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Evaluation of bioclimatic comfort area with heat index: A case study of Kocaeli

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Abstract

The main reason for technological developments is to make human life more comfortable. Bioclimatic comfort areas are areas where people feel the most comfortable and comfortable in terms of climate. As a result of global climate changes, the temperature in the world is increasing day by day moreover increase in terms of people living in our country and other countries which the need for comfortable and comfortable spaces increases in all seasons. Bioclimatic comfort areas are the most needed in the summer months. However, the average temperature increases day by day in all seasons due to climate change. For this reason, within the scope of this study, the most suitable bioclimatic comfort areas were calculated with the HEAT index by using the average temperature and humidity maps for the fall, winter, spring, and summer seasons of 2019. While creating temperature and humidity maps, a point database was created for the neighborhoods in Kocaeli Province, temperature and humidity data were combined in this database. The temperature and humidity map for each season was open-source code the Inverse Distance Weighted (IDW) interpolation method in the QGIS 3.16 software was transformed into a map in raster format. The heat index was created by using temperature and relative humidity maps in raster format. Then, the relationship between the created heat index maps and morphological factors was examined.

1. Introduction

The most important factor affecting human life and relationships can be considered climate. Humans interact in various ways with their environment. It wants the environmental conditions to be suitable during this interaction. The suitability of these environmental conditions is directly related to the bioclimatic comfort zones.

When the accepted researches in the world are examined, people are comfortable in a certain temperature and humidity range and clean air environments. This range is defined as the comfort zone. Excessive or low temperature causes discomfort such as dry throat and burning in the eyes, as well as excessive humidity, which causes sweating and a feeling of suffocating warmth. In addition, the air in the environment should be clean and fresh. It is necessary to filter dust, smoke, pollen, and other harmful substances, and air circulation to bring clean air and remove polluted air [1].

The most appropriate values for the climatic comfort situation; For the summer months, the felt temperature values evaluated considering the absolute humidity are between 22.8 - 26.1 °C, while it is considered to be between 20.0 - 23.9 °C in the winter months. The temperature value ranges felt in the trial rooms were obtained subjectively with the experiments conducted on middle-aged groups. In these laboratory experiments, the individual's responses to temperature in indoor and outdoor environmental conditions were examined and the average temperature values felt were revealed.

The temperature felt by individuals in a space, which appears to be a completely separate atmospheric feature, is affected separately by all atmospheric features (humidity, wind, cloudiness, solar radiation, etc.). Due to this accumulative effect, the temperature of the air in an

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area has a dominant effect on all beings in that area and represents all-climate elements [2- 12].

Factors affecting bioclimatic comfort; external factors are divided into three as factors that vary depending on the individual and other factors. External factors that affect bioclimatic comfort in an environment are air temperature, radiation, wind, and absolute humidity [13-18]. The parameters that vary depending on the individual are the temperature regulation of the metabolism depending on the activity, the activity level, and the clothing insulation [2, 3, 8, 11, 12, 19-28].

There are many approaches to calculating bioclimatic comfort. These approaches are generally based on the human heat balance model or the physiological approach. According to physiological approaches, the sum of the heat gained or produced by the body and the heat lost should be equal to zero. Factors with positive or negative values in this balance refer to the physiological and physical characteristics of the body and environmental factors [2-12, 29].

People spend a certain amount of energy to reach a bioclimatic comfort state or to adapt to their environment. According to the report of Çınar [30] the bioclimatic comfort state is; It is defined as the conditions in which a person can adapt to his environment by spending the least amount of energy. One of the most used methods in determining bioclimatic comfort is the "Bioclimatic Comfort Chart" developed by Olgyay [2-12, 19-26, 31].

According to Olgyay [32], the bioclimatic comfort value is; 21.0 – 27.5 °C temperature value in an open area, 30-65 % relative humidity and wind speeds up to 5 m/sec were taken as a combination and used in bioclimatic evaluation [2, 3, 6-12, 19-26].

In order to determine the bioclimatic comfort situation in space, first of all, it is necessary to determine and evaluate the temperature, relative humidity, radiation, and wind conditions. Besides these basic factors; The number of hot days, precipitation, diseases, and pests due to weather events, air pollution, and the amount of oxygen in the atmosphere also affect human comfort. "Bioclimatic Comfort" status can be determined by considering all of these effects [2, 3, 6-12, 19-26]. In this study, bioclimatic comfort areas were tried to be determined by using the heat index.

2. Bioclimatic Comfort

In many climatic indices, bioclimatic comfort status was evaluated depending on the combination of temperature, humidity, and wind elements, sometimes alone or all together. The most used criterion in determining comfort is 'Feel Temperature'. Thermal comfort is 80% effective in creating bioclimatic comfort. In this context, bioclimatic comfort has been examined as 'human temperature comfort' in many works of literature [21, 24-26, 31]. Bioclimatic comfort is accepted as the perceived temperature value of 17.0 – 24.9 °C depending on temperature, humidity, and wind in the middle latitudes where Turkey is located [22, 24-26, 34].

As Çınar [30] it is emphasized that the bioclimatic comfort status based on the temperature felt is a subjective value and varies according to space, time, and person. The temperature values felt at 15.0 – 27.0 °C in the evaluations; It was calculated for a person aged 25 years, indoors, with no health problems, normally dressed and not moving (Table 1). In outdoor conditions, these values can be 5°C, low or high.

Table 1. The temperature values felt in determining the bioclimatic comfort [21,22,24,25]

Sensed Temperature (°C)	Comfort Class
28>	Comfort is highly impaired
27-28	Comfort is disturbed
25-26.9	pass value (hot)
17-24.9	Comfort
15-16.9	pass value (cold)
15<	Comfort is disturbed

3. Method

The main material of the study are the climate data of Kocaeli Province. Climate data were obtained from the General Directorate of Meteorology. Kocaeli spatial boundary information was obtained from Kocaeli Metropolitan Municipality. The polygon data received from the relevant Municipality has been converted into a point database. A database was prepared for the analysis by assigning climate data to the database (Figure 1). The reason why the study was chosen as Kocaeli is that the climate of both the Marmara region and the Black Sea region is effective because it is located in the southern part of the Marmara Region. Materials used in the study: Temperature and relative humidity information for Kocaeli province.

WP1 Providing Data: The polygon type data obtained from Kocaeli Metropolitan Municipality was transferred to the QGIS 3.16 environment. It has been arranged by taking the average temperature and relative humidity values from the Provincial Meteorology Directorate. After the editing process was completed, it was saved in CSV format.

WP2 Transformation of Data: A dot was drawn in the middle of the polygon type data using QGIS 3.16 software. After the point data were prepared in excel and saved in CSV format, the average temperature and relative humidity values of the autumn, winter, spring, and summer months of 2019 were combined. By using the temperature and relative humidity values on the combined point data, it has been converted into a raster with the Inverse Distance Weighted interpolation method.

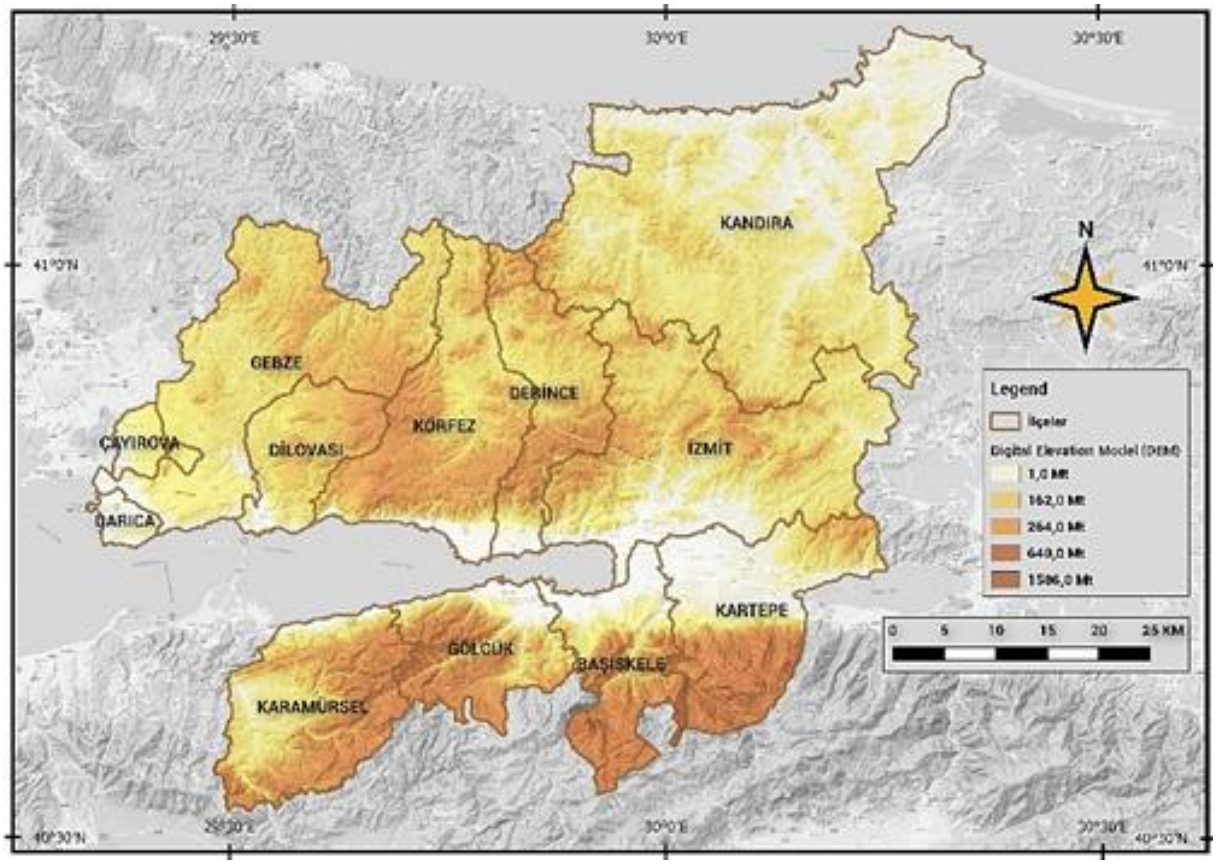

Figure 1. Location map of the study area

The workflow chart of the study is given in Figure 2.

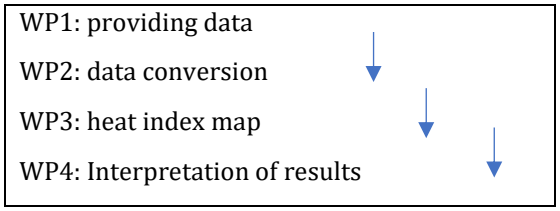

Figure 2. Work flow chart

WP3 Creating a Heat Index Map: The heat index is an index that combines the air temperature and relative humidity in shaded areas, the equivalent temperature perceived by the human, how warm it feels if the humidity is another value in the shade. The perceived air temperature is also known as the apparent temperature, the actual feel, or the felt temperature.

Effects of heat index (Shadow values)

• 26-32 °C caution: fatigue is possible with prolonged exposure and activity. Continued activity can cause heat cramps.

• 32-41 °C extreme caution: heat cramps and heat exhaustion are possible. Continued activity can cause heatstroke.

• 41-54 °C danger: heat cramps and heat exhaustion are likely. Heatstroke is likely with continued activity.

• hazard above 54 °C: heat stroke is inevitable.

How people are affected by temperature can be revealed with the heat index. The formula to be used during this study:

$$HI = 0.5 * \{T + 61.0 + [(T-68.0) * 1.2] + (RH*0.094)\}$$

HI: heat index
T: Temperature
RH: Relative Humidity

The calculation of the heat index is a refinement of a result obtained by multiple regression analysis conducted by lans P. Rothfusz [35] National Weather Service (NWS) technical supplement (SR 90-23). Rothfuss's regression equation, the symbol T represents the Fahrenheit unit of temperature measurement. The RH symbol represents relative humidity in percent and is the English abbreviation of relative humidity. However, if the temperature values in the heat index calculation are 80°F, the heat index calculations do not give accurate results, so Steadman's simplified formula is used [34].

While calculating the heat index, the calculation was made in °F in the first place, then the formula °C= (°F – 32) / 1.8 was converted to degrees Celsius (°C) in the raster calculator tool in QGIS 3.16.

4. Research Findings

The average temperature map and relative humidity maps required for the determination of bioclimatic comfort zones were created in Figure 3 and Figure 4 for each season in 2019.

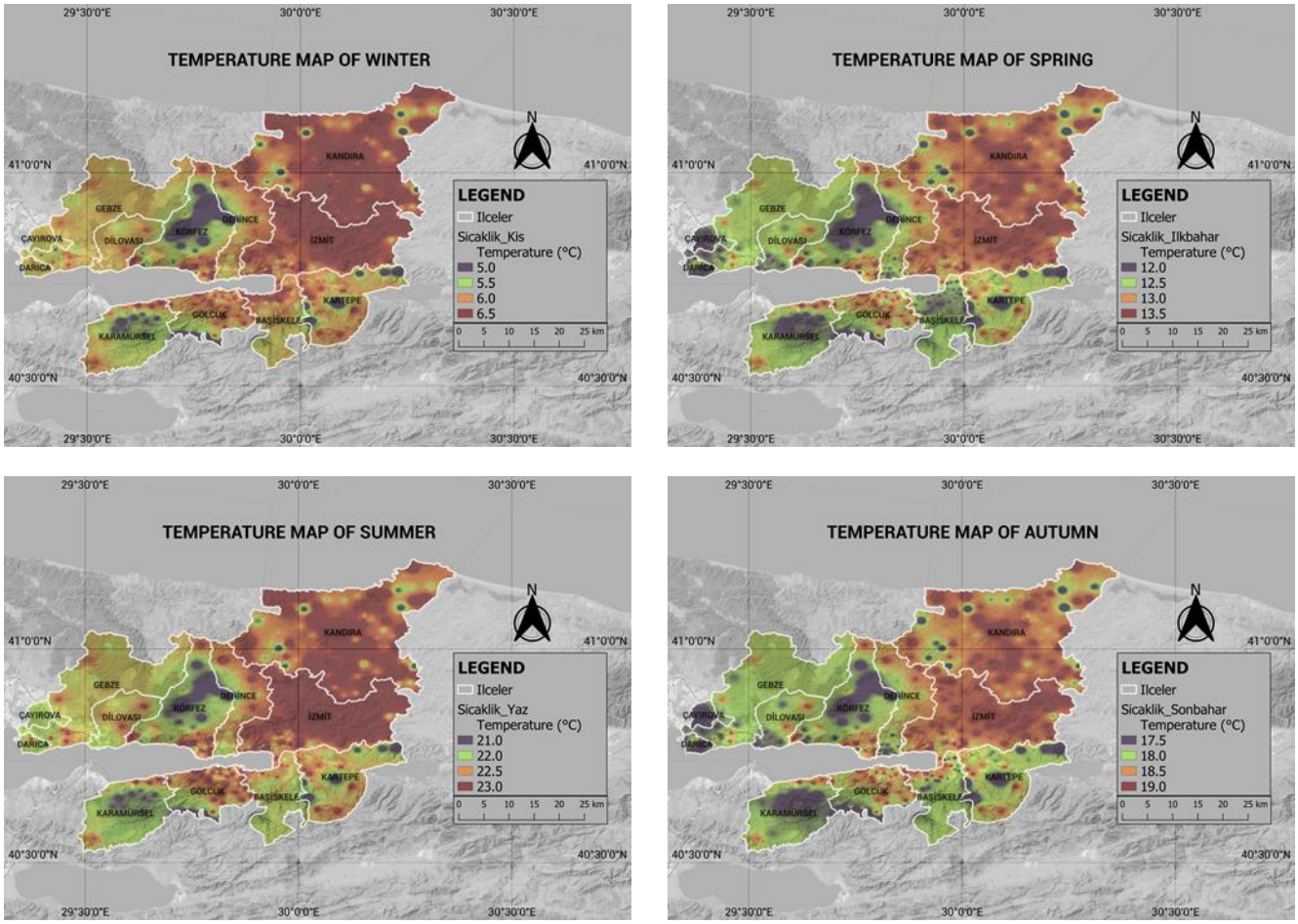

Figure 3. Average temperature maps for the four seasons of Kocaeli Province

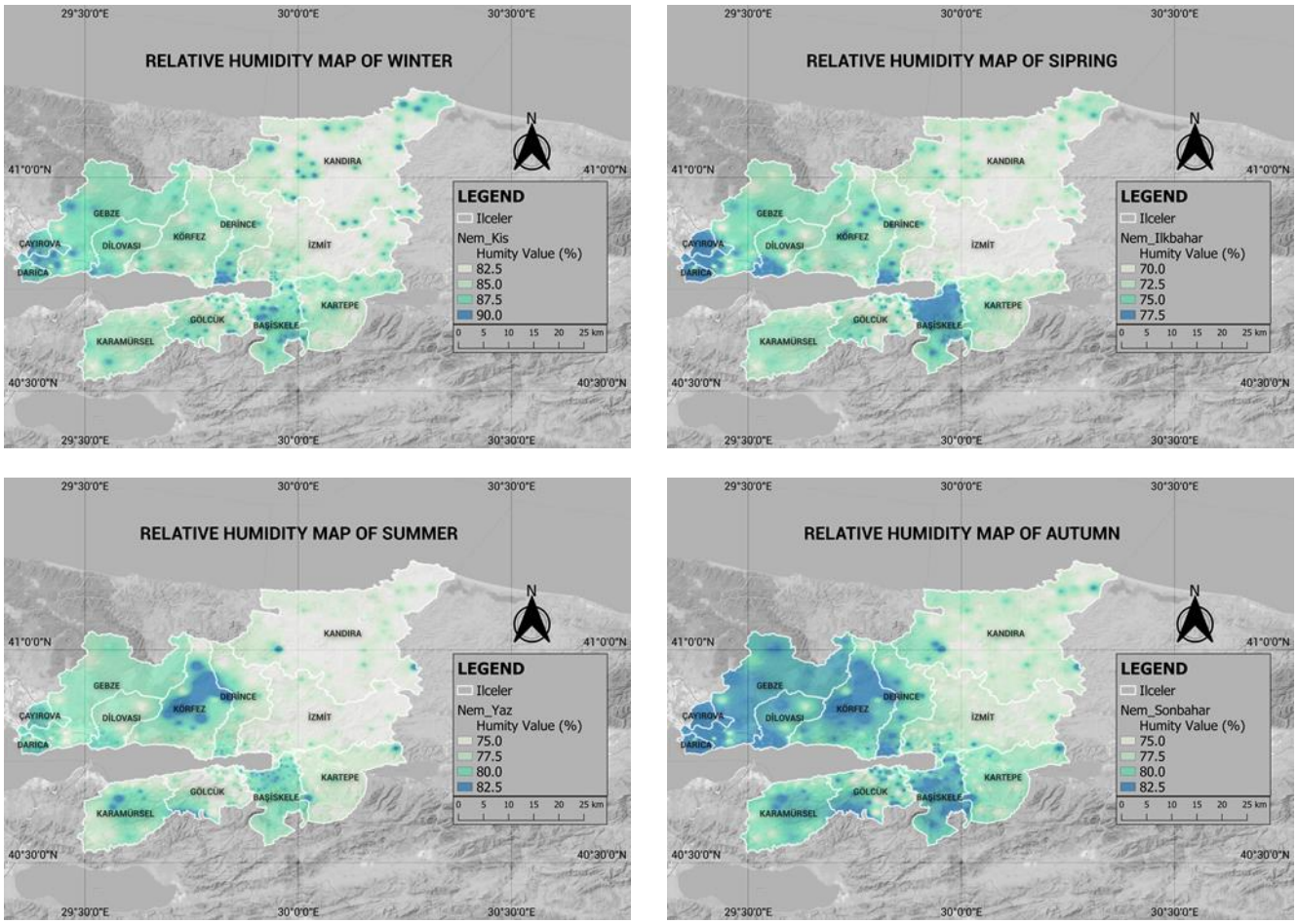

Figure 4. Average relative humidity maps for Kocaeli Province for four seasons

When the average temperature map is examined seasonally, the lowest temperature values for the autumn season are 14.58 °C, and the temperature values are low in the northern parts of the Gulf, Çayırova, Darıca, Dilovası, Gebze, and Karamürsel in the southern parts. The highest temperature is 20.16 °C in Izmit, Kandıra, Derince, partly in Gölcük and in the southern parts of Körfez District. In winter, temperatures vary between 7.77 and 2.04 °C. The lowest temperature in the winter period was observed in Çayırova, Körfez, Karamürsel, and partially in Gebze. The highest temperature is observed in İzmit, Kandıra, partially Gölcük Districts and northern parts of Başiskele District. The lowest temperature in the spring is seen in Başiskele, Çayırova, Darıca Districts and partially in Körfez District. The highest temperature is observed in İzmit, Kandıra, and partially Gölcük Districts. The lowest temperature in summer is seen in Başiskele, Çayırova, Darıca Districts and partially in Körfez and Gebze Districts. The highest temperature is observed in İzmit, Kandıra, and partially Gölcük Districts.

When the average relative humidity map is examined seasonally, the lowest humidity value for the autumn season is seen in Izmit, Kandıra Districts and partially in Gölcük, Karamürsel, Kartepe Districts. The highest humidity value is seen in Başiskele, Çayırova, Darıca, Derince, Dilovası and Gebze Districts.

The lowest humidity value in winter was seen in Izmit, Kandıra Districts and partially in Derince, Gölcük, Karamürsel, Kartepe and Körfez Districts. The highest humidity value is seen in Başiskele, Çayırova, Darıca, Dilovası and Gebze Districts.

The lowest humidity value in spring is seen in Izmit and Kandıra Districts, partially in Derince, Gölcük and Kartepe Districts. The highest humidity value is seen in Başiskele, Çayırova, Darıca, Dilovası, Gebze, Karamürsel, Körfez and partially Gölcük Districts.

The lowest humidity value in summer is seen in Izmit, Kandıra Districts, and partially in Derince and Gölcük Districts. The highest humidity value is seen in Başiskele, Çayırova, Darıca, Dilovası, Gebze, Karamürsel, Körfez and partially Gölcük Districts.

The bioclimatic comfort map created according to the heat index is shown in Figure 5.

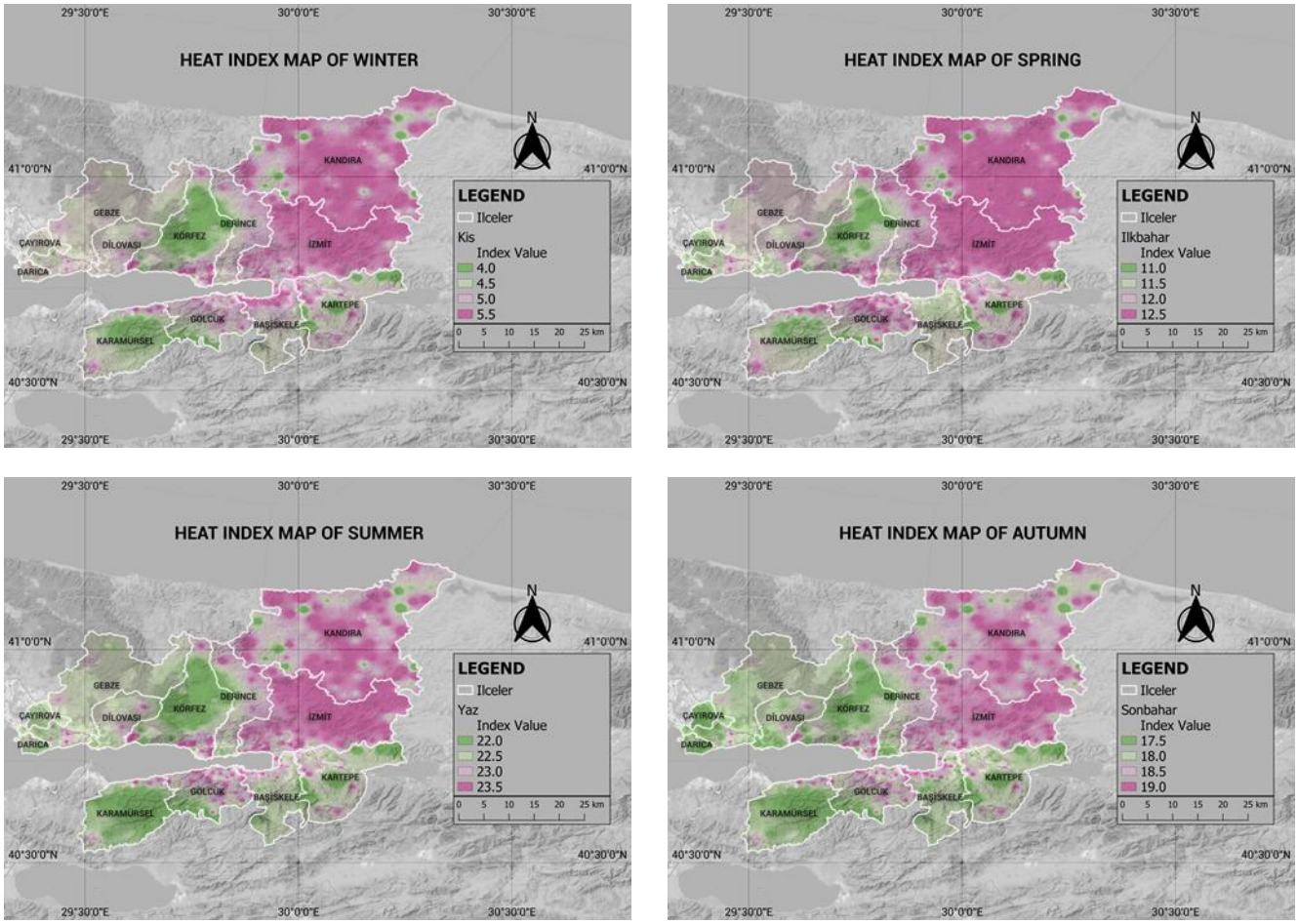

Figure 5. Bioclimatic comfort zone map according to the heat index

The relationship between comfort maps and topography was examined seasonally.

For the autumn season, the temperature index value in the high regions of Kartepe and Başiskele Districts is around 17 degrees. In the districts of Körfez, İzmit, Başiskele, and Gölcük near the sea, the temperature value is around 19 degrees.

For the winter season, the heat index value in the limited area in the districts in the high regions was around 5 degrees. The remaining fields have values close

to 0. In areas at altitudes close to the sea level, the temperature index was around 6 degrees.

For the spring season, the heat index value in the high regions was around 11 degrees. In areas at high sea level, the heat index was around 12.5.

For the summer season, there are very few places where the heat index value is high in high regions. In the regions close to the sea, especially in Gölcük, İzmit, and Körfez Districts, the temperature index is around 20 degrees, and the highest values are observed in the low-altitude seaside location of Gölcük District, almost all of the İzmit District and the majority of Kandıra District. This shows that they are the most uncomfortable areas according to the heat index in the summer seasons.

5. Discussion and conclusions

The seasonal heat index map for the province of Kocaeli for 2019 was created with relative humidity and temperature maps. There are many indices for the evaluation of bioclimatic comfort zones. With the heat index, comfort zones can be determined and they can shape the daily lives of living things.

According to the heat index results, the lowest heat index value for the autumn season is 14.3 degrees. The highest temperature is 20.3. It should not be exposed to a temperature for a long time in these range values. Fatigue is possible with activity.

According to the heat index results, the lowest heat index value for the winter season is 0.6 degrees. The highest temperature is 6.8. Since the air temperature is low, the heat index does not affect the winter season.

According to the heat index results, the lowest heat index value for the spring season is 8 degrees. The highest temperature is 13.6. When the heat index effects are examined, it is seen that it is comfortable.

According to the heat index results, the lowest heat index value for the summer season is 18.3 degrees. The highest temperature is 24.9. It should not be exposed to a temperature for a long time in these range values. Fatigue is possible with activity.

It should not be forgotten that the evaluation of the regions that provide bioclimatic comfort values in terms of settlement is very important for human health, and settlement areas should be determined by considering bioclimatic comfort in future planning studies for Kocaeli province.

Conflicts of interest

The authors declare no conflicts of interest.

References

1. Çınar, A. (2007). Psikometri nedir? Türk Tesisat Mühendisleri Derneği Isıtma, Soğutma, Havalandırma, Klima, Yangın ve Sıhhi Tesisat Dergisi, sayı 49 (s.ek 1-7).
2. Adiguzel, F., Cetin, M., Kaya, E., Simsek, M., Gungor, S., & Sert, E. B. (2020). Defining suitable areas for bioclimatic comfort for landscape planning and landscape management in Hatay, Turkey. Theoretical and Applied Climatology, 139(3), 1493-1503.
3. Bozdogan Sert, E., Kaya, E., Adiguzel, F., Cetin, M., Gungor, S., Zeren Cetin, I., & Dinc, Y. (2021). Effect of the surface temperature of surface materials on thermal comfort: a case study of Iskenderun (Hatay, Turkey). Theoretical and Applied Climatology, 144(1), 103-113
4. Cetin, M., Adiguzel, F., Gungor, S., Kaya, E., & Sancar, M. C. (2019). Evaluation of thermal climatic region areas in terms of building density in urban management and planning for Burdur, Turkey. Air Quality, Atmosphere & Health, 12(9), 1103-1112.
5. Cetin, M., Adiguzel, F., Kaya, O., & Sahap, A. (2018). Mapping of bioclimatic comfort for potential planning using GIS in Aydin. Environment, Development and Sustainability, 20(1), 361-375.
6. Cetin, M., Yildirim, E., Canturk, U., & Sevik, H. (2018). Chapter 25: investigation of bioclimatic comfort area of Elazig city centre. In book title: recent researches in science and landscape management. 324-333.
7. Cetın, M., & Zeren, I. (2016). Bioclimatic mapping of rural areas in Bozkurt, Turkey, for recreation. In VII International Scientific Agriculture Symposium," Agrosym 2016", 6-9 October 2016, Jahorina, Bosnia and Herzegovina. Proceedings (pp. 2924-2931). University of East Sarajevo, Faculty of Agriculture.
8. Cetin, M., & Zeren, I. (2016). Evaluation of the value of biocomfort for Kastamonu-Inebolu. In International conference GREDIT, 4-35.
9. Cetin, M., Sevik, H., & Zeren, I. (2017). Chapter 7_ Coastal biocomfort mapping for Doganyurt. OMICS, E-Books International, The Effects of Environmental Policies on Sustainability: Theory and Methods. Eds: Nurcan Kilinc-Ata, 51-55.
10. Gungor, S., Cetin, M., & Adiguzel, F. (2021). Calculation of comfortable thermal conditions for Mersin urban city planning in Turkey. Air Quality, Atmosphere & Health, 14(4), 515-522.
11. Zeren Cetin, I., Ozel, H. B., & Varol, T. (2020). Integrating of settlement area in urban and forest area of Bartin with climatic condition decision for managements. Air Quality, Atmosphere & Health, 13(8), 1013-1022.
12. Zeren Cetin, I. & Sevik, H. (2020). Investigation of the relationship between bioclimatic comfort and land use by using GIS and RS techniques in Trabzon. Environmental monitoring and assessment, 192(2), 1-14.
13. Atılgan İ., Ataer Ö. E. (2009). Isıl Konfor Analizinin Uygulanması. IX. Tesisat Mühendisliği Kongresi ve Sergisi Bildiri Kitabı, 571-581.
14. Fanger, P. O. (1972). Thermal comfort, analysis, and applications in environmental engineering. 5th Edition, McGraw-Hill,
15. Givoni B., (1976). Climate and Architecture. Van Nostrand Reinhold.
16. Höppe P. (1984). Die Energiebilanz des Menschen. Wiss. Mitt. Meteorol. Inst. Uni München, 43, 71- 75.

17. Landsberg H.E. (1972). The Assessment of Human Bioclimate, a Limited Reviewof Physical Parameters", World Meteorological Organization, Technical Note No.123, WMO-No. 331, 221-242.
18. Parsons K. C. (2003). Human thermal environments: the effects of hot, moderate, and cold environments on human health, comfort and performance. Taylor & Francis, 5, 258-271.
19. Çınar, İ., (1999). Fiziksel Planlamada Biyoiklimsel Veriler Kullanarak Biyokonforun Oluşturulması Üzerine Fethiye Merkezi Yerleşimi Üzerinde Araştırmalar. Yüksek Lisans Tezi, EÜ Fen Bilimleri Enstitüsü, 89s.
20. Cetin, M. (2019). The effect of urban planning on urban formations determining bioclimatic comfort area's effect using satellitia imagines on air quality: a case study of Bursa city. Air Quality, Atmosphere & Health, 12(10), 1237-1249.
21. Cetin, M. (2020). The changing of important factors in the landscape planning occur due to global climate change in temperature, Rain and climate types: A case study of Mersin City. Turkish Journal of Agriculture-Food Science and Technology, 8(12), 2695-2701.
22. Cetin, M. (2020). Climate comfort depending on different altitudes and land use in the urban areas in Kahramanmaras City. Air Quality, Atmosphere & Health, 13(8), 991-999.
23. Cetin, M. (2018, September). The finding of suitable biocomfort area mapping for Karabük City Center. In International Agricultural, Biological & Life Science Conference (pp. 295-299). 2018, September, Edirne.
24. Cetin, M. (2016). Determination of bioclimatic comfort areas in landscape planning: A case study of Cide Coastline. Turkish Journal of Agriculture-Food Science and Technology, 4(9), 800-804.
25. Cetin, M. (2015). Determining the bioclimatic comfort in Kastamonu City. Environmental monitoring and assessment, 187(10), 1-10.
26. Cetin, M., Topay, M., Kaya, L. G., & Yılmaz, B. (2010). Efficiency of bioclimatic comfort in landscape planning process: case of Kutahya. Süleyman Demirel Üniversitesi Orman Fakültesi Dergisi Seri A, (1), 83-95.
27. Matzarakis A., (2003). Assessing Climate for Tourism Purposes: Existing Methodsand Tools for The Thermal Complex. Meteorological Institute, University of Freiburg, 101-105.
28. Nikolopoulou M., Baker N., Steemers K. (2001). Açık alanlardaki kentsel alanlarda termal konfor: insan parametresini anlama. Solar Energy, 70(3),227-235
29. Blazejczyk K. (2005). New indices to assess thermal risks outdoors. [in:] I. Holmér, K.Kuklane, Ch. Gao (red.), Environmental Ergonomics XI", Proc. Of the 11th International Conference, 222-225, 22-26 May.
30. Çınar, İ. (2004). Biyoklimatik Konfor Ölçütlerinin Peyzaj Planlama Sürecinde Etkinliği Üzerinde Muğla-Karabağlar Yaylası Örneğinde Araştırmalar. Doktora tezi, Ege Üniversitesi Fen Bilimleri Enstitüsü, İzmir, 227s.
31. Evans, J. M. (2003). Evaluating comfort with varying temperature: a graphic design tool, Energy and Bulding, 35(2003) 87-93.
32. Olgyay, V., (1973). Desıgn wıth Clımate, Bıoclimatic Approach to Archıtectural Regıonalism. Prınceton Universsıty Press, New Jersey.
33. Koçman, A. (1991). İzmir'in Kentsel Gelişimini Etkileyen Doğal Çevre Faktörleri ve Bunlara İlişkin Sorunlar, Coğrafya Araştırmaları Dergisi, 3 s: 101, İzmir.
34. Steadman, R. G. (1994). Norms of Apparent Temperature in Australia. Aust. Met. Mag. 43, 1–16.
35. Rothfusz L. P., (1990). The Heat Index Equation (or, More Than You ever wanted to know about heat index). Technology Attachment, SR/SSD 90-23, NWS S. Reg. Headquarters, Forth Worth, TX.