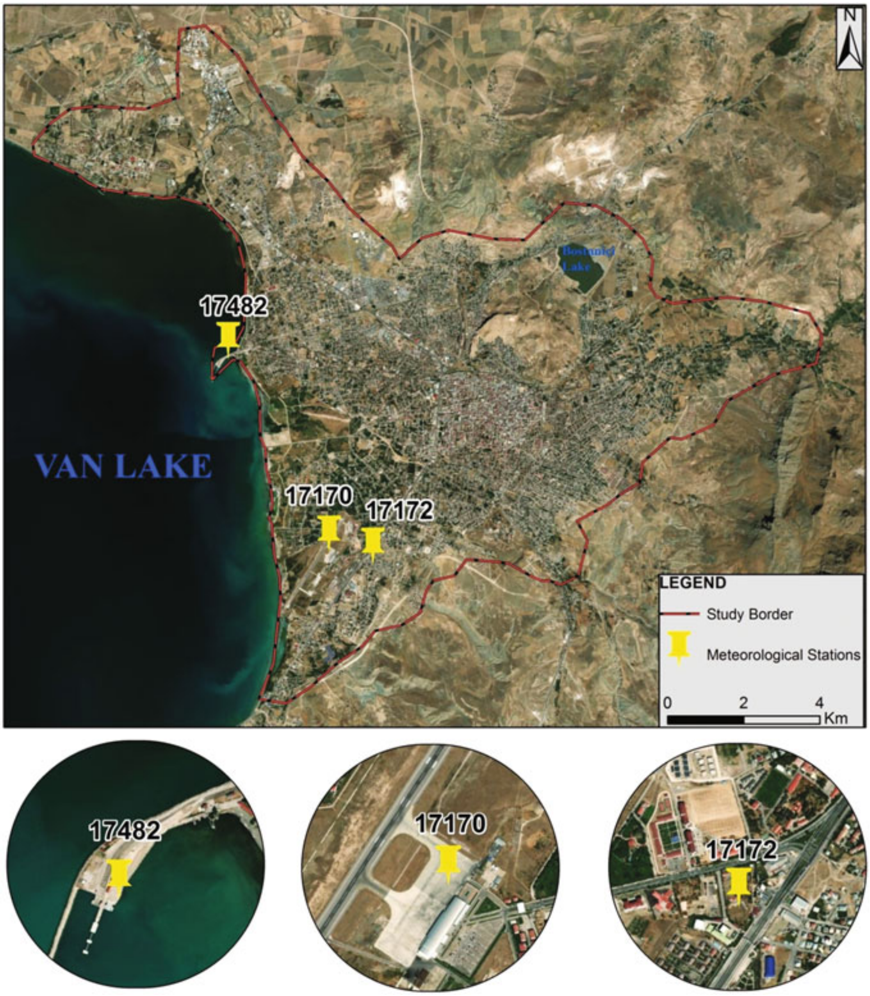

Fig. 33.4 Meteorology stations used in the study

Among these indices, the radiation model RayMan, which is widely used in the world, was used. The RayMan model calculates both atmospheric factors (temperature, relative humidity, wind speed, cloudiness and solar radiation) and personal factors (clothing, activity, metabolic processes, etc.) together in determining thermal comfort conditions (Matzarakis and Mayer 1999). The physiological equivalent temperature (PET) index obtained from the model is calculated by taking 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) (Höppe 1999; Matzarakis and Mayer 1999; Gulyas et al. 2006). Details about the RayMan model are given

Table 33.3 Examples of some of the thermal comfort indices

Year	Index	Short	Researcher
1923	Effective temperature	ET	Houghten and Yagloglou
1937	Operative temperature	OP	Winslow, Herington and Gagge
1945	Wind chill temperature	WCT	Siple and Passel
1959	Discomfort index	D	Thom
1970	Predicted mean vote	PMV	Fanger
1971	Standard effective temperature	SET	Gagge et al
1984	Physiological equivalent temperature	PET	Höppe
2000	Universal thermal climate index	UTCI	COST Action 730

in the studies (Matzarakis et al. 2007, 2010; Fröchlic et al. 2018). Thermal sensation levels of PET index were determined by considering a 35-year-old, 175 cm tall, 75 kg, male, healthy individual with 0.9 clothing load and 80 W workload (Höppe, 1999; Matzarakis and Mayer 1999; Table 33.4).

Geographic Information Systems (GIS) technology, which has developed in recent years, is used in the spatial distribution of thermal comfort conditions. Interpolation methods are based on station data with GIS software; IDW, Kriging, CoKriging, Radial Basis Functions, etc. (Matzarakis et al. 2010; Caliskan 2012; Daneshvar et al. 2013; Ketterer and Matzarakis 2016). However, the variables related to the land cover are not taken into account in the comfort maps produced by these techniques. Therefore, in the study, solar radiation, average radiant temperature, wind speed, aspect, etc. The newly developed model approach, which takes into account the variables related to the land cover and was found to be more than 95% reliable in the spatial distribution of thermal comfort conditions (PET), was used (Çağlak 2021). In this method approach, the distribution of PET values is determined by the ArcGIS 10.5 program (demo version) from the Geographical Information Systems

Table 33.4 Human thermal sensation and stress ranges for PET (Matzarakis and Mayer 1999)

PET (°C)	Thermal sensation	Level of thermal stress
<−4.0	Extreme cold	Freezing cold stress
−3.9–0.0	Very cold	Extreme cold stress
0.1–4.0	Moderate cold	Strong cold stress
4.1–8.0	Cold	Moderate cold stress
8.1–13.0	Cool	Cool stress
13.1–18.0	Slightly cool	Slight cold stress
18.1–23.0	**Neutral (comfortable)**	**No thermal stress**
23.1–29.0	Slightly warm	Slight warm stress
29.1–35.0	Warm	Moderate heat stress
35.1–41.0	Hot	Strong heat stress
>41.0	Very hot	Extreme heat stress

Table 33.5 Parameters affecting the spatial distribution of the PET index (Steeneveld et al. 2011; Koopmans et al. 2018, 2020; Perkhurova et al. 2019)

Parameters	Change	PET (°C)
Wind velocity	1 (m/s)	2.50
Mean radiant temperature (mrt)	1 °C	0.6
Elevation	100 (m)	0.5
Solar radiation (time 14:00)	100 (w/m^2)	0.4
Solar radiation (time 07:00)	100 (w/m^2)	1.2

software; altitude, land use, solar radiation, mean radiant temperature (MRT) and wind speed base maps (Table 33.5 and Fig. 33.5). In the method, first of all, PET values of meteorology stations in the field were distributed to the surface using Inverse Distance Weighted (IDW), one of the interpolation techniques. This technique is mostly the preferred method for generating grids by interpolation from sample point data. Then, taking into account the elevation, land cover, wind velocity, mean radiant temperature and solar radiation bases, in Table 33.4, the PET distribution obtained by the IDW technique was recalculated. Then, the values were classified according to the thermal comfort ranges of the PET index. In this calculation, the raster calculator tool in ArcGIS 10.5 software was used. Because the sun's position on the horizon changes throughout the day, the solar radiation base map time of day must be taken into account (Fig. 33.5).

Wind speed maps are arranged as 1.1 m, which constitutes the reference level of the centre of gravity of the human body (Nastos et al. 2013; Nastos and Matzarakis 2019). The wind speed data obtained from the meteorology station was evaluated according to 1.1 m using the following formula (Eq. 33.1).

$$\mathrm{WS}_{1.1} = \mathrm{WS}_h \cdot (1.1/h)^a \tag{33.1}$$

In the equation, $a = 0.12 \cdot z0 + 0.18$;
WS_h: wind speed value measured at altitude (m/s) (usually 10 m).
H: height of the station (usually 10 m).
A: an empirical exponent based on surface roughness.
$z0$: surface roughness length (Troen and Petersen 1989).
The roughness length ($z0$) value was obtained from the European Wind Atlas.

Results

The spatial distribution of the thermal comfort conditions of the city of Van was prepared monthly as mean, maximum and minimum. The distribution of thermal comfort conditions was followed in astronomical seasonal order to explain similar conditions one after another throughout the year.

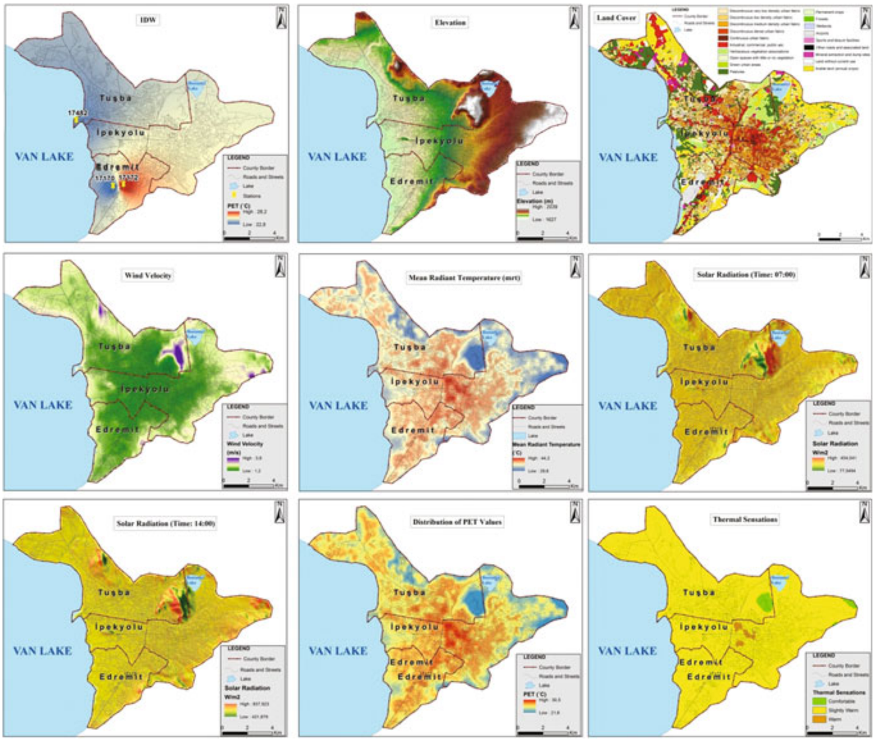

Fig. 33.5 Base maps used in the spatial distribution of thermal comfort conditions

Mean Conditions

According to the distribution of monthly average thermal comfort conditions, in December, ‘very cold’ stress is perceived in urban areas and ‘extreme cold’ stress in areas on the periphery of the city. While ‘very cold’ stress is perceived in the majority of the city in February, ‘moderate cold’ stress is perceived in densely populated areas in the city, and ‘extreme cold’ stress is perceived in high areas on the city periphery. In March and November, ‘cold’ stress is experienced in medium and dense urban areas, ‘moderate cold’ stress in low-density urban areas and ‘very cold’ stress in non-residential high areas of the city. While ‘cool’ stress was dominant in the urban area in April, ‘slightly cool’ stress was determined in dense and high-rise areas in the city, and ‘cold’ stress was determined in the hilly area in the Tusba district. While the ‘slightly cool’ stress is effective in May, ‘comfortable’ conditions in the densely textured urban area and ‘cool’ stress in the hilly area of the Tusba district are effective. ‘Slightly warm’ stress is experienced in the middle and densely textured urban area in June, ‘comfortable’ conditions on the city periphery and ‘slightly warm’ stress in the city in July and August, and ‘warm’ stress is experienced in dense and high-rise buildings in İpekyolu district. While ‘comfortable’ conditions are dominant in the city in September, ‘slightly warm’ stress is also seen in dense and high-rise buildings in the İpekyolu district. In October, ‘slightly cool’ stress is perceived in urban areas and ‘cool’ stress in urban peripheries (Fig. 33.6).

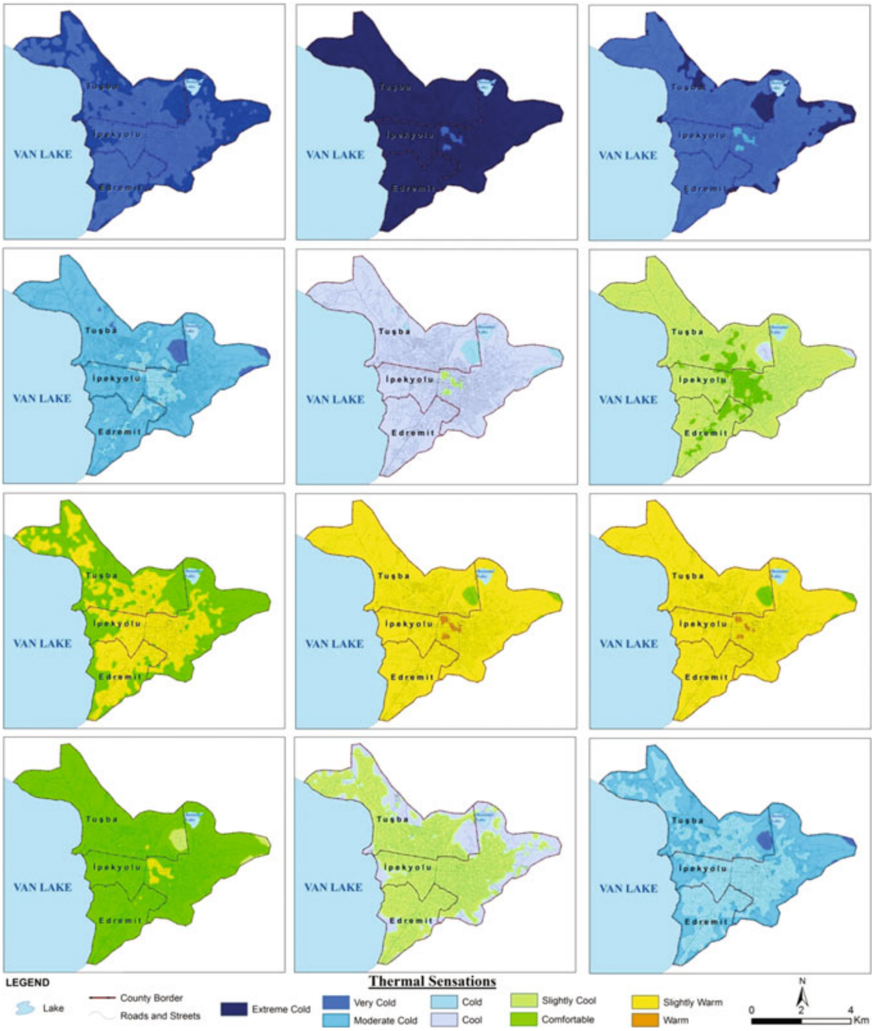

Fig. 33.6 Distribution of monthly average thermal comfort conditions of the city of Van

Maximum Conditions

According to the monthly maximum thermal comfort conditions, 'extreme cold' stress was not determined in any month in Van. In December, 'cold' stress is perceived in medium and densely textured urban areas, and 'moderate cold' stress is perceived in low-density urban areas and city peripheries. In January, 'moderate cold' stress in urban areas and 'very cold' stress in urban peripheries were determined in 'cold' stressed areas. In February, 'cold' stress is experienced in urban areas, 'moderate cold' stress is experienced in urban peripheries, and 'cool' stress is experienced in dense and high-rise buildings. In March and November, the 'cool' stress prevails in the city. In April, 'comfortable' conditions are perceived in the medium and densely textured urban area, while 'slightly cool' stress is perceived in other areas. 'Slightly warm' stress in the urban area in May, 'comfortable' conditions in the city periphery, 'warm' stress in the urban area in June, 'slightly warm' stress in the city periphery and 'hot' stress in the city in July are effective. In August, 'hot' stress is perceived in densely textured urban areas, and 'warm' stress in other areas. Although the 'slightly warm' stress was dominant in the city in September, 'warm' stressed areas were also seen. While 'comfortable' conditions are experienced in the majority of the city in October, 'slightly warm' stress is experienced in the high areas of the city (Fig. 33.7).

Minimum Conditions

According to the minimum thermal comfort conditions, from December to March in the city of Van, 'extreme cold' stress with freezing effects is experienced throughout the field. 'Moderate cold' stress in urban areas in April, 'very cold' stress in urban areas, 'cool' stress in urban areas in May, 'cold' stress in urban areas, 'slightly cool' stress in urban areas in June and 'cool' stress in urban areas were determined. 'Comfortable' conditions in the urban area in July, 'slightly cool' stress in the city periphery, 'comfortable' conditions in the medium and dense urban area in August and 'slightly cool' stress in the low-density urban area and the city periphery were determined. While the 'slightly cool' stress is experienced in the densely textured urban area in September, the 'cool' stress is experienced in other areas. In October, 'cold' stress in urban areas and 'moderate cold' stress in urban peripheries were determined. In November, 'extreme cold' stress is dominant in the city, but 'very cold' stress is effective in dense and high-rise buildings in İpekyolu district (Fig. 33.8).

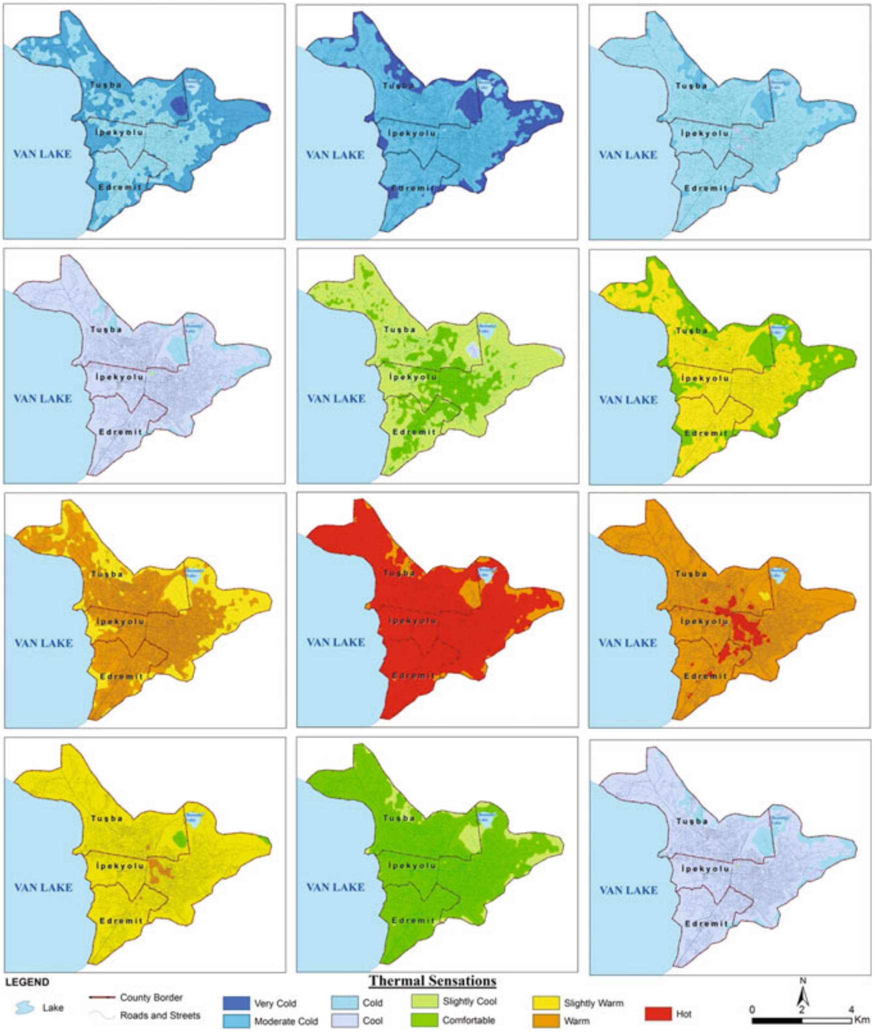

Fig. 33.7 Distribution of monthly maximum thermal comfort conditions of the city of Van

Percentages of Spatial Distributions of Thermal Comfort Conditions

The city of Van, which is the study area, consists of a total area of 133 km^2. According to the areal distributions of the average thermal comfort conditions of this area, ‘extreme cold’ stress is effective for three months in the city, in December, January and February (respectively, 37.6%, 99.1%, 10.7% of the field), and ‘very cold’ stress is effective from November to March (respectively, 1.5%, 1.5% of the field). About

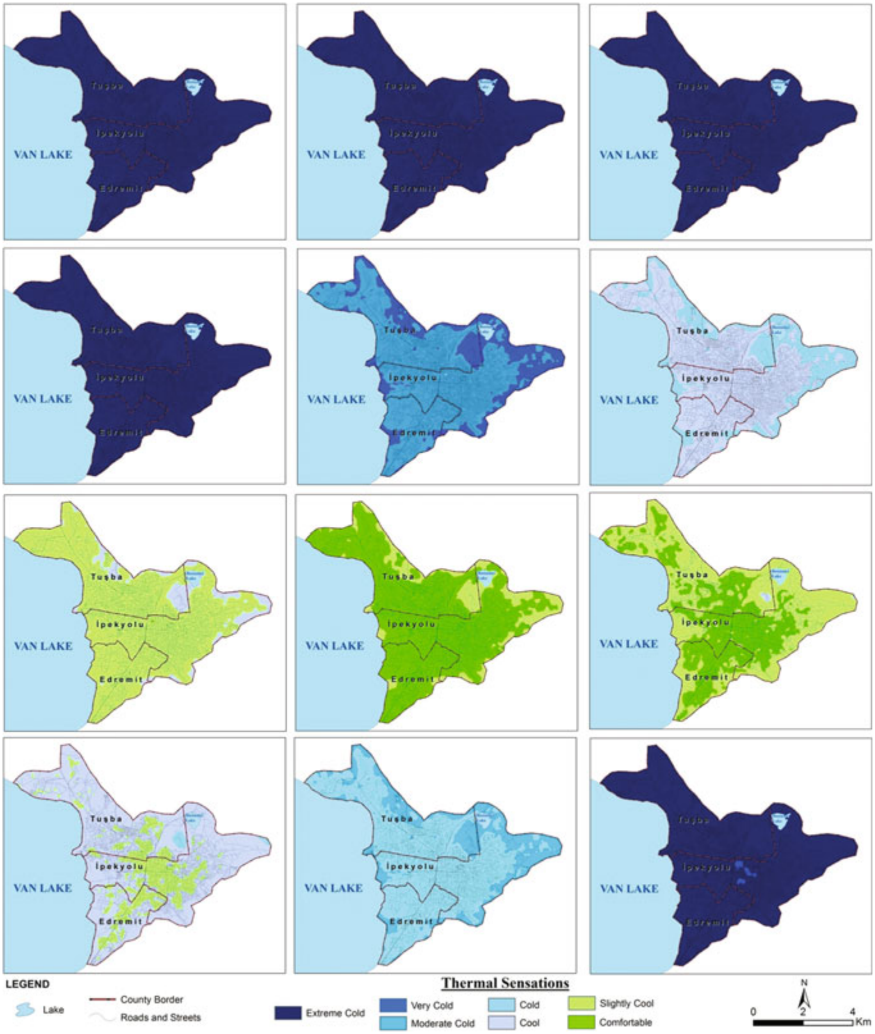

Fig. 33.8 Distribution of monthly minimum thermal comfort conditions of the city of Van

62.4, 0.9, 88.4 and 3.4% were observed to be effective for 5 months. 'Moderate cold' stress is in the city during the three months of February, March and November (0.9%, 87.7%, 50.3% of the field, respectively), and 'cold' stress is in March, April and November (respectively, 8.8%, % of the field). About 3.4, 48.2% for three months, 'cool' stress for three months in April, May and October (95.7%, 1.5%, 26.0% of the field, respectively) and 'slightly cool' stress for April, May, September and October months (0.9%, 89.6%, 2.4%, 74.0% of the field, respectively) were determined. 'Comfortable' conditions in the city from May to September (respectively, 8.8%, 51.8%, 1.5%, 1.8%, 95.9% of the field) for 5 months and 'slightly warm' stress

Table 33.6 Percentages of spatial distributions of monthly mean thermal comfort conditions

Months	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Extreme cold	99.1	10.7										37.6
Very cold	0.9	88.4	3.4								1.5	62.4
Moderate cold		0.9	87.7								50.3	
Cold			8.8	3.4							48.2	
Cool				95.7	1.5					26.0		
Slightly cool				0.9	89.6				2.4	74.0		
Comfortable					8.8	51.8	1.5	1.8	95.9			
Slightly warm						48.2	97.6	97.7	1.7			
Warm							0.9	0.5				

from June to September (respectively, 48.2% of the field; 97.6%, 97.7%, 1.7%) are experienced for four months, and ‘warm’ stress is experienced in July (0.9%) and August (0.5%) (Table 33.6).

According to maximum thermal comfort conditions, the city has not experienced any ‘extreme cold’ stress in any month. ‘Very cold’ stress in December (1.5%) and January (22.1%), ‘moderate cold’ stress from December to February (50.3%, 77.8%, 13.1%, respectively) for three months, ‘cold’ stress from November to March for 5 months (10.7%, 48.2%, 0.1% 86.4%, 8.6%, respectively), ‘cool’ stress in February, March, April and November (0.5%, 91.4%, 1.0% 89.25%, respectively), ‘slightly’ ‘cool’ stress in March, April, October and November (0.1%, 73.1%, 10.7%, 0.05%, respectively) are perceived. ‘Comfortable’ conditions are in April, May, September and October (25.9%, 30.5%, 1.1%, 89.25%, respectively) for 4 months, ‘slightly warm’ stress is in May, June, August, September and October (69.5%, 30.5%, 0.1% 97.2%, 0.05%, respectively) for 5 months, ‘warm’ stress is for four months from June to September (69.5%, 10.7%, 99.3%, 1.7%, respectively), and ‘hot’ stress is for July (89.3%)) and in August (0.6%) (Table 33.7).

According to the minimum thermal comfort conditions, ‘extreme cold’ stress was determined in the entire field from December to March (4 months) and in 99.1% of the field in November in the city of Van. ‘Very cold’ stress is in April (26.0%) and November (0.9%), ‘moderate cold’ stress is in April, May and October (73.95%, 26.0%, 26.0% of the field, respectively), ‘cold’ stress is in April, May, in September and October (0.05%, 74.0%, 1.1%, 73.95% of the field, respectively), and ‘cool’ stress is perceived in May, August, September and October (10.7%, 0.3%, 76.7%, 0.05% of the field, respectively). ‘Slightly cool’ stress is for four months from June to September (89.25%, 17.2%, 58.1%, 22.2% of the pitch, respectively), and ‘comfortable’ conditions are from June to August (0.05%, 82.8%, 41.6% of the field, respectively) for three months (Table 33.8).

Table 33.7 Percentages of spatial distributions of monthly maximum thermal comfort conditions

Months	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Very cold	22.1											1.5
Moderate cold	77.8	13.1										50.3
Cold	0.1	86.4	8.6								10.7	48.2
Cool		0.5	91.4	1.0							89.25	
Slightly cool			0.1	73.1						10.7	0.05	
Comfortable				25.9	30.5				1.1	89.25		
Slightly warm					69.5	30.5		0.1	97.2	0.05		
Warm						69.5	10.7	99.3	1.7			
Hot							89.3	0.6				

Table 33.8 Percentages of spatial distributions of monthly minimum thermal comfort conditions

Months	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Extreme cold	100	100	100								99.1	100
Very cold				26.0							0.9	
Moderate cold				73.95	26.0					26.0		
Cold				0.05	74.0				1.1	73.95		
Cool						10.7		0.3	76.7	0.05		
Slightly cool						89.25	17.2	58.1	22.2			
Comfortable						0.05	82.8	41.6				

Discussion

Van, one of the developed cities of the Eastern Anatolia Region of Turkey, was established and developed on the shores of Lake Van, which is Turkey's largest lake with its high altitude. The city of Van, which was founded in BC, is growing in terms of population and structure by getting immigrants from the surrounding rural areas day by day.

The thermal comfort conditions of the city of Van were evaluated according to the PET index, and their spatial distribution was explained with GIS. As a result of the study, according to mean PET values, cold stress perceptions were dominant in the city from November to March (five months), and 'slightly warm' and 'warm' stresses were dominant in the summer season. In the transitional seasons (Spring and Autumn), 'slightly cool' stress and 'comfortable' conditions are effective. According to the maximum PET values, 'cool' stress in winter and 'warm' and 'hot' stress in summer are perceived. During the transition seasons, 'slightly warm' stress and ‘comfortable’ conditions are effective. According to the minimum PET values, ‘extreme cold’ stress is experienced from November to March (five months), ‘slightly cool’ stress and ‘comfortable’ conditions in summer and ‘cold’ and ‘cool’ stresses in transition seasons. In addition, Urban Heat Islands were observed in all evaluations (mean, maximum, minimum) depending on urbanisation.

When the findings are compared with the studies in the literature, it has been stated that cold stresses are experienced more and hot stresses are less experienced in Erzurum, which has altitudes close to and close to the city of Van (Toy 2010). This shows that Lake Van has a mild effect on the thermal conditions of the city. Similar findings are similar to those of Sun Moon Lake in Taiwan (Lin and Matzarakis 2008) and Ourmieh Lake in Iran (Farajzadeh and Matzarakis 2012).

Erzurum, (Toy 2010; Çağlak et al. 2022), Ankara (Çiçek 2003; Türkoğlu et al. 2011), Eskişehir, (Toy et al. 2021) where the city centre has negative thermal comfort conditions due to urbanisation.), Samsun, Bolu (Çağlak 2017; Çağlak et al. 2021), Aydın and İzmir (Kestane and Ulgen 2013; Tonyaloğlu 2019). These findings are in Athens, Greece (Charalampopoulos et al. 2013), Munich, Germany (Mayer 1993), Szeged, Hungary (Unger 1999), Cincinnati, USA (Clarke and Bach 1971). It has also been demonstrated in the Polish cities of Warsaw and Łodz (Blażejczyk et al. 2016). In this respect, the results of the study are similar to the studies in the literature.

According to the results, city centres have different thermal comfort conditions depending on urbanisation and lake, etc. It has been observed that the thermal conditions of the cities near the water have slightly milder characteristics.

Conclusion

This study evaluated the thermal comfort conditions of urban areas by taking into account many variables of the land. In this respect, the study has revealed in detail how urban land use affects thermal comfort conditions. Thermal comfort conditions of cities should be calculated by taking into account all climatic parameters. At the same time, the spatial distribution of the obtained values should be done by taking into account all the variables of the land. These studies are guiding decision-makers and planners.

Although the world population is increasing day by day, the majority of the population lives in cities. It is necessary to reduce these negative thermal comfort conditions of cities and to adapt to climate-resistant sustainable cities. In addition, to reduce the impact of climate change and prevent climate change, anthropogenic greenhouse gas emissions must be reduced very quickly and effectively. To reduce these negative thermal conditions of cities and to adapt to climate-resistant sustainable cities, environments such as green spaces, city parks, green building designs and water surfaces should be increased in urban areas. In addition, when the green areas are distributed evenly in the urban area, the ‘fresh air’ air circulation of the city will also be positively affected. Urban design and planning should be done from a geographical perspective (taking into account human, biotic and physical environmental conditions) to reduce the negative thermal conditions of cities and for sustainable healthy cities.

References

Aboubakri O, Kahnjani N, Jahani Y, Bakhtiari B (2020) Thermal comfort and mortality in a dry region of iran, kerman; a 12-year time series analysis. Theoret Appl Climatol 139:403–413. https://doi.org/10.1007/s00704-019-02977-8

Anderson BG, Bell ML (2009) Weather-related mortality: how heat, cold, and heat waves affect mortality in the United States. Epidemiology 20:205–213. https://doi.org/10.1097/EDE.0b013e318190ee08

Blażejczyk K, Kuchcik M., Dudek W, Kręcisz B, BLażejczyk A, Milewski P, Szmyd J, PaLczyński C (2016) Urban heat ısland and bioclimatic comfort in Warsaw. In: Musco F (ed), Counteracting urban heat Island effects in a global climate change scenario, pp 305–321. https://doi.org/10.1007/978-3-319-10425-6_11

Blazejczyk K, Baranowski J, Blazejczyk A (2018) Climate related diseases. Current regional variability and projections to the year 2100. Quaestiones Geographicae 37(1): 23–36

Bölük E (2016) Turkish climate according to Köppen climate classification. MGM Publications, Ankara. https://www.mgm.gov.tr/FILES/iklim/iklim_siniflandirmalari/koppen.pdf

Charalampopoulos I, Tsiros I, Sereli AC, Matzarakis A (2013) Analysis of thermal bioclimate in various urban configurations in Athens, Greece. Urban Ecosyst 16:217–233. https://doi.org/10.1007/s11252-012-0252-5

Clarke JF, Bach W (1971) Comparison of the comfort conditions in different urban and suburban microenvironments. Int J Biometeorol 15:41–54

Çağlak S (2017) Investigation of samsun's bioclimatic comfort conditions and the effect of urbanization on bioclimatic comfort conditions.(Unpublished Master's Thesis) Ondokuz Mayıs University/Social Sciences Institute, Department of Geography, Samsun

Çağlak S (2021) Effects and possible consequences of climate change on bioclimatic comfort conditions. Doctoral Thesis. Ondokuz Mayıs University

Çağlak S, Aydemir KPK, Kazancı G (2021) Effects of urbanization on bioclimatic comfort conditions Bolu example. City Health J 2(2):47–55

Çağlak S, Toy S, Esringü A (2022) An approach to evaluate the effects of cities on bioclimatic conditions: the sample of Erzurum city. J Kesit Acad 8(31):220–239

Çalışkan O (2012) Analysis of Turkey's bioclimatic conditions and ınvestigation of the effect of urbanization on bioclimatic conditions on Ankara scale. Doctoral Thesis. Ankara University

Çiçek İ (2003) The effect of urbanization on bioclimatic conditions in Ankara. In: Prof. Dr. Climatology Workshop in Memory of Sirri Erinç 2002, 11–13 April 2002, Ege University. Ed. fac. Arrow. No:121: 145–157

Çiçek İ, Doğan U (2005) Investigation of the city heat Island in Ankara. J Geog Sci 3(1):57–72

de Freitas CR, Grigorieva EA (2015) A comprehensive catalogue and classification of human thermal climate indices. Int J Biometeorol 59:109–120

Driscoll DM (1992) Thermal comfort ındexes. Current uses and abuses. Nat Weather Digest 17(4): 33–38

Daneshvar MRM, Bagherzadeh A, Tavousi T (2013) Assessment of bioclimatic comfort conditions based on physiologically equivalent temperature (PET) Using the RayMan model in Iran. Central Eur J Geosci 5:53–60

Epstein Y, Moran DS (2006) Thermal comfort and the heat stress indices. Ind Health 44:388–398

Eriçok AK (2019) Investigation of the urban tourism possibilities of the city of van in the context of globalization. J Soc Sci Inst 44:171–191

Fallah Ghalhari G, Mayvaneh F (2012) Effect of air temperature and universal thermal climate index on respiratory diseases mortality in Mashhad Iran. Arch Iran Med 19(9):618–624
Farajzadeh H, Matzarakis A (2012) Evaluation of thermal comfort conditions in Ourmieh Lake, Iran. Theor Appl Climatol 107: 451–459. https://doi.org/10.1007/s00704-011-0492-y
Fröhlich D, Gangwisch M, Matzarakis A (2018) Effect of radiation and wind on thermal comfort in urban environments—application of the RayMan and SkyHelios model. Urban Clim 27:1–7
Gulyas A, Unger J, Matzarakis A (2006) Assessment of the micro climatic and human comfort conditions in a complex urban environment: modelling and measurements. Build Environ 4:1713–1722
Haldane JS (1905) The influence of high air temperature. J Epideomology Infect 5(4):494–513
Heberden W (1826) An account of the heat of July 1825, some remarks on sensible cold. Phil Trans 2:69–75
Houghton FC, Yaglou CP (1923) Determining equal comfort lines. J Am Soc Heat Vent Engrs 9:165–176
Höppe P (1999) The physiological equivalent temperature—a universal index for the biometeorological assessment of the thermal environment. Int J Biometeorol 43:71–75
Huang F, Zhao A, Chen RJ, Kan HD, Kuang XY (2015) Ambient temperature and outpatient visits for acute exacerbation of chronic bronchitis in Shanghai: a time series analysis. Biomed Environ Sci 28:76–79. https://doi.org/10.3967/Bes2015.008
Kestane Ö, Ülgen K (2013) Determination of bioclimatic comfort zones for İzmir Province. Süleyman Demirel Univ J Tech Sci 5(3):18–25
Ketterer C, Matzarakis A (2016) Mapping the physiologically equivalent temperature in urban areas using artificial neural network. Landsc Urban Plan 150:1–9
Koopmans S, Ronda R, Steeneveld GJ, Holstlag AM, Tank AMG (2018) Quantifying the effect of different urban planning strategies on heat stress for current and future climates in the agglomeration of the Hague (The Netherlands). Atmosphere 9(3):1–20
Koopmans S, Heusinkveld G, Steeneveld GJ (2020) A standardized physical equivalent temperature urban heat map at 1-M spatial resolution to facilitate climate stress tests in The Netherlands. Build Environ 181:1–13
Koyuncu B, Karakılçık Y (2019) A theoritical study on administrative problems of Van Lake watershed. Mehmet Akif Ersoy Univ J Soc Sci Inst 11(27):170–187. https://doi.org/10.20875/makusobed.515600
Landsberg HE (1972) The assessment of human bioclimate, a limited review of physical parameters. World Meteorological Organization, Technical Note No. 123, WMO-No. 331, Geneva
Lerner D (1964) The passing of traditional society modernizing the middle east. The Free Press, New York
Lin TP, Matzarakis A (2008) Tourism climate and thermal comfort in Sun Moon Lake, Taiwan. Int J Biometeorol 52:281–290. https://doi.org/10.1007/s00484-007-0122-7
Matzarakis A, Mayer H, Iziomon MG (1999) Applications of a universal thermal ındex: physiological equivalent temperature. Int J Biometeorol 43:76–84
Matzarakis A, Rutz F, Mayer H (2000) Estimation and calculation of the mean radiant temperature within urban structures. In: de Dear RJ, Kalma JD, Oke TR, Auliciems A (eds) Biometeorology and urban climatology at the turn of the millenium, Selected Papers from the Conference ICB-ICUC'99, Sydney, WCASP-50, WMO/TD No. 1026, pp 273–278
Matzarakis A, Rutz F, Mayer H (2007) Modelling radiation fluxes in simple and complex environments—application of the RayMan model. Int J Biometeorol 51:323–334
Matzarakis A, Rutz F, Mayer H (2010) Modelling radiation fluxes in simple and complex environments—basics of the RayMan model. Int J Biometeorol 54:131–139
Mayer H (1993) Urban bioclimatology. Experientia 49:957–963
Nastos TP, Matzarakis A (2011) The effect of air temperature and human thermal indices on mortality in Athens, Greece. Theor Appl Climatol 3(4):591–599

Nastos PT, Giaouzaki KN, Kampanis NA, Matzarakis A (2013) Acute coronary syndromes related to bio-climate in a Mediterranean area. The case of IeraTHIra, Crete Island, Greece. Int J Environ Health Res 23(1):76–90

Nastos PT, Matzarakis A (2019) Present and future climate—tourism conditions in Milos Island, Greece. Atmosphere 10(3):97–107

Oke TR (1973) City size and the urban heat island. Atmos Environ 7(8):769–779

Oke TR (1981) Canyon geometry and the nocturnal urban heat island: comparison of scale model and field observation. J Climatol 1:237–254

Olgyay V (1973) Design with climate, bioclimatic approach to architectural regionalism. Princeton University Press, New Jersey

Parsons KC (2003) Human thermal environments: the effects of hot, moderate, and cold environments on human health, comfort and performance. Taylor & Francis, London, New York

Parsons K (2014) The effects of hot, moderate, and cold environments on human health, comfort, and performance, 3rd edn. CRC Press, Singapore. ISBN 9781466595996

Perkhurova AA, Konstantinov PI, Varentsov MI, Shartova NI, Samsonov TE, Krainov VN (2019) Real-time microscale modeling of thermal comfort conditions in Moscow Region. IOP Conf Ser: Earth Environ Sci, 386: 1–8

Scherber K, Langner M, Endlicher W (2014) Spatial analysis of hospital admissions for respiratory diseases during summer months in Berlin taking bioclimatic and socio-economic aspects into account. DIE ERDE—J Geog Soc Berlin 144(3–4):217–237. https://doi.org/10.12854/erde-144-16

Steeneveld GJ, Koopmans S, Heusinkveld BG, Hove LWA, Holstlag AAM (2011) Quantifying urban heat island effects and human comfort for cities of variable size and urban morphology in The Netherlands. J Geophys Res 116:1–14

Sungur KA (1980) An essay on monthly distribution of suitable and unsuitable heat values for human life in Turkey. J Istanbul Univ Inst Geogr 23:27–36

Tonyaloğlu EE (2019) The evaluatıon of the ımpact of urbanısatıon on urban thermal envıronment in the case of Aydın. Turk J Landscape Res 2(1):1–13

Toy S (2010) Investigation of Eastern Anatolia region recreational areas in terms of bioclimatic comfort values. (Unpublished PhD Thesis), Atatürk University/Institute of Science and Technology, Department of Landscape Architecture, Erzurum

Toy S, Çağlak, S, Esringü A (2021) Assessment of bioclimatic sensitive spatial planning in a Turkish City, Eskisehir. Atmosfera. Early Onlıne Release. https://doi.org/10.20937/ATM.52963

Troen I, Petersen E (1989) European wind atlas. National Laboratory Roskilde, ISBN 87-550-1482-8

Türkeş M, Erlat E (2017) A scientific evaluation of changes and trends observed in the world and Turkey in extreme weather and climate events. In Ucal M (ed), Climate change and the green dimension: green economy, green growth, pp 5–38. Heinrich Böll Stiftung Association Turkey Representative, Istanbul

Türkoğlu N, Çalışkan O, Çiçek İ, Yılmaz E (2011) The analysis of impact of urbanization on the bioclimatic conditions in the scale of Ankara. Int J Hum Sci 9(1):932–955

Unger J (1999) Urban-rural air humidity differences in Szeged, Hungary. Int J Climatol 19(13):1509–15015