



The assessment of the thermal behavior of an urban park surface in a dense urban area for planning decisions

Fatih Adiguzel · Mehmet Cetin ·
Mesut Dogan · Senay Gungor · Mustafa Kose ·
Elif Bozdogan Sert · Efdal Kaya

Received: 17 September 2021 / Accepted: 28 May 2022 / Published online: 22 June 2022
© The Author(s), under exclusive licence to Springer Nature Switzerland AG 2022

Abstract The new summer index (SSI) which was established to determine climate comfort was classified according to the index. Climatic comfort areas will increase and thus raising the quality of living in areas. The temperature values felt in the study were calculated with the SSI formula, and then the maps of the study area were classified. The study area was the Hayal Park and its surroundings in the Toros Quarter of Cukurova District, which is surrounded by multi-story and dense buildings in the north of Adana. Although the vertical construction is very high, it is richer in terms of green areas compared to other large central districts. Cukurova, which is one of the largest districts of Adana (according to population), has

Seyhan dam lake in the north and Seyhan district in the south. The study area is on the border of Seyhan district and is adjacent to Yüreğir and Sarıçam districts. With the portable Smart SENSOR AS 847 measuring device, temperature and relative humidity were measured at 1.5 m above the ground on Tuesday, August 20 at 07.00, at 14.00, and 21.00. Bioclimatic comfort areas were determined by measuring temperature and relative humidity at 25 points with different textures in the study area. In this study, measured instantaneous temperature (°C) and relative humidity (%) data were transferred to GIS medium by ArcGIS 10.6 program and then modeled with the Kriging method, which is one of the interpolation methods, and temperature and

F. Adiguzel · S. Gungor
Faculty of Arts and Sciences, Department of Geography,
Nevşehir Hacı Bektaş Veli University, Nevşehir, Turkey

M. Cetin
Faculty of Engineering and Architecture, Department
of Landscape Architecture, Kastamonu University,
Kastamonu, Turkey

Present Address:
M. Cetin (✉)
Faculty of Architecture, Department of City and Regional
Planning, Ondokuz Mayıs University, Samsun, Turkey
e-mail: mcetin@kastamonu.edu.tr

M. Dogan
Faculty of Letters, Department of Geography, Istanbul
University, Istanbul, Turkey
e-mail: esutan@istanbul.edu.tr

M. Kose
Faculty of Arts and Sciences, Department of Geography,
Afyon Kocatepe University, Afyonkarahisar, Turkey
e-mail: mustafakose@aku.edu.tr; kosemustafa01@gmail.
com

E. Bozdogan Sert
Faculty of Architecture, Department of Landscape
Architecture, Iskenderun Technical University, Iskenderun,
Turkey

E. Kaya
Iskenderun Vocational School, Department of Architecture
and Urban Planning, Program of Map and Cadastre,
Iskenderun Technical University, Iskenderun, Hatay,
Turkey

relative humidity maps were created. The temperature map created in degrees Celsius ($^{\circ}\text{C}$) by the Kriging method and was converted to Fahrenheit degrees ($^{\circ}\text{F}$) in the Raster Calculator. The reason for this change is that SSI is calculated with the formula Fahrenheit ($^{\circ}\text{F}$). These maps were then calculated on the Raster Calculator using the SSI formula, and sensed temperature values were obtained. The SSI, which normally has 8 classes, has 3 classes in the study area. These classes are $83 \leq \text{SSI} < 91$ slightly hot, $91 \leq \text{SSI} < 100$ hot, and $100 \leq \text{SSI} < 112$ very hot. When we look at the maps, the places outside of Hayal Park are in the hot class at 07.00 in the morning, and we can see that the green spaces have a positive effect on the bioclimatic comfort areas. The small area is in a very hot class. When we look at 14.00 h, it is a totally hot class. Normally, the temperature is the highest of these times and also coincides with the multi-story buildings in the study area; asphalt and concrete areas increased the temperature. As a result, there is a very hot air in the study area. It was determined that the maps identified non-comfortable areas. Since urban form and settlement affect climate comfort values, the urban plan should be revised, and the area should be brought to the bioclimatic comfort value range. For reducing the effect of temperature in the working area and creating comfortable areas is increasing the density of green areas compared to asphalt and concrete areas. Considering that the Cukurova district will grow further, urban planning should be done very well to reach the comfort range in the following settlements.

Keywords Thermal comfort zone · Urban heat island · Cukurova district · GIS · Summer index

Abbreviations

SSI Summer index

GIS Geographic information systems

Introduction

Urbanization has gained pace and momentum in recent decades all over the world including Turkey. This is due to the rapid developments in technology, the increase of transportation facilities and so on. This has resulted in destabilizing the ecological balance in urban areas (Bakhtiari & Bakhtiari, 2013; Bode et al., 2003; Cetin, 2015; De Freitas, 2003; Hamilton & Tol,

2004; Harlfinger, 1991; Kaya et al., 2019; Scott & Lemieux, 2009; Wang et al., 2016). The natural areas in the city are replaced by stone and concrete structures, and the natural land cover (forests, pastures, streams, ponds, etc.), which we call rural areas, are pushed further away from the city center with time. More industrial, transportation, and shopping services are being developed to serve the spatially growing city. Horizontal and vertical structures arranged side by side have negative effects on temperature, relative humidity, wind and precipitation, and distinguished the urban climate from its environment (Adiguzel et al., 2020; Amelung et al., 2007; Amelung & Viner, 2006; Clements & Georgiou, 1998; De Freitas, 2003; Farajzadeh & AhmadAbadi, 2010; Fielding & Shortland, 2011; Fletcher & Morakabati, 2008; Grassl, 1976, 1979, 1981, 1989, 2006, 2011; Gungor et al., 2021; Zeren Cetin et al., 2020; Zeren Cetin & Sevik, 2020; Zhong & Chen, 2019).

According to the research, it shows that the average annual temperature increases by 2–3 $^{\circ}\text{C}$ compared to the rural environment of cities. This temperature value reaches 5–13 $^{\circ}\text{C}$, depending on the spatial size of the city, the presence of industry, the excess of motor vehicles, and the insufficiency of green areas (Ataei & Hasheminasab, 2012; Auliciems & Kalma, 1979; Bozdogan Sert et al., 2021; Hejazizadeh et al., 2019; Hernandez & Ryan, 2011; Kovács & Unger, 2014a, b; Lei et al. 2013; Maddison, 2001; Matzarakis, 2002, 2006, 2007; Méndez-Lázaro et al., 2014; Mieczkowski, 1985; Moreno et al., 2008; Scott et al., 2004, 2016; Scott & Lemieux, 2009). Because the high-rise and dark-colored buildings in cities, floors covered with asphalt and concrete, the temperatures from urban heat islands also high-rise buildings which block wind paths and prevent wind circulation within the area are the reasons for the warming of cities.

When the difference in the climate of cities reaches extreme values, it brings negative effects on human health. These effects limit the mental, physical, and biological activities in activities of human beings. Too hot, cold, and excessive humidity are undesirable due to the difficulty of adaptation for people. Owing to the difficulty of adaptation, too hot, too cold, and excessive humidity are undesirable for people (Olgay, 1973). According to Olgay (1973), the condition in which the necessary climatic conditions (temperature, relative humidity, wind, and precipitation) coexist with the human being is called bioclimatic comfort (Berrittella

et al., 2006; Cetin, 2016, 2019, 2020a, b; De Freitas, 2003, 2005; Lin & Matzarakis, 2008; Scott & Lemieux, 2009; Scott & McBoyle, 2001).

The geometry of the city affects the bioclimatic comfort areas and creates urban heat islands. According to Oke (1981), urban heat island formations generally occur at night. While it has a positive effect in winter, it is observed that temperatures increase excessively in summer months (Canan, 2017; Cetin, 2016, 2019, 2020a, b).

Many studies indicate that urban forests, green spaces, and roofs, regular urban uniforms have a significant impact on the reduction of urban heat islands (Amiranashvili et al., 2008, 2010, 2018; De Freitas, 2003; Lin & Matzarakis, 2008; Lise & Tol, 2002; Scott & Lemieux, 2009; Zhong & Chen, 2019). As the number of green areas in the city increases, the positive effect on the temperature increases. In the study conducted by Monteiro et al. (2016), the city

of London was selected, and the correlation between green areas and night temperatures was studied.

In this study, a narrow study area was selected in the Adana-Cukurova district. The urban form in the study area, the structure of buildings and ground areas, and the presence of green and open spaces investigated the amount of the bioclimatic comfort areas. For this purpose, a study was carried out on Hayal Park, which has the densest urban structures of the Cukurova district and its surroundings and on some streets.

Material and methods

The study area was the Hayal Park and its surroundings in the Toros Quarter of Cukurova District, which is surrounded by multi-story and dense buildings in the north of Adana (Fig. 1). Although the vertical construction is very high, it is richer in terms of green areas compared

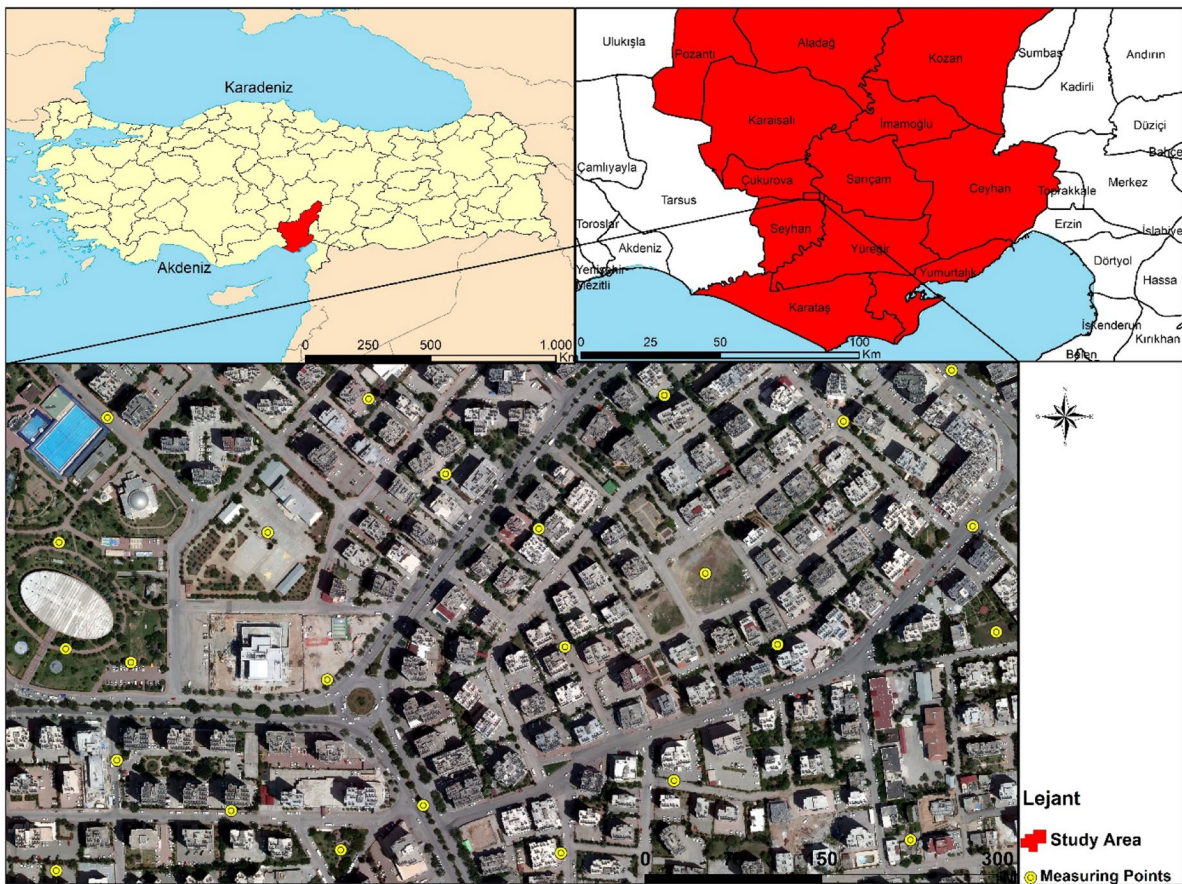


Fig. 1 Work area location map

to other large central districts. Cukurova, which is one of the largest districts of Adana (according to population), has Seyhan dam lake in the north and Seyhan district in the south. The study area is on the border of Seyhan district and is adjacent to Yüreğir and Sarıçam districts.

With the portable Smart SENSOR AS 847 measuring device, temperature and relative humidity were measured at 1.5 m above the ground on Tuesday, August 20 at 07.00, at 14.00, and 21.00. Bioclimatic comfort areas were determined by measuring temperature and relative humidity at 25 points with different textures in the study area.

In this study, measured instantaneous temperature ($^{\circ}\text{C}$) and relative humidity (%) data were transferred to GIS medium by ArcGIS 10.6 program and then modeled with the Kriging method, which is one of the interpolation methods, and temperature and relative humidity maps were created. The temperature map created in degrees Celsius ($^{\circ}\text{C}$) by the Kriging method and was converted to Fahrenheit degrees ($^{\circ}\text{F}$) in the Raster Calculator. The reason for this change is that SSI is calculated with the formula Fahrenheit ($^{\circ}\text{F}$). These maps were then calculated on the Raster Calculator using the SSI formula, and sensed temperature values were obtained (Pepi, 1987).

$$\text{SSI Formula} = 1.98[Ta - (0.55 - 0.0055Ur) \\ (Ta - 58)] - 56.83$$

In this index formula, Ta represents air temperature Fahrenheit ($^{\circ}\text{F}$) and Ur relative humidity (Tzenkova et al., 2007).

The temperature values were converted to degrees Celsius ($^{\circ}\text{C}$) for a better understanding of the maps. According to the SSI given in Table 1, thermal

Table 1 Classification of thermal comfort is that prepared from Pepi (1987)

SSI Value ($^{\circ}\text{F}$)	Thermal comfort class
$\text{SSI} < 70$	Cold
$70 \leq \text{SSI} < 77$	Cool
$77 \leq \text{SSI} < 83$	Comfortable
$83 \leq \text{SSI} < 91$	Warm
$91 \leq \text{SSI} < 100$	Hot
$100 \leq \text{SSI} < 112$	So hot
$112 \leq \text{SSI} < 125$	Scorching heat
$125 \leq \text{SSI} < 150$	Dangerously hot
$\text{SSI} > 150$	Hot threatening life

comfort values were determined and classified. The classification table was adapted to the SSI values created by analyses and calculations, and thermal comfort classes were created (Tzenkova et al., 2007).

Results

Residential areas and land cover

In recent years, as a result of rapid population growth and unplanned growth models in many cities, green areas have decreased; climatic changes have been experienced and adversely affected urban comfort and ecosystem (Matzarakis & Endler, 2010; Topay, 2012). Adana was affected by these problems, and uncomfortable areas increased throughout the city center. When we look at the study area, in particular, the Cukurova district has become a settlement, where rapid population growth, rapid urbanization, and other developments related to these have caused many environmental problems, and the proper use of natural values has been restricted. With the development plan prepared in 1985, the development of high-density vertical constructions started in Northern Adana and gained speed. Nowadays, it is seen that almost all of Northern Adana is surrounded by multi-story buildings (Fig. 2), which causes the city to be much hotter in the summer months, and the temperature is extremely high due to the humidity.

Floor heights are highly effective in weather temperatures, especially in terms of changing wind directions and storing temperatures due to surface characteristics and the spatial size of the city, causing cities to warm up (Oke, 2004). When we look from this perspective, the distribution and proportions of the building floors in our study area are different. The number of floors ranges from 1 to 19 (Fig. 3). In non-buildings, there are green spaces and a small number of empty spaces. Although building heights may harm urban temperature, this effect may vary due to factors such as street-to-street widths and various urban forms.

Temperature and relative humidity

Mobile measurements performed in the study area were carried out on Tuesday, August 20 at 07.00 in



Fig. 2 3D view of the workspace

the morning, at 14.00 in the afternoon, and 21.00 in the evening. As a result of these measurements, significant differences were found in temperature and humidity values.

According to the temperature maps prepared within the scope of this study; temperatures range between 24 and 28.5 °C in the morning, 31–35 °C in the noon, and 27–34.5 °C in the evening. While lower values were observed in the west, the highest temperature values in the mobile measurements were found in the east and many places (Fig. 4). This difference

in temperature distributions between morning, noon, and evening can be explained by the differences in building height and the presence of light-green areas. It is seen that the temperature values of Hayal Park which is located to the west of the study area are the lowest. It has been determined that the temperatures are quite high in places where floor heights are dense and in narrow streets.

When we look at relative humidity maps, humidity ranges between 70 and 80 % in the morning, 38.8–47.33 % at noontime, and 56.89–64.5 % in



Fig. 3 Building floor numbers

Fig. 4 Working area temperature maps of the study area

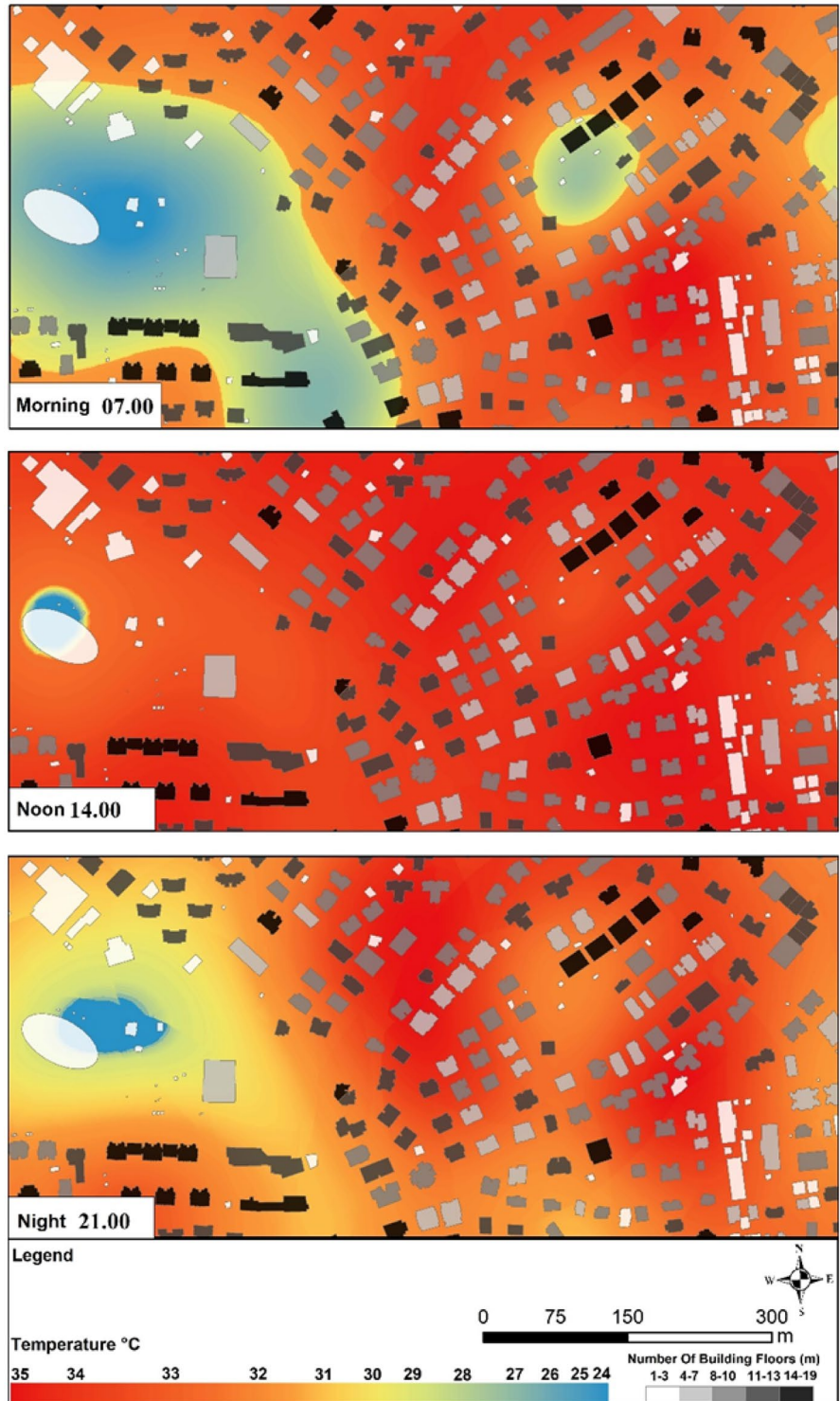


Fig. 5 Working area relative humidity maps of study area

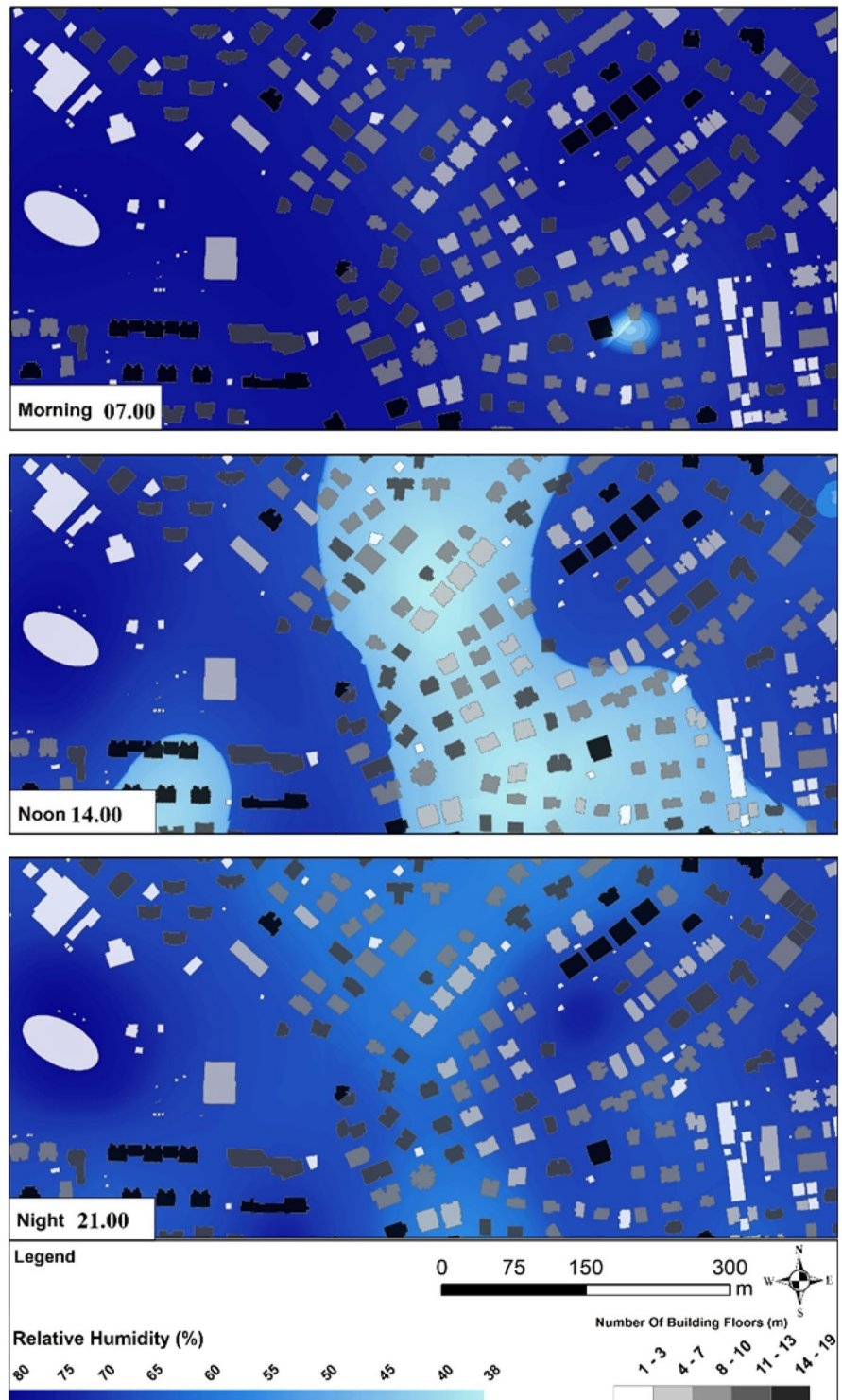


Fig. 6 Felt temperature maps made with SSI formula

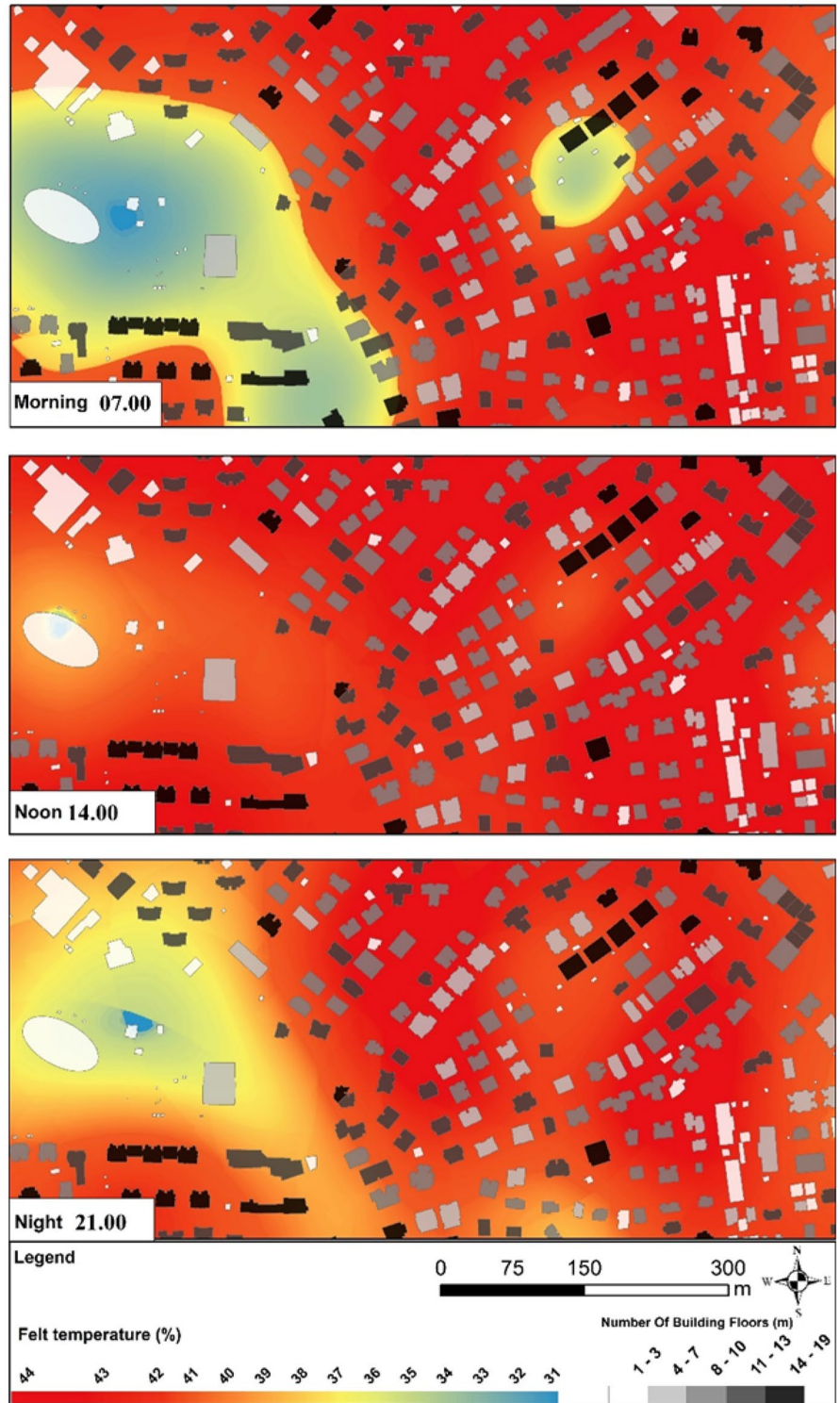
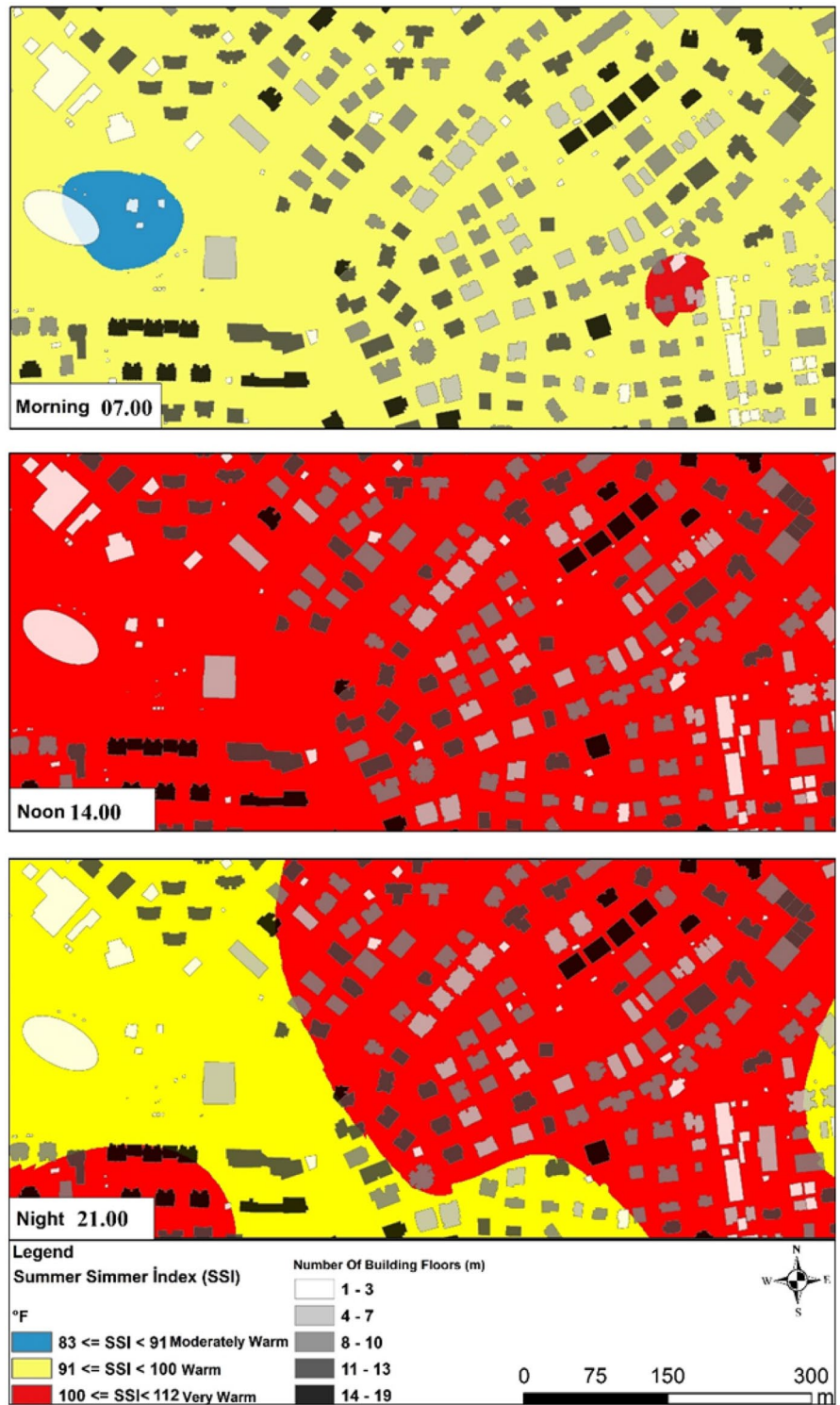


Fig. 7 Workspace new summer index (SSI) classification



the evening (Fig. 5). The highest relative humidity values are observed in the morning, and the lowest values are at noon. When we compare the temperature and relative humidity maps, we see that the values are inversely proportional. Relative humidity values are the lowest at noon when temperature is the highest. This is since the temperature increases this month, allowing the air to expand and the rainfall does not fall. In this way, in the summer season, high relative humidity, which does not turn into precipitation, is over 50% but not 100% in the morning and evening hours and causes a sweltering air.

Discussions

Felt temperature and bioclimatic comfort

In many climate indices, temperature, humidity, and wind values are sometimes evaluated by applying different combinations to determine bioclimatic comfort areas. The most sensible temperature criterion is used to determine the areas of bioclimatic comfort. The sensed temperature can be defined as the temperature that a person feels or perceives, unlike normal air temperature. Accordingly, temperature and relative humidity maps made for the study area, SSI formula ($SSI \text{ formula} = 1.98 [Ta - (0.55 - 0.0055 Ur) (Ta - 58)] - 56.83$) felt temperature maps were created (Pepi, 1987). In this formula, the temperature values are calculated as °F. The temperature map in °C was converted to °F with ArcGIS Raster Calculator for formula application. The temperature and relative humidity of the study area were obtained by the SSI formula. When this map is examined, the sensed temperatures vary between 31.88 and 38 °C in the morning, 38.92 and 43 °C in the morning, and 34.72 and 43.65 °C in the evening (Fig. 6). This means that bioclimatic comfort areas cannot be determined by simply looking at temperature maps.

The temperature values felt in the study were calculated with the SSI formula, and then the maps of the study area were classified. The SSI, which normally has 8 classes, has 3 classes in the study area. These classes are $83 \leq SSI < 91$ slightly hot, $91 \leq SSI < 100$ hot, and $100 \leq SSI < 112$ very hot (Fig. 7). When we look at the maps, the places outside of Hayal Park are in the hot class at 07.00 in the

morning, and we can see that the green spaces have a positive effect on the bioclimatic comfort areas. The small area is in a very hot class. When we look at 14.00 h, it is a totally hot class. Normally, the temperature is the highest of these times and also coincides with the multi-story buildings in the study area; asphalt and concrete areas increased the temperature. As a result, there is a sweltering air in the work area.

In settlements like Cukurova, because of the high temperatures in the summer months, the urban heat islands emerge, and in this case, there are problems in terms of bioclimatic comfort and health conditions for the people living in Cukurova.

Conclusions

It was determined that the maps identified non-comfortable areas. It was observed to be in little hot, hot, and very hot categories. According to the results of the map, it is seen that the lowest temperature values are 31.88 °C, and the highest is 43.65 °C. Since urban form and settlement affect climate comfort values, the urban plan should be revised, and the area should be brought to the bioclimatic comfort value range. One of the most important factors for reducing the effect of temperature in the working area and creating comfortable areas is increasing the density of green areas compared to asphalt and concrete areas. Green spaces provide cooling effect, thanks to plants, and reduce the urban heat island formation. Considering that the Cukurova district will grow further, urban planning should be done very well to reach the comfort range in the following settlements.

Author contribution EBS, EK, FA, SG, MD, MK, and MC designed the study and performed the experiments; EBS, EK, FA, and MC performed the experiments, analyzed the data, and wrote the manuscript.

Availability of data and materials All the data are given in the manuscript.

Declarations

Competing interests The authors declare no competing interests.

References

- Adiguzel, F., Cetin, M., Kaya, E., Simsek, M., Gungor, S., & Bozdogan Sert, E. (2020). Defining suitable areas for bioclimatic comfort for landscape planning and landscape

- management in Hatay, Turkey. *Theoretical and Applied Climatology*, 139(3), 1493–1503. <https://doi.org/10.1007/s00704-019-03065-7>
- Amelung, B., & Viner, D. (2006). Mediterranean tourism: Exploring the future with the tourism climate index. *Journal of Sustainable Tourism*, 14(4), 349–366. <https://www.tandfonline.com/doi/abs/10.2167/jost549.0>
- Amelung, B., Nicholls, S., & Viner, D. (2007). Implications of global climate change for tourism flows and seasonality. *Journal of Travel research*, 45, 285–296. <https://journals.sagepub.com/doi/abs/10.1177/0047287506295937>
- Amiranashvili, A., Matzarakis, A., & Kartvelishvili, L. (2008). Tourism climate index in Tbilisi. *Transactions of the Georgian Institute of Hydrometeorology*, 115, 27–30. <http://dspace.gela.org.ge/bitstream/123456789/744/1/TCI-Tb-Konf08En.pdf>
- Amiranashvili, A., Matzarakis, A., & Kartvelishvili, L. (2010). Tourism climate index in Batumi, Modern problems of using of health resort resources, Collection of Scientific Works of International Conference, Sairme, Georgia, June 10–13, 2010, ISBN 978-9941-0-2529-7, Tbilisi, 2010, pp. 116–121. <http://dspace.gela.org.ge/bitstream/123456789/660/1/TCI-Batumi-Konf-2010-En.pdf>
- Amiranashvili, A. G., Japaridze, N. D., Kartvelishvili, L. G., Khazaradze, K. R., & Kurdashvili, L. R. (2018). Tourism climate index in Kutaisi (Georgia), International Scientific Conference, ISSN 1512–1976, v. 6, Kutaisi, Georgia. <http://www.openlibrary.ge/handle/123456789/7330>
- Ataei, H., & Hasheminasab, F. (2012). Comparative assessment of human bioclimatic in Isfahan City using Terjunde, TCI, PET, PMV. *Urban Regional Studies and Research*, 4(14), 17–19.
- Auliciems, A., & Kalma, J. D. (1979). A climatic classification of human thermal stress in Australia. *Journal of Applied Meteorology and Climatology*, 18, 616–626. https://journals.ametsoc.org/view/journals/apme/18/5/1520-0450_1979_018_0616_accoht_2_0_co_2.xml
- Bakhtiari, B., & Bakhtiari, A. (2013). Determination of tourism climate index in Kerman province. *Desert*, 18(2), 113–126. https://jdesert.ut.ac.ir/article_50003_e04a9ca8e1009d1a9602927aa991decb.pdf
- Berrittella, M., Bigano, A., Roson, R., & Richard, S. J. T. (2006). A general equilibrium analysis of climate change impacts on tourism. *Tourism Management*, 27, 913–924. <https://www.sciencedirect.com/science/article/abs/pii/S0261517705000518>
- Bode, S., Hapke, J., & Zisler, S. (2003). Need and options for a regenerative energy supply in holiday facilities. *Tourism Management*, 24, 257–266. <https://www.sciencedirect.com/science/article/abs/pii/S0261517702000675>
- 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. <https://doi.org/10.1007/s00704-021-03524-0>
- Canan, F. (2017). Determination of urban heat island effect based on urban geometry: The case of Konya. *Journal of Çukurova University Faculty of Engineering and Architecture*, 32, 69–80. <https://doi.org/10.21605/cukurovaummfd.357202>
- Cetin, M. (2015). Determining the bioclimatic comfort in Kas-tamonu City. *Environmental Monitoring and Assessment*, 187(10). <https://doi.org/10.1007/s10661-015-4861-3>
- 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. <http://www.agrifoodscience.com/index.php/TURJAF/article/view/872/374>
- 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. <https://doi.org/10.1007/s11869-019-00742-4>; <https://rd.springer.com/article/10.1007/s11869-019-00742-4>
- Cetin, M. (2020a). Climate comfort depending on different altitudes and land use in the urban areas in Kahramanmaraş city. *Air Quality, Atmosphere & Health*, 13, 991–999. <https://doi.org/10.1007/s11869-020-00858-y>
- Cetin, M. (2020b). 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.
- Clements, M. A., & Georgiou, A. (1998). The impact of political instability on a fragile tourism product. *Tourism Management*, 19(3), 283–288. <https://www.sciencedirect.com/science/article/abs/pii/S0261517798000120>
- de Freitas, C. R. (2003). Tourism climatology: evaluating environmental information for decision making and business planning in the recreation and tourism sector. *International Journal of Biometeorology*, 48(1), 45–54. <http://link.springer.com/article/10.1007/s00484-003-0177-z>
- De Freitas, C. R. (2005). The climate-tourism relationship and its relevance to climate change impact assessment, in: Hall, M.C. and Higham, J. (eds.). *Tourism, recreation and climate change*, Channel View Publications, Clevendon, 29–43. https://books.google.com.tr/books?hl=en&lr=&id=7nNEFApnJAcC&oi=fnd&pg=PA29&dq=The+Climate-Tourism+Relationship+and+its+Relevance+to+Climate+Change+Impact+Assessment,+in:+Hall,+M.C.+and+Higham&ots=MhY3tQ4FNq&sig=A9SeB_suGGmZ9jIEluWnrazWPw4&redir_esc=y#v=onepage&q&f=false
- Farajzadeh, M., & AhmadAbadi, A. (2010). Assessment and zoning of tourism climate of Iran using tourism climate index (TCI). *Physical Geography Research Quarterly*, 71, 42–31. https://jphgr.ut.ac.ir/m/article_21546.html?lang=en
- Fielding, D., & Shortland, A. (2011). How do tourists react to political violence? An empirical analysis of tourism in Egypt. *Defence and Peace Economics*, 22(2), 217–243. <https://www.tandfonline.com/doi/abs/10.1080/10242694.2011.542340>
- Fletcher, J., & Morakabati, Y. (2008). Tourism activity, terrorism and political instability within the commonwealth: The cases of Fiji and Kenya. *International Journal of Tourism Research* 10: 537–556. <https://onlinelibrary.wiley.com/doi/abs/10.1002/jtr.699>
- Grassl, H. (1976). The dependence of the measured cool skin of the ocean on wind stress and total heat flux. *Boundary-Layer Meteorology*, 10(4), 465–474.

- Grassl, H. (1979). Possible changes of planetary albedo due to aerosol particles. In *Developments in atmospheric science* (Vol. 10, pp. 229–241). Elsevier.
- Grassl, H. (1981). The climate at maximum entropy production by meridional atmospheric and oceanic heat fluxes. *Quarterly Journal of the Royal Meteorological Society*, 107(451), 153–166.
- Grassl, H. (1989). Extraction of surface temperature from satellite data. In *Applications of remote sensing to agrometeorology* (pp. 199–220). Springer, Dordrecht.
- Grassl, H. (2006). Climate change, new weather extremes and climate policy. In *Earth system science in the Anthropocene* (pp. 41–50). Springer, Berlin, Heidelberg.
- Grassl, H. (2011). Climate change challenges. *Surveys in Geophysics*, 32(4–5), 319.
- 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. <https://doi.org/10.1007/s11869-020-00955-y>
- Hamilton, J. M., & Tol, R. S. J. (2004). The impacts of climate change on tourism and recreation. Working paper FNU-52, Research Unit Sustainability and Global Change, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg.
- Harlfinger, O. (1991). Holiday bioclimatology: A study of Palma de Majorca. *Spain. Geojournal*, 25(4), 377–381.
- Hejazizadeh, Z., Karbalaee, A., Hosseini, S. A., & Tabatabaei, S. A. (2019). Comparison of the holiday climate index (HCI) and the tourism climate index (TCI) in desert regions and Makran coasts of Iran. *Arabian Journal of Geosciences*, 12, 803. <https://link.springer.com/article/10.1007/s12517-019-4997-5>
- Hernandez, A. B., & Ryan, G. (2011). Coping with climate change in the tourism industry: A review and agenda for future research. *Tourism and Hospitality Management*, 17(1), 79–90. <https://hrcak.srce.hr/69285>
- Kaya, E., Agca, M., Adiguzel, F., & Cetin, M. (2019). Spatial data analysis with R programming for environment. *Human and Ecological Risk Assessment: An International Journal*, 25(6), 1521–1530. <https://www.tandfonline.com/doi/full/10.1080/10807039.2018.1470896>
- Kovács, A., & Unger, J. (2014a). Modification of the tourism climatic index to Central European climatic conditions—Examples. *időjárás/quarterly. Journal of the Hungarian Meteorological Service*, 118(2), 147–166.
- Kovács, A., & Unger, J. (2014b). Analysis of tourism climatic conditions in Hungary considering the subjective thermal sensation characteristics of the South-Hungarian residents. *Acta Climatologica Et Chorologica*, 47, 77–84.
- Lei, X. J., Zhang, W. J., & Zhao, X. M. (2013). The effects of precipitation on tourism during “GoldWeek” and assessment in Xi’an City. *Journal of Northwest University (Natural Science Edition)*, 43, 133–138. https://en.cnki.com/Article_en/CJFDTotal-XBDZ201301026.htm
- Lin, T. P., & Matzarakis, A. (2008). Tourism climate and thermal comfort in Sun Moon Lake, Taiwan. *International journal of biometeorology*, 52(4), 281–290.
- Lise, W., & Tol, R. S. J. (2002). Impact of climate on tourist demand. *Climatic Change*, 55(4), 429–449. <https://link.springer.com/article/10.1023/A:1020728021446>
- Maddison, D. (2001). In search of warmer climates? The impact of climate change on flows of British tourists. *Climatic Change*, 49, 193–2208. <https://link.springer.com/article/10.1023/A:1010742511380>
- Matzarakis, A. (2002). Examples of climate and tourism research for tourism demands. In *Proceedings of the 15th Conference on Biometeorology and Aerobiology joint with the International Congress on Biometeorology*, 2002, October (Vol. 27, pp. 391–392).
- Matzarakis, A. (2006). Weather and climate related information for tourism. *Tourism and Hospitality Planning & Development*, 3(99), 115. <https://www.tandfonline.com/doi/abs/10.1080/14790530600938279>
- Matzarakis, A. (2007). Climate change and tourism: Assessment and coping strategies. (Eds: Amelung, B. and Blazejczyk, K. and Matzarakis, A.). *Climate, thermal comfort and tourism*, 139–154.
- Matzarakis, A., & Endler, C. (2010). Climate change and thermal bioclimate in cities: impacts and options for adaptation in Freiburg, Germany. *International Journal of Biometeorology*, 54, 479–483. <https://link.springer.com/article/10.1007/s00484-009-0296-2>
- Méndez-Lázaro, P. A., Terrasa-Soler, J. J., Torres-Peña, C., Guzmán-González, P., Rodríguez, S., Alemán, M., & Seguinot, T. (2014). Tourism and climate conditions in San Juan, Puerto Rico, 2000–2010. *Ecology and Society*, 19(2). <https://www.jstor.org/stable/26269527>
- Mieczkowski, Z. (1985). The tourism climatic index: A method of evaluating world climates for tourism. *Canadian Geographer*, 29(3), 220–233. <https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1541-0064.1985.tb00365.x>
- Moreno, A., Amelung, B., & Santamarta, L. (2008). Linking beach recreation to weather conditions: a case study in Zandvoort, Netherlands. *Tourism in Marine Environments*, 5(2–3), 111–119. <https://www.ingentaconnect.com/content/cog/tme/2008/00000005/F0020002/art00004>
- Monteiro, M. V., Doick, K. J., Handley, P., & Peace, A. (2016). The impact of greenspace size on the extent of local nocturnal air temperature cooling in London. *Urban Forestry & Urban Greening*, 16, 160–169.
- Oke, T. R. (1981). Canyon geometry and the nocturnal urban heat island: Comparison of scale model and field observations. *Journal of Climatology*, 1(3), 237–254.
- Oke, T. R. (2004). Initial guidance to obtain representative meteorological observations at urban sites World Meteorological Organization, Report No. 81, WMO/TD No. 1250.
- Olgay, V. (1973). *Design with climate, bioclimatic approach to architectural regionalism* (p. 190p). Princeton University Press.
- Pepi, J. W. (1987). The summer simmer index. *Weatherwise*, 40(3), 143–145. <https://doi.org/10.1080/00431672.1987.9933356>
- Scott, D., & McBoyle, G. (2001). Using a ‘tourism climate index’ to examine the implications of climate change for climate as a natural resource for tourism. In A. Matzarakis, & C. de Freitas (Eds.). *Proceedings of the First International Workshop on Climate, Tourism and Recreation*. 5–10 October 2001: International Society of Biometeorology, Commission on Climate, Tourism and Recreation, Greece.
- Scott, D., McBoyle, G., & Schwartzentruber, M. (2004). Climate change and the distribution of climatic resources for tourism in North America. *Climate Research*, 27(2),

- 105–117. <https://www.int-res.com/abstracts/cr/v27/n2/p105-117/>
- Scott, D., & Lemieux, C. (2009). Weather and climate information for tourism. Commissioned White Paper for the World Climate Conference 3. World Meteorological Organization: Geneva and United Nations World Tourism Organization: Madrid.
- Scott, D., Rutt, M., Amelung, B., & Tang, M. (2016). An inter-comparison of the holiday climate index (HCI) and the tourism climate index (TCI) in Europe 2016. *Atmosphere* 7(6), 80. <https://www.mdpi.com/2073-4433/7/6/80>
- Topay, M. (2012). Importance of thermal comfort in the sustainable landscape planning. *Journal of Environmental Protection and Ecology*, 13(3), 1480–1487. <https://www.cabdirect.org/cabdirect/abstract/20133080934>
- Tzenkova, A., Ivancheva, J., Koleva, E., & Videnov, P. (2007). The human comfort conditions at Bulgarian Black Sea side. *Developments in Tourism Climatology*, 150, 157.
- Wang, Y. F., Yin, X. M., & Cheng, X. P. (2016). Analysis of the tourism climate comfortable index in Panzhuhua region based on fuzzy analysis hierarchy process. *Environmental Engineering*, 34(1083–1086), 1107.
- Zeren Cetin, I., Ozel, H. B., & Varol, T. (2020). Integrating of settlement area in urban and forest area of Bartin with climatic conditions decision for managements. *Air Quality, Atmosphere and Health*, 13, 1013–1022. <https://doi.org/10.1007/s11869-020-00871-1>
- 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, 71. <https://doi.org/10.1007/s10661-019-8029-4>
- Zhong, L., & Chen, D. (2019). Progress and prospects of tourism climate research in China. *Atmosphere*, 10(11), 701. <https://www.mdpi.com/2073-4433/10/11/701>

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.