© by PSP Volume 31– No. 08A/2022 pages 8264-8270 Fresenius Environmental Bulletin

A RESEARCH TO DETERMINE THE THERMAL COMFORT RANGES OF ERZURUM CITY

Elif Akpinar Kulekci[1,*], Isik Sezen[1], Suleyman Toy[2]

[1]Ataturk University, Faculty of Architecture and Design, Department of Landscape Architecture, 25240, Erzurum, Turkey
[2]Ataturk University, Faculty of Architecture and Design, Department of City and Region Planning, 25240, Erzurum, Turkey

ABSTRACT

This research was carried out in the city of Erzurum, which is located on a highland above 1800m in East Anatolia Region of Turkey [1]. In the stıdy, the effects and perception patterns of cold stress on people tried to be determined through a questionnaire survey, which was conducted in a densely used commercial and recreative area of the city occupied with cafes and restaurants. In addition to survey results, Physiologically Equivalent Temperature (PET) values were calculated using RayMan Model and meteorological values measured near the survey point to compare present comfort ranges and thermal perception of people surveyed. PET values obtained were matched with the comfort levels of the individuals and the relationship between these values tried to be determined. As a result of the study, it was found that all comfort intervals are different, sunlight directly affects the comfort value, and the perceived and calculated PET values are different. As a result of the study, it was concluded that with the improvement of thermal comfort conditions of people outdoor they prefer to use outdoor spaces longer.

KEYWORDS:
Thermal Comfort, Physiologically Equivalent Temperature (PET), RayMan Model, Erzurum, Turkey

INTRODUCTION

Since the beginning of anthropogenic activities and their unprecedented intensification with the Industrial Revolution, emission of greenhouse gases and particles into atmosphere have caused global warming and changes in climatic characteristics. In the special report of the Intergovernmental Panel on Climate Change (IPCC), Global Warming of 1.5 ºC [2] it is estimated that so far human activities have caused nearly 1.0°C of global warming above pre-industrial levels (in a range of 0.8°C to 1.2°C) which is likely to reach 1.5°C between 2030 and 2052 at the current rate. All the impacts of climate change today attract the attentions all over the world because of their deteriorations and harms on public health and natural ecosystems. Among the most obvious impact of climate change is the changed frequency, length, severity (extremity) and time of heat – cold waves [3,4] which may have disastrous impacts on humans.

Cities are the areas perhaps the most affecting and affected by climate change even though they only cover about 3% of earth's land surface [5]. UN states that urban areas are inhabited by more people than their rural counterparts with 55% of global population in 2018 (one in eight of which lives in 33 megacities with 10 million and above inhabitants) being projected to increase from 30% in 1950 to 68% by 2050 (UNDESA 2018), around one in eight live. Depending on the increasing urban population rate, cities have gained importance never seen before and thus seeking for funding for supporting findings to develop new strategies to increase human quality of life, liveability and public health are considerably important for all major (metropolitan) cities in the world, no matter where they are located.

Urban atmosphere is warmer, drier and calmer (less windy) compared to rural area due mainly to urban heat island effect (UHI) which intensifies depending on climate change [6]. As a result of such conditions, urban dwellers face uncomfortable thermal situations due to increased heat more frequently causing physical and mental illnesses and economic losses. Bioclimatic evaluation (or determination of thermal comfort conditions outdoor) to assist decision makers to provide comfortable urban environment is an important study area for different fields (e.g. urban and landscape design, tourism/recreation etc. [7,8,9,10,11,12,13,14,15,16,17,18].

Although the thermal comfort studies are generally conducted to detect thermal stress level against higher temperature combined effect of other climatic variables, cold cities (or winter cities) also need such studies to make decisions on spatial designs and socioeconomic development strategies. For the determination of human bioclimatic comfort conditions represented by only one index value, some types of indices have long been used all over the world considering some variables e.g. climatic elements or additional factors on climatic elements (work load, clothing insulation etc.). Index values calculated need to be categorised to find thermal

stress level of humans in this regard this categorisation of thermal stress levels and its indicators may change depending on the study areas i.e. it may differ for example for Europe, tropics or cold cities [19]. Since in the bioclimatic analyses index values are categorized predefined "thermal comfort-ranges" (Table 1) using threshold values [20] for a defined region it may not suit other places. In a study [19] conducted on the coldest Turkish cities, Erzurum, which is also the study area of present study, one of the most popular thermal comfort indices, Physiological Equivalent Temperature – PET index [21,22], was used for the assessment of cold conditions together with the categories given in Table 1. As the result of the study, winter period is seen to be under the effect of extremely cold stress even though people in great majority live happily in the area. That study suggested the reorganization of these categories but some questionnaires should be conducted to define them. The aim of the present study is to test the applicability of these categories in a winter city using both questionnaire and actual thermal comfort values calculated using PET in the example of Erzurum city.

MATERIALS AND METHODS

Study area, data and calculation. The study area is chosen to be the city of Erzurum in northeast of Turkey (39.55N and 41.16E; TRA1 NUTSII Region; Figure 1), located at a changing altitude from 1.850m to 2.100m in the city center. Population of the city is 762.062 [26]. It has harsh continental climate characteristics. Long-term yearly average temperature is 5.1°C (temperature extremes −37.2°C and 35.6°C), rainfall is 413.3 mm and relative humidity is 63.3% on yearly basis. Prevalent wind directions are ENE in summer and WSW in winter.

TABLE 1
Categorisation of PET values for human thermal sensation [23,24,25].

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
Internal heat production by activity: 80W, heat transfer resistance of clothing: 0.9 clo.		



FIGURE 1
Geographical location of Erzurum

TABLE 2
Questionnaire survey

Outdoor Thermal Comfort Questionnaire

Place: .....
Date: .....
Time: .....

1. Personal information

Sex: ☐ Male ☐ Female

Age: ☐ 18-20 ☐ 21-35 ☐ 36-50 ☐ 51-65 ☐ 66-80 ☐ >80

☐ Live in the neighborhood ☐ Work in the neighborhood ☐ Neither of them

2. What is the reason for being in this place?

☐ On my way to home/work/school/etc ☐ See other people/relax/get fresh air

☐ Both ☐ Other reason .....

3. How often do you pass by this place?

☐ Daily ☐ A few times/week ☐ A few times/month ☐ Rarely ☐ First time

4. Where were you the last half hour?

☐ Outdoors in the sun ☐ Outdoors in shade ☐ Indoors without AC ☐ Indoors with AC

5. How did you spend the last half hour?

☐ Sitting ☐ Standing ☐ Walking ☐ Other .....

6. How do you feel in this place right now?

Very cold	Cold	Cool	Slightly cool	Neutral	Slightly warm	Warm	Hot	Very hot
☐	☐	☐	☐	☐	☐	☐	☐	☐

7. How would you prefer the climate in this place?

Temperature:	☐ Warmer	☐ No change	☐ Cooler
Sun:	☐ More sunny	☐ No change	☐ More shady
Humidity:	☐ More humid	☐ No change	☐ Less humid
Wind:	☐ More windy	☐ No change	☐ Less windy

8. Where do you prefer to spend your free time?

☐ Indoors ☐ Outdoors ☐ Both ☐ Other .....

9. Do you have air conditioning?

☐ At home ☐ At work/school etc ☐ Both ☐ None

10. What type of clothing do you wear?

Shirt	*Trousers*	*Shoes*	*Jacket*	*Head*	*Other*
☐ Short sleeves	☐ Shorts/skirt	☐ Sandals	☐ Jacket	☐ Cap	☐ ....
☐ Long sleeves	☐ Long trousers	☐ Shoes	☐ Sweater	☐ Parasol	
☐ Singlet top	☐ Bermudas			☐ Hat	

PET values were calculated using air temperature Ta [°C], relative humidity RH [%], cloudiness C [octa] and wind speed v [m/s] measured actually at the time and place of questionnaire survey in urban area on 21st February 2020 from 09.00 to 17.00 local time and widely-known RayMan software [24,25]. The survey and measurement point is the urban weather observation station established in the Regional Meteorological Administration Office in the city center (1856m; 39º.55'N-41º.16'E), reflecting urban characteristics being surrounded by structured surface (3-6-storey buildings) and facing heavy traffic load due to densely used city part (Figure 2). Weather station takes data on every two seconds and calculations were performed using data every minute which coincides with the questionnaire time.

Questionnaire survey. On – site surveys were performed by asking individuals their feelings about

the ambient air condition measured simultaneously by the weather station operated by Turkish State Meteorological Service. Time of survey was recorded for each interview to check the bioclimatic comfort ranges according to calculated PET values. Questionnaire was translated from that used also by [29] (Table 2). Thermal perception of the subjects was asked based on a nine-point scale as in the generally accepted forms in Table 1 adding extreme values very cold and hot (accordance with [30,31,32]. Results of the questionnaire were analysed using SPSS software and Chi square test to analyse differences.

RESULTS

Questionnaire survey was conducted on 21st February 2020 between 10:00 and 15:05 local time (GMT+3). Figure 2 gives the tendency in air temperature (Ta°C), relative humidity (RH%) and wind velocity (WVm/s) in minutes over the study hours.

According to Figure 2 and Table 3, which gives the mean, maximum and minimum of Ta, RH, WV and calculated PET values, there is a consistent increase in temperature in a short time from the values below zero to positive values. RH shows a gradual decrease depending on temperature increase while wind velocity changes between light values and calm. Cloudiness values showed nearly no changes from 6 octas therefore it is not given in the Table 3.

All the PET values calculated in the questionnaire survey time are below 4°C, i.e. lower than the "very cold" category (in Table 1) and changed between -8.9°C and 2.2°C (Table 3 and Figure 3) therefore the values are not classified (distributed) into thermal stress categories given in Table 1 above, which means that whole period is in "very cold" range and under "extreme cold stress".

Results obtained about individuals' thermal perception is given in Table 4 according to the questions in the survey. Table 4 gives the demographic information about the 99 respondents (53% female, 59% 21 – 35 aged).

TABLE 3
Mean, maximum and minimum values of parameters

	Mean	Max	Min
PET	-5,0	-2,2	-8,9
Temp	1,0	3,5	-3,4
RH	69,5	91,0	58,0
WV	1,0	2,6	0,0

TABLE 4
Demographic characteristics of the respondents

Variables		Total Number	%
Gender	Female	43	53
	Male	56	57
	Total	99	100
Age	18-20	27	27
	21-35	58	59
	36-50	9	9
	51-65	2	2
	66-80	3	3
	Above 81	-	100

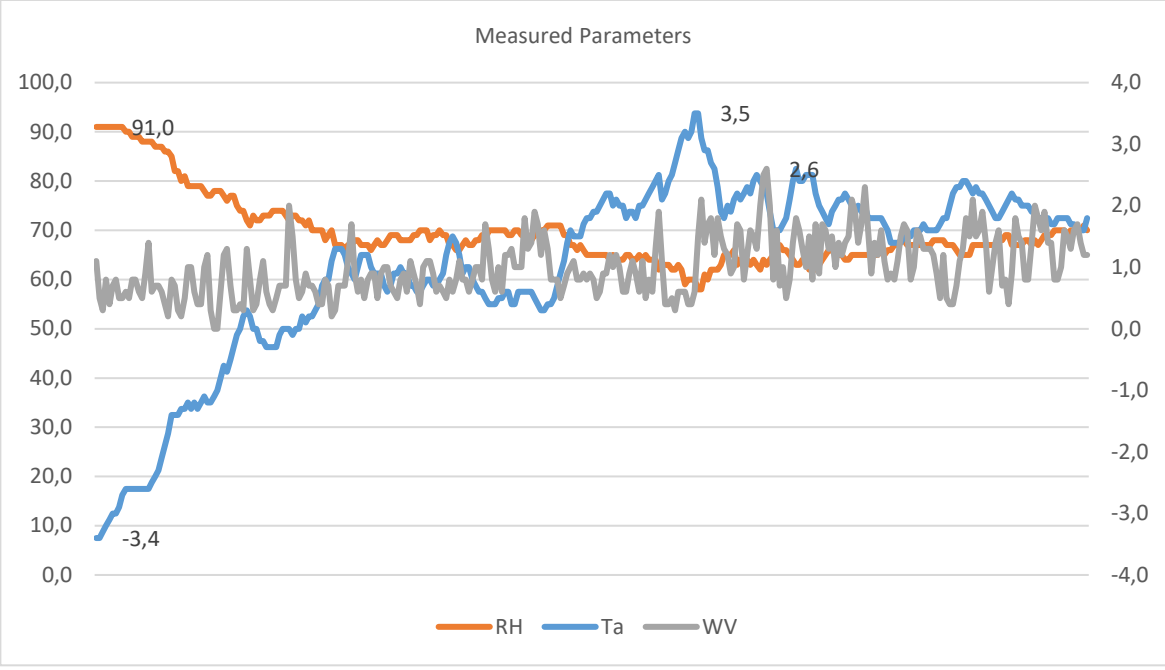


FIGURE 2
Tendency in the meteorological parameters

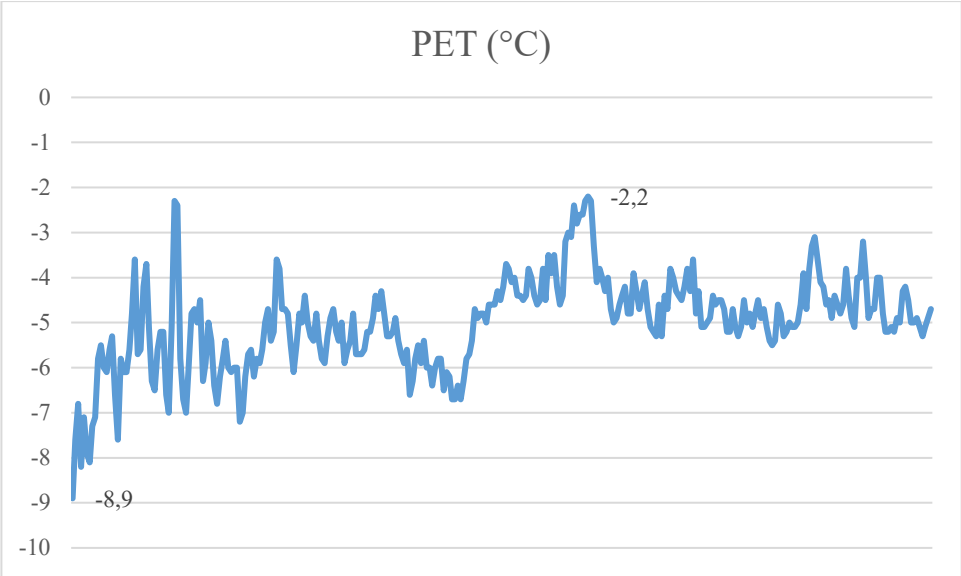


FIGURE 3
Tendency in PET values

TABLE 5
Chi square test results of the responses related to feeling cold or warm

Variable		How do you feel now?																	
		Very cold		Cold		Cool		Slightly cool		Neutral		Slightly warm		Warm		Hot		Very hot	
		N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Gender	Female	2	4.7	12	27.9	6	14.0	5	11.6	14	32.6	3	7.0	0	0.0	1	2.3	0	0
	Male	5	8.9	9	16.1	16	28.6	3	5.4	22	39.3	0	0.0	1	1.8	0	0.0	0	0
	Total	7	7.1	21	21.2	22	22.2	8	8.1	36	36.4	3	3.0	1	1.0	1	1.0	0	0
	Chi – square (x^2)=12,038								(Sig.)=**0.051***										
Age	18-20	2	7.4	7	25.9	8	29.6	3	11.1	7	25.9	0	0.0	0	0.0	0	0.0	0	0
	21-35	5	8.6	12	20.7	14	24.1	4	6.9	19	32.8	3	5.2	0	0.0	1	1.7	0	0
	36-50	0	0.0	2	22.2	0	0.0	1	11.1	5	55.6	0	0.0	1	11.1	0	0.0	0	0
	51-65	0	0.0	0	0.0	0	0.0	0	0.0	2	100	0	0.0	0	0.0	0	0.0	0	0
	66-80	0	0.0	0	0.0	0	0.0	0	0.0	3	100	0	0.0	0	0.0	0	0.0	0	0
	Total	7	7.1	21	21.2	22	22.2	8	8.1	36	36.4	3	3.0	1	1.1	1	1.0	0	0
	Chi – square (x^2)=27.657								(Sig.)=**0.005****										

TABLE 6
Preference of air for temperature Chi square (x^2) test

Variables		How would you prefer the ambient air?					
		Warmer		No change		Cooler	
		N	%	N	%	N	%
Gender	Female	24	55.8	18	41.9	1	2.3
	Male	43	76.8	13	23.2	0	0.0
	Total	67	67.7	31	31.3	1	1.0
	Chi square (x^2)= 5.584				(Sig.)= **0.020***		
Age	18- 20	16	59.3	10	37.0	1	27
	21-35	41	70.7	17	29.3	0	58
	36-50	7	77.8	2	22.2	0	9
	51-65	1	50.0	1	50.0	0	2
	66-80	2	66.7	1	33.3	0	3
	Total	67	67.7	31	31.3	1	99
	Chi square (x^2)=4.077				(Sig.)= **0.850**		

Table 5 shows the results of Chi-square (x2) test of the answers related to feeling cold or warm. According to gender, females feel cold more than males do while males feel comfortable in higher rate (39.3%) than females (32.6%). Rates of those feeling cold, cool and neutral (comfortable) are 21.2%, 22.2% and 36.4% in total, respectively. A significant rate of participants was found to be comfortable with the extremely cold conditions according to the predefined categories. Results are statistically significant ($p<0.05$).

Preference of ambient air conditions (for temperature) also differs according to the age and gender (Table 6). Among the respondents 67.7% prefers warmer air while 31.3% stated their satisfaction (comfortable). Results were found to be not significant for age and significant for gender ($p<0.05$).

CONCLUSION

Human thermal comfort is a significant study field due to the changing and variable climatic characteristics of urban environments. Even though the heat stress - related discomfort is mainly the topic of the studies, cold stress and thermal comfort in winter cities also attract attention. This study shows the predefined thermal perception categorisation gives inefficient results in cold seasons in its present situation (ranges i.e. below 4°C is accepted to be extremely cold stress). Therefore, this categorisation should be revised considering the human responses to ambient air conditions. Categorisation using nine – point classes may be reorganised considering the extreme values and "very cold" category should be accepted lower than 4°C PET because the rate of participants feeling comfortable is the highest compared to other categories. In such a categorisation additional ranges may be added to the points or threshold values of the ranges may be flexed for winter cities as it is seen that even at -8.9°C of PET values, more than one third of people say they feel comfortable, of course, depending on their clothes and work activities. With such a refinement effort thermal comfort studies help make decisions for spatial and socioeconomic designs.

REFERENCES

[1] Doğanay, H. (1988) General Geographic Characteristics of Erzurum., Erzurum Municipality Cultural Publications: 1, Yorum Publishing, Ankara. pp.243-354.

[2] IPCC (2018). V. Masson-Delmotte, et al. (Eds.), Global warming of 1.5°C: An IPCC special report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, World Meteorological Organization, Geneva, Switzerland. pp. 32.

[3] WMO (2015). Heatwaves and Health: Guidance on Warning-System Development, WMO-No: 1142, Geneva. https://www.who.int/globalchange/publications/WMO_WHO_Heat_Health_Guidance_2015.pdf?ua=1 (Accessed date:6th May 2022:13:30)

[4] WMO, (2018). Guidelines on the Definition and Monitoring of Extreme Weather and Climate Events, Draft Version – First Review By Tt-Dewce December 2015, Geneva.

[5] Liu, Z., He, C., Zhou, Y. and Wu, J. (2014). How much of the world's land has been urbanized, really? A hierarchical framework for avoiding confusion. Landscape Ecology. 29(5), 763-771.

[6] Toy, S., Demircan, N. (2019). Possible ways of mitigating the effects of climate change using efficient urban planning and landscape design principles in Turkey. Fresen. Environ. Bull. 28 (2/2019) 710-717.

[7] de Freitas, C.R. (2003). Tourism climatology: evaluating environmental information for decision making and business planning in the recreation and tourism sector. Int. J. Biometeorol. 48, 45-54.

[8] Matzarakis, A. (2007). Assessment method for climate and tourism based on daily data. In: A. Matzarakis, C. R. de Freitas, D. Scott (Eds.), Developments in Tourism Climatology. 52-58.

[9] de Freitas, C.R., Scott, D., McBoyle, G. (2008). A second-generation climate index for tourism (CIT): specification and verification. Int. J. Biometeorol. 52, 399-407.

[10] Lin, T.P., Matzarakis, A. (2008). Tourism climate and thermal comfort in Sun Moon Lake, Taiwan. Int. J. Biometeorol. 52, 281-290.

[11] Huttner, S., Bruse, M., Dostal, P. (2008). Using ENVI-met to simulate the impact of global warming on the microclimate in central European cities. Ber Meteor Inst Albert-Ludwigs-Univ Freiburg. 18, 307-312.

[12] Matzarakis, A., Amelung, B. (2008). Physiologically Equivalent Temperature as indicator for impacts of climate change on thermal comfort of humans. In: M. C. Thomson, R. Garcia-Herrera, M. Beniston (eds.), Seasonal Forecasts, Climatic Change and Human Health. Advances in Global Change Research 30, Springer-Sciences and Business Media. 161-172.

[13] Endler, C., Oehler, K., Matzarakis, A. (2010). Vertical gradient of climate change and climate tourism conditions in the Black Forest. Int. J. Biometeorol. 54, 45-61.
[14] Fröhlich, D., Matzarakis, A. (2013). Modelling of changes in thermal bioclimate: examples based on urban spaces in Freiburg, Germany. Theor. Appl. Climatol. 111, 547–558.
[15] Müller, N., Kuttler, W., Barlag, A.B. (2014). Counteracting urban climate change: adaptation measures and their effect on thermal comfort. Theor. Appl. Climatol. 115, 243-257.
[16] Morris, K.I., Chan, A., Morris, K.J.K., Ooi, M.C.G., Oozeer, M.Y., Abakr, Y.A., Nadzir, M.S.M., Mohammed, I.Y., Al-Qrimli, H.F. (2017). Impact of urbanization level on the interactions of urban area, the urban climate, and human thermal comfort. Appl. Geogr. 79, 50–72.
[17] Toy, S., Aytac, A.S., Kantor, N. (2018). Human biometeorological analysis of the thermal conditions of the hot Turkish city of Şanliurfa. Theoretical And Applied Climatology. 131(1-2), 611-623.
[18] Asur, F. (2019). Ornamental Plants Which Can Be Used in Visual Landscape Improvement in Cold Climate Regions. Journal of International Environmental Application and Science. 14(4), 152-159.
[19] Toy, S., Kántor, N. (2017). Evaluation of human thermal comfort ranges in urban climate of winter cities on the example of Erzurum city. Environ. Sci. Pollut. Res. 24, 1811–1820.
[20] Mayer, H., Höppe, P. (1987). Thermal comfort of man in different urban environments. Theor. Appl. Climatol. 38, 43-49.
[21] Höppe, P. (1999). The physiological equivalent temperature - a universal index for the biometeorological assessment of the thermal environment. Int. J. Biometeorol. 43, 71–75.
[22] Matzarakis, A., Mayer, H. (1996). Another kind of environmental stress: thermal stress. WHO Newsletter 18, 7-10.
[23] Matzarakis, A., Mayer, H., Izomon, M.G. (1999). Application of a universal thermal index: physiological equivalent temperature. Int. J. Biometeorol. 43, 76-84.
[24] Matzarakis, A., Rutz, F., Mayer, H. (2000). Estimation and calculation of the mean radiant temperature within urban structures. In: Biometeorology and Urban Climatology at the Turn of the Millenium (ed. by R.J. de Dear, J.D. Kalma, T.R. Oke and A. Auliciems): Selected Papers from the Conference ICB-ICUC'99, Sydney. WCASP-50, WMO/TD No. 1026, 273-278. Rayman: A Tool for Tourism and Applied Climatology.
[25] Matzarakis, A., Rutz, F. (2005) Application of RayMan for tourism and climate investigations. Annalen der Meteorologie. 41(2), 631-636.
[26] TurkStat (2019). Regional Statistics. https://biruni.tuik.gov.tr/bolgeselistatistik/tabloOlustur.do (Accessed date: 6th May 2022. 13:45)
[27] Johansson, E., Yahia, M.W., Arroyo, I., Bengs C. (2018). Outdoor thermal comfort in public space in warm-humid Guayaquil, Ecuador. Int. J. Biometeorol. 62, 387–399.
[28] ISO 10551 (1995). Ergonomics of the thermal environment—assessment of the influence of the thermal environment using subjective judgement scales. International Organization for Standardization, Geneva.
[29] Thorsson, S., Honjo, T., Lindberg, F., Eliasson, E., Lim, E.M. (2007) Thermal comfort and outdoor activity in Japanese urban public places. Environ. Behav. 39, 660–684.
[30] Kántor, N., Égerházi, L., Unger, J. (2012). Subjective estimation of thermal environment in recreational urban spaces—part 1: investigations in Szeged, Hungary. Int. J. Biometeorol. 56, 1075–1088.
[31] Yahia, M.W., Johansson, E. (2013). Evaluating the behaviour of different thermal indices by investigating various outdoor urban environments in the hot dry city of Damascus, Syria. Int. J. Biometeorol. 57(4), 615–630
[32] Cohen, P., Potchter, O., Matzarakis, A. (2013). Human thermal perception of coastal Mediterranean outdoor urban environments. Appl. Geogr. 37, 1–10

Received: **25.03.2022**
Accepted: **17.04.2022**

CORRESPONDING AUTHOR

Elif Akpinar Kulekci
Ataturk University,
Faculty of Architecture and Design,
Department of Landscape Architecture,
25240 Erzurum – Turkey

e-mail: eakpinar@atauni.edu.tr /
elif25akpinar@hotmail.com