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RESEARCH

Human comfort analysis for Turkey's coastal tourism in a changing climate

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Abstract

When the regional and sectoral impacts caused by climate change are evaluated with different levels of vulnerability, the climate change risks that each region and sector may be exposed also vary. It can be expected that the risk posed by climate change on human comfort, especially due to heat stress, may significantly affect coastal tourism, one of Turkey's priority sectors. In the study, human comfort changes due to climate change in the 10 most important coastal tourism destinations of Turkey (i.e., Manavgat, Çeşme, Alanya, Kemer, Serik, Bodrum, Marmaris, Kuşadası, Aksu, and Fethiye) in the period of May–October were examined. For this purpose, changes in human comfort in the tourism season were projected in these destinations in the near (2026–2050) and mid-future (2051–2075) by using the Discomfort Index (DI), which is one of the most useful indicators of human comfort. In the study, high-resolution climate data, i.e., temperature and relative humidity produced for Turkey under optimistic (RCP4.5) and pessimistic (RCP8.5) scenarios using the regional climate model RegCM4.4, was used to calculate DI. Within the scope of both scenarios in examined destinations, it is predicted that DI values will increase in the near and mid-future. It shows that the thresholds of discomfort may be exceeded in these destinations.

1 Introduction

As one of the world's high-volume and rapidly growing industries, tourism is the third-largest export item after fuel and chemical products (UNWTO 2021). The significant impact of tourism on economic growth has led several researchers to examine the main factors that determine the sector's development, such as income from tourists, relative prices, political stability, socio-cultural and economic relations between countries, and infrastructure (Dwyer 2015). Climate change, a significant factor in tourism demand, has recently become increasingly important. Although the available resources determine the touristic activities (e.g., the need for water and wind for sailing), the planning of these activities at the most appropriate time is determined by the weather and climate conditions. This is because climate conditions affect when, for what reason, and where tourists travel, making the industry dependent on climate (Hamilton and Lau 2006; IISD 1997; Kozak et al. 2008; Maddison 2001; Scott and Lemieux 2010). Tourism is among the economic sectors least prepared for the risks and opportunities brought about by climate change (Scott 2011). Current climate conditions and predicted changes have a strong potential to influence the tourism sector in the future because of the effect of extreme climate events associated with temperature and precipitation (Becken and Wilson 2013; Demiroglu et al. 2017; Kostopoulou and Jones 2005; Rutty and Scott 2010). Nevertheless, unlike many studies on sectors such as water resources, agriculture, ecosystems, forestry, health, insurance, and industry, the effects of climate change on tourism have been examined in few studies (IPCC 2014a). Even though these studies have gained momentum in recent years, the significance of this issue, in general, has not been fully understood.

Climate determines the nature and location of various types of tourism, including sun and surf tourism, snow-based tourism, ecotourism, and coastal tourism (Gössling

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and Hall 2006; Perch-Nielsen 2010). Many destinations owe their popularity to their favorable climate conditions during the traditional holiday seasons. In other words, the climate conditions of the destinations can determine the travel motivation of the tourists. In the context of tourist profiles (Plog 1974), which link tourist activities to personality types, tourists often have more than one motivation to travel. Tourists' attempts to address these motivations depend on their physical, financial, and other capabilities (Amelung et al. 2007) and "push" and "pull" factors (Epperson 1983). Push factors include the desires of tourists and negative or undesirable aspects of the climate in their region. The fact that heatwaves cause tourists to change their travel plans is an example of climate as a push factor in the Mediterranean. Natural resources of destinations, cultural attractions, and favorable climate conditions are characteristics related to the pull factors (Kozak 2002). As can be seen, climate can be both a push and a pull factor (Amelung et al. 2007; Hamilton et al. 2005).

Since timing is critical in tourism, climate seasonality changes are vital. For many people, for example, summer vacations represent a "window of opportunity" for planning holiday activities. Shoemaker's (1994) list of features a destination should have includes a favorable climate and sunbathing opportunities. For this reason, to plan the adaptation process correctly, it is precious to realize that the effects of climate change can lead to severe consequences for coastal tourism destinations. Weather events linked to climate change in coastal destinations include increases in air temperature and duration of sunshine, rising sea levels, and more frequent and severe extreme weather disasters (Lewsey et al. 2004). While some recent studies have identified the effects of climate change on coastal tourism (Demiroglu et al. 2017; Rutty and Scott 2010), there is a lack of integrated assessments that analyze potential climate-related impacts at the local level (Scott and Verkoeyen 2017).

Since sun-sea-sand experiences in the Mediterranean dominate travel motives, favorable climate conditions and unspoiled environmental resources are essential prerequisites for vacationing. About half of the tourists in the Mediterranean visit coastal areas, and it will increase further in the future (UNEP/DTIE - PAP/RAC - UNWTO 2009). However, several recent studies show that summer temperatures in the Mediterranean are sensitive to global warming, which is the most popular destination despite intense competition with others. Besides, both the frequency and duration of heatwaves are expected to increase (Almeida-Garcia et al. 2014; Diffenbaugh et al. 2007; Fischer and Schär 2010; Founda and Giannakopoulos 2009; Gao and Giorgi 2008; Giorgi 2006; Gómez-Martín et al. 2014; Nouri et al. 2018; Rutty and Scott 2010). The world's top 10 tourist destinations account for 40% of global tourist arrivals (UNWTO 2021). Turkey, as a Mediterranean country, takes its place among the countries most visited between 1995 and 2019 (World Bank 2022).

The potential impacts of global warming on comfort are not limited solely to the tourism industry but extend to various other sectors as well. In the face of the threat of the Mediterranean Basin becoming a hotspot in the future (IPCC 2022), the primary economic sectors, including agriculture, fisheries, forestry, building, and health, are vulnerable to climate-related hazards, both at the regional and global levels. Lowland areas are particularly prone to risks, such as agricultural damage. According to the IPCC (2022), certain regions may experience a 64% decline in rain-fed crop yields. The livestock sector in arid and semi-arid regions is vulnerable to rising temperatures and reduced precipitation (Downing et al. 2017; Balamurugan et al. 2018). Drought and heat stress will significantly impact livestock production in the context of climate change (Habeeb et al. 2018). Desertification will primarily impact southern and southeastern regions. Forest fires could potentially experience a significant increase ranging from 96 to 187% (IPCC 2022). The potential impacts of ocean warming and acidification on marine ecosystems and fisheries remain uncertain. Both annual and seasonal climate analyses are required in these sectors.

Thermal comfort research is utilized in architecture, building design, and construction to help create indoor environments that are favorable for human health. These studies can inform the development of safe working conditions in industrial settings, particularly for workers exposed to extreme temperatures (Ghani et al. 2021). Climatic conditions, particularly during summer, have a direct impact on the energy consumption of buildings in the construction sector, specifically for air conditioning purposes. Energy-efficient buildings with smart building control systems are emerging as the prevailing trend for future generations of buildings. Buildings are primarily constructed to serve as residential spaces for individuals. Moreover, a significant majority of individuals, approximately 90%, allocate the majority of their time within built environments (Shaikh et al. 2013a). Indoor comfort significantly affects occupant health, morale, work efficiency, productivity, and satisfaction (Shaikh et al. 2013b).

The environment is to a large extent a factor of human physiological comfort; thus, it is an indicator of human health. Environmental conditions become the source of possible discomfort situations, especially by affecting the heat balance between the human body and the environment (Tselepidaki et al. 1992). Extreme temperatures lead to serious heat-related illnesses and significant increases in death rates and threaten tourists' life safety (Christidis et al. 2015; Michailidou et al. 2016).

Some climate indices have been developed to evaluate tourism destinations' current and potential climate attractiveness and the impacts of climate change on human comfort. These indices consider the important climate components for tourist comfort, such as temperature, humidity, precipitation, cloud cover, and wind speed. Tourism climate indices as a concept emerged from the idea of gaining more general information about the impact of climate conditions on people's well-being. Mieczkowski (1985) was one of the first to study human comfort levels in specific tourism-related activities and developed the Tourism Climate Index (TCI). However, considering that TCI is very subjective, the Holiday Climate Index (HCI) was developed (Scott et al. 2016). HCI does not rely on subjective opinions as it uses the available literature on tourists' climate preferences to determine rating scales and weights for sub-indices (Demiroglu et al. 2020). Climate Index for Tourism (CIT), another index designed in 2008, sets thresholds for precipitation and wind speed and considers factors such as clear skies and light breezes (de Freitas et al. 2008). However, all participants examined in the study are from a single country, and the survey sample group has a narrow age distribution (i.e., young adults), CIT lacks cross-cultural information (de Freitas et al. 2008; Demiroglu et al. 2020). These tourism climate indices have been developed based on the questionnaires organized on the preferences declared by tourists to define the scales that better reflect the comfort perceptions of tourists (de Freitas et al. 2008). However, it is debatable whether it is reliable to use questionnaires as threshold sources to examine thermal comfort (Dubois et al. 2016; Hejazizadeh et al. 2019; Olya and Alipour 2015; Scott et al. 2016). Determining parameters and thresholds based on these surveys may limit the usefulness of such indices in the long-term projections and the assessment of climate change impacts. Also, differences in surveys may influence the choice of thresholds, particularly for thermal comfort.

According to the studies in the literature, Discomfort Index (DI) has been used for many years (e.g., Md Din et al. 2014; Giles et al. 1990; Kambezidis 2021; Katavoutas and Founda 2019; Pantavou et al. 2011; Poupkou et al. 2011; Tout 1980; Tselepidaki et al. 1992). The regions examined in these studies are popular tourist destinations, but the studies are not focused on the tourism sector. In addition, as stated in some studies, research examining local approaches to human thermal comfort thresholds in Mediterranean climates is insufficient (Nouri et al. 2017, 2018). Since the effects of global warming are characterized by latitudinal variations (IPCC 2014b), regional studies stand out as an essential tool for scientists, researchers, and decision-makers. Interest in interactions between climate and tourism has increased significantly over the past decade in response to climate change concerns; however, studies in the local context are relatively few. Our study aimed to evaluate the effects that climate change may cause on Mediterranean coastal tourism regarding tourist health and comfort. The DI was calculated within the scope of climate change projections for the 10 most popular coastal tourism destinations in the tourism season in Turkey. The way to be protected from the damaging effects of climate change and reduce these effects and risks, in other words, to adapt to the changing climate, is to determine the needs based on correct risk definitions. It is critical to identify risks accurately and promptly, starting with priority sectors. Therefore, this research will benefit many individuals, stakeholder groups, and policymakers.

2 Materials and method

2.1 Study area

As it is known, the areas where tourism movements in the world are most concentrated are the sea and lake shores. Coastal tourism is of great importance for Turkey, which is surrounded by seas on three sides and has various climatic characteristics. Especially the Mediterranean and Aegean coasts, which have a long holiday period and the sea water temperature is 20–28°C in the May–October period, are considered coastal tourism paradises with their uniquely beautiful beaches, sand, and sun (Zengin 2006). Their climate makes the Aegean and Mediterranean regions so suitable for coastal tourism. Turkey's Aegean and Mediterranean regions, which offer sea-sand-sun-oriented touristic products, owe their popularity to the warm weather and favorable climatic conditions during the holiday season.

The provinces where the 10 districts studied in the study are located in the south-southwest and west of Turkey (Fig. 1). As of 2021, the population of Antalya is 2,619,832 (Aksu 75,633, Alanya 350,636, Kemer 46,615, Manavgat 245,740, Serik 134,953), while Aydın has a population of 1,134,031 (Kuşadası 125,812) and İzmir 4,425,789 (Çeşme 48,167), and Muğla's population is 1,021,141 (Bodrum 187,284, Fethiye 170,379, Marmaris 95,849) (TURKSTAT 2022). Tourism is an important sectoral activity that increases the population of a settlement and causes seasonal population movements throughout the year. As stated before, Turkey is among the top 10 destinations in world tourism (World Bank 2022). Since the population and population densities increase multiple times in the summer months in most of the Mediterranean countries (Stefano 2004), the populations of the provinces subject to the research also increase by several times during the tourism season.

2.2 Materials

The study aims to assess the effect of future extreme temperatures on human comfort in 10 destinations that receive the most visitors in Turkey as coastal tourism locations. For this purpose, considering both the existing literature (Türkeş et al.

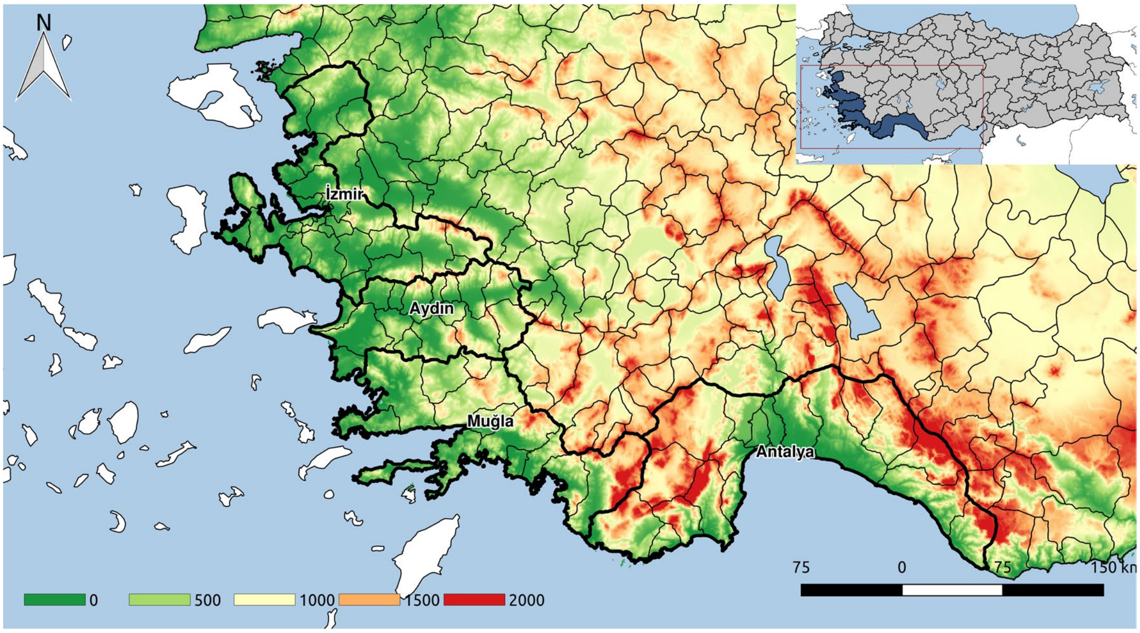

Fig. 1 Map of the study region

2009; Cook et al. 2016; Gao and Giorgi 2008; Demiroglu et al. 2017; Rutty and Scott 2010) and monthly tourist statistics (as disclosed in Supplementary Fig. 1), May–October period was determined as the tourism season. The percentages of incoming tourists show that summer tourism constitutes an integral part of total tourism numbers.

In the study, the DI was examined for Turkey's 10 most attractive destinations in coastal tourism. In the selection of these destinations, firstly, the monthly tourist data requested from the Ministry of Culture and Tourism was examined, and the normalized values of the standard deviations of the monthly tourist numbers visiting the coastal provinces on the Mediterranean and Aegean seas in Turkey were determined (as disclosed in Supplementary Fig. 2). The standard deviation of the number of monthly tourists in a province was considered a measure of how dependent a region is on summer tourism since summer tourism is more decisive in coastal provinces than other types of tourism and seasonal differences depend on this situation. This usage considers the change observed in seasonal tourism in the region and the region's contribution to the country's summer tourism. The destinations where summer tourism is at the forefront were determined with the same method. The ratio of the standard deviations of the monthly total number of domestic and foreign people coming to the ministry-certified tourism establishments between 2016 and 2019 in 64 locations of 7 provinces was taken to the root of the total number of tourists per month, and 10 destinations were determined (as disclosed in Supplementary Fig. 3). Sixty-four of 109 locations in the data set were used, and 4 years were examined instead of 11 years due to missing data. Manavgat, Çeşme, Alanya, Kemer, Serik, Bodrum, Marmaris, Kuşadası, Aksu, and Fethiye destinations were included in the analysis.

High-resolution climate data were obtained from the RegCM4.4 regional climate model using low-resolution MPI-ESM-MR global climate model outputs as input. The study covers the future periods of 2026–2050 and 2051–2075 compared to the 1976–2000 reference period under the RCP4.5 and RCP8.5 scenarios. The data with the highest temperature and the lowest relative humidity during the day were considered, and a time series was created using the daily relative humidity and maximum temperature data. The daily maximum temperature data were used to obtain the daily maximum wet bulb temperature, and the daily minimum relative humidity data was used since the relationship between temperature and relative humidity is related to a significant negative correlation where high temperature is usually associated with low humidity. Wet bulb temperature values were calculated over these series. Finally, DI values were obtained using wet bulb temperature and maximum temperature values. Average values at certain time intervals were used to minimize the problems that may arise from the model on a daily basis. The values of the destinations were determined by taking the averages of the grid points within the district borders.

2.3 Method

Changes in the comfort levels of tourists in the future were projected for two different future periods (2026–2050 and 2051–2075) using the Discomfort Index (DI) (Thom 1959). Although DI was developed six decades ago, it is still efficient and objective. All input variables were directly obtained from the regional climate model RegCM4.4. The dynamically computed variables in the model were used without the need for an additional calculation, which minimizes the uncertainties that may arise from extra calculations. The study mainly focused on the Mediterranean (southeastern-south parts) and Aegean (western part) regions of Turkey. The DI offers quite valuable and valid information required for comfort and energy objectives for a comprehensive assessment of comfort conditions, especially outdoors (Poupkou et al. 2011; Assael et al. 2010).

The temperature and relative humidity data used in calculating the index were obtained with the regional climate model RegCM. It was developed by the Abdus Salam International Center for Theoretical Physics of Italy and has been widely used in climate-related studies in different parts of the world (An et al. 2020; Ozturk et al. 2015, 2017, 2018; Sylla et al. 2016; Turp et al. 2014). For this purpose, in this study, version 4.4 of RegCM (RegCM4.4) dynamically downscaled the low-resolution (200 km × 200 km) outputs of the global climate model MPI-ESM-MR (Giorgetta et al. 2013) of the Max Planck Institute of Meteorology in Germany under the RCP4.5 (optimistic) and RCP8.5 (pessimistic) scenarios and produced high-resolution (10 km × 10 km) climate data. Temperature and relative humidity data obtained from RegCM4.4 were used, and the DI values were compared under two different scenarios as optimistic (RCP4.5) and pessimistic (RCP8.5) for the reference period of 1976–2000 and the future periods of 2026–2050 and 2051–2075. In this study, since the last quarter of the last century and two quarters (near and middle future periods) of this century after 2025 are aimed to be compared, 25-year periods were preferred. Another advantage of choosing this reference period is to be able to more clearly show the change in the 21st century, when temperature increases began to become more evident, compared to the 20th century.

2.3.1 Discomfort Index

Several studies have been carried out to empirically explain what effects the atmospheric environment has on the human body. However, this explanation is not easy to make as it is challenging to quantify the degree of stress exerted on the body's thermoregulation mechanisms by climate factors such as temperature and humidity. DI (Thom 1959) has been one of the most basic solutions to this problem. It determines the level of human discomfort based on climate ambient temperature and relative humidity. It is the most convenient and common method of calculating discomfort at a given time and location (Md Din et al. 2014).

This index was used in several countries as a criterion for emergency measures to be taken for the population when the value exceeds a specific limit (e.g., Thom 1959 for the USA; Jáuregui and Soto 1967 for Mexico; Tout 1980 for England; Adegoke and Dombo 2019 for Nigeria). There are also studies analyzing DI for Mediterranean countries (Giannaros and Melas 2012; Giles et al. 1990; Kambezidis 2021; Pantavou et al. 2008, 2011; Tselepidaki et al. 1992).

$$DI = 0.4\left(T_{\rm d} + T_{\rm w}\right) + 4.8 \tag{1}$$

DI is calculated with the following formula (Thom 1959):

The formula was formed as a function of dry-bulb ($T_{\rm d}$; DBT) and wet bulb ($T_{\rm w}$, WBT) temperatures in °C (Thom 1959). While the RegCM4.4 model outputs were used directly for $T_{\rm d}$ values, calculations were made using the formula developed by Stull (2011) for $T_{\rm w}$ values (Eq. 2). WBT was calculated because it cannot be obtained directly from observation records or outputs.

$$\begin{aligned} T_w =& T\, atan\left[0.151977(RH\% + 8.313659)^{1/2}\right] + atan(T + RH\%) - atan(RH\% - 1.676331) \\ & + 0.00391838(RH\%)^{3/2}\, atan(0.023101RH\%) - 4.686035 \end{aligned} \tag{2}$$

T stands for temperature (°C) and RH for relative humidity (%) in the equation. This approach is suitable for 5% to 99% relative humidity and temperatures between −20 and 50°C (Stull 2011), which are reasonable ranges for this study since this empirical formula is mostly valid at standard sea level pressure (Lee and Wang 2018). This formula may slightly underestimate the actual value of WBT at other pressure levels, especially in arid conditions (Stull 2011; Lee and Wang 2018). However, it is not a problem since the altitudes of the locations in the Aegean

Table 1 The classification of DI (Thom 1959)

DI (°C)	Human Comfort Conditions
DI < 21	No discomfort
21 ≤ DI < 24	Under 50% of the population feels discomfort
24 ≤ DI < 27	Over 50% of the population feels discomfort
27 ≤ DI < 29	Most of the population feels discomfort
29 ≤ DI < 32	Everyone feels discomfort
DI ≥ 32	State of a medical emergency

and Mediterranean regions examined in this study are close to sea level, and the area has relatively high humidity. Considering the classification of human thermal sensation according to DI scales, as the DI value increases, the level of discomfort in terms of human comfort also increases (Table 1).

3 Results and discussion

The average DI differences between past and future periods for 10 destinations are given in Fig. 2. Under the RCP4.5 scenario, DI is expected to increase by 1.2–1.3°C in the near future with no decrease in any region. Furthermore, the average DI is expected to rise by 1.3–1.4°C in the southernmost parts of Turkey. For the pessimistic scenario (RCP8.5), there will be a slightly higher increase in DI, about 1.4°C, which will affect the coastline significantly. In the mid-future RCP4.5 scenario, the increment is expected to be as high as 1.8°C. Moreover, it is important to note that the maximum DI to be observed on days with extreme temperatures is expected to increase much more than the average expected increase.

Under the RCP8.5 mid-future scenario, there will be a 2°C increase in all regions. Additionally, there are some regions where the projected increase is more than 2.5°C. When yearly average DI values of summer months (from May to October) are considered, there is an expectation of an increase in DI values of the Aegean and Mediterranean coasts of Turkey (Fig. 2) in both scenarios (RCP4.5 and RCP8.5) and both periods (2026–2050 and 2051–2075). In each of the 10 destinations, an increase in DI is expected in future periods compared to the reference period (1976–2000). The highest difference is observed in RCP8.5 (pessimistic scenario) in the mid-future, whereas the slightest difference is observed in RCP4.5 (optimistic scenario) in the near future (Fig. 2). In general, the change in DI is more drastic for eastern destinations as opposed to western destinations. Although the places with higher altitudes have smaller DI values, the increase is expected to be higher than average expectations. This change is particularly noticeable for the western part of the Western Taurus and Central Taurus mountains.

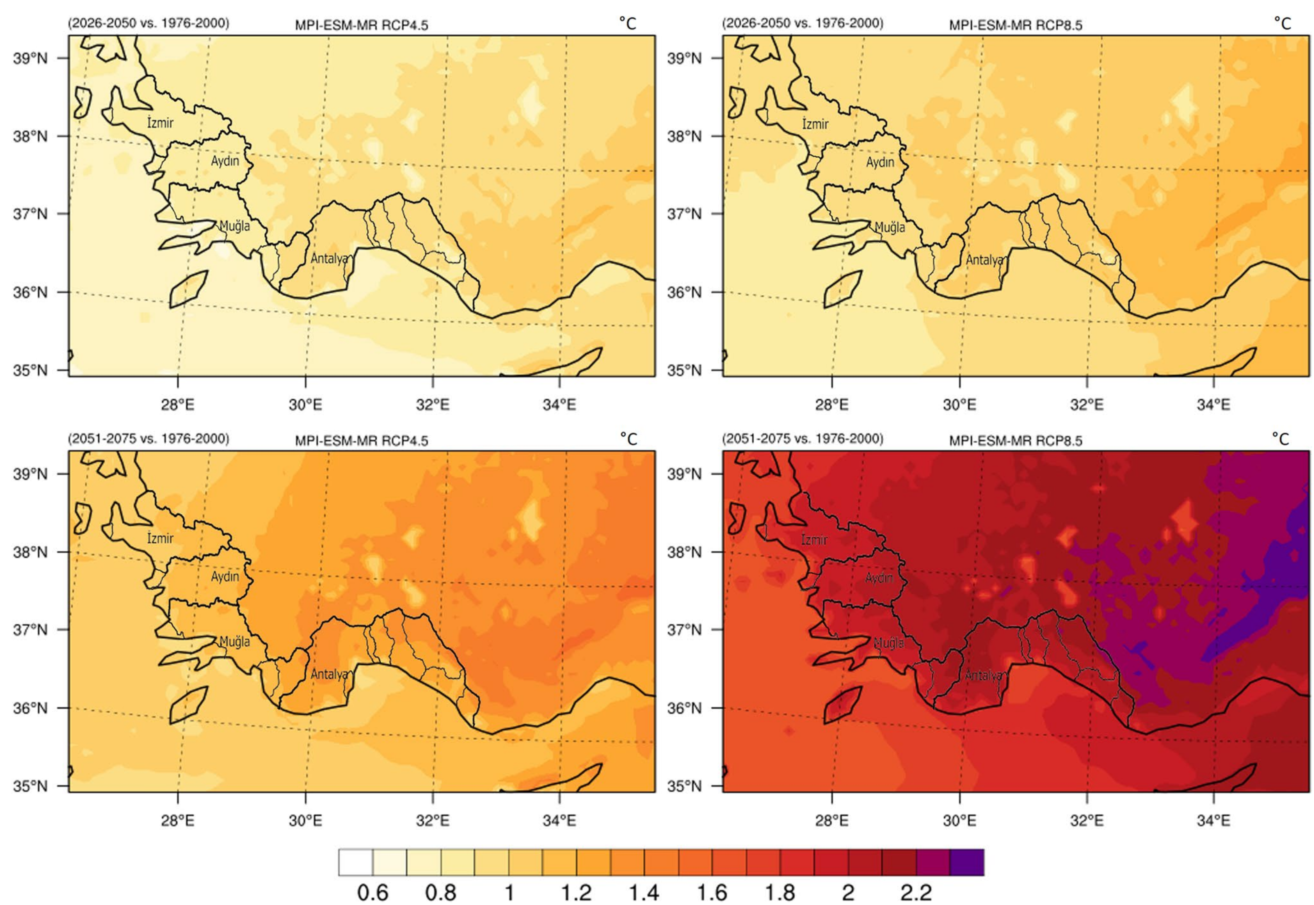

Fig. 2 Spatial distributions of change in DI. Difference of DI between reference year interval (1976–2000) and near future (2026–2050) and mid-future (2051–2075) periods for both RCP4.5 and RCP8.5

When we evaluate the results individually by destinations (Fig. 2), it is found that the projected increases in DI under the optimistic scenario in the near future are 0.91°C in Aksu, 0.88°C in Alanya, 0.77°C in Bodrum, 0.77°C in Çeşme, 0.81°C in Fethiye, 1.01°C in Kemer, 0.81°C in Kuşadası, 0.92°C in Manavgat, 0.81°C in Marmaris, and 0.91°C in Serik. The predicted increases in DI under the pessimistic scenario in near future are 0.99°C in Aksu, 1.03°C in Alanya, 0.88°C in Bodrum, 0.94°C in Çeşme, 0.92°C in Fethiye, 1.05°C in Kemer, 0.92°C in Kuşadası, 1.03°C in Manavgat, 0.90°C in Marmaris, and 1.00°C in Serik. The predicted increases in DI under the optimistic scenario in mid-future are 1.20°C in Aksu, 1.19°C in Alanya, 1.02°C in Bodrum, 1.04°C in Çeşme, 1.10°C in Fethiye, 1.27°C in Kemer, 1.06°C in Kuşadası, 1.24°C in Manavgat, 1.06°C in Marmaris, and 1.21°C in Serik. The predicted increases in DI under the pessimistic scenario in mid-future are 1.94°C in Aksu, 1.98°C in Alanya, 1.76°C in Bodrum, 1.74°C in Çeşme, 1.83°C in Fethiye, 2.04°C in Kemer, 1.79°C in Kuşadası, 2.00°C in Manavgat, 1.83°C in Marmaris, and 1.95°C in Serik.

Under the RCP8.5 scenario, the number of days below 21°C DI will decrease by approximately 51% on average between 2051 and 2075, indicating that comfortable days will be reduced by half. Annual average DI values were calculated for the summer months (Fig. 3), and an increase is expected in DI values for each of the 10 destinations for both scenarios (RCP4.5 and RCP8.5) and the periods (2026–2050 and 2051–2075). It is estimated that the highest DI values will be seen in Aksu, Kemer, Kuşadası, Marmaris, and Serik, and the lowest DI values will be seen in Alanya and Çeşme for both future periods. The low DI values in Alanya can be explained by the fact that the average elevation is higher due to the effect of the West Taurus and Geyik Mountains within the borders. It is thought that relatively colder sea temperatures likely cause the low DI values for Çeşme at its shores. The Mediterranean and Western Black Sea coasts are quite warm. The Mediterranean Sea is warm due to the sirocco wind blowing from the Sahara Desert in the southeast and bringing warm Mediterranean air (Orlić et al. 1994; Suman 1996). On the other hand, the waters that warm the sea surface come towards the shores of Turkey and warm the coastal part of the Black Sea. This is exactly the opposite for the Aegean coasts. In the Aegean Sea, the water gets colder in the coastal areas that receive winds blowing from the land towards the sea. Since the wind blowing from the north drags the surface waters to the open sea, it has a cooling effect especially on the Aegean coasts (Türkeş 2021).

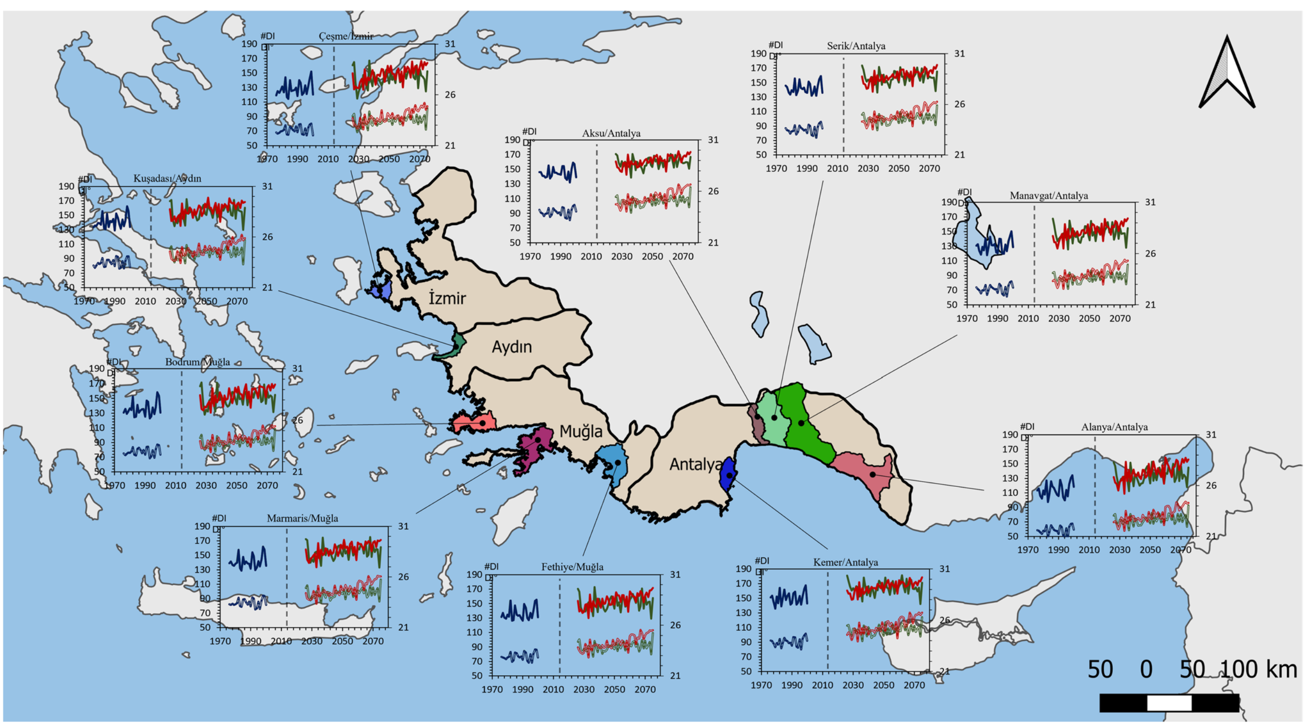

Fig. 3 Annual time series of DI during the summer season (June–August) for the RCP4.5 and RCP8.5 scenarios by destinations. The reference years (1976–2000) are represented by the blue line. The green and red lines represent predictions for RCP4.5 and RCP8.5 scenarios, respectively, for the period 2026–2075. The solid line represents the annual average of DI (the right axis) and the dashed line represents the annual number of days with DI > 21°C (the left axis with labeled #DI)

For the summer months, the number of days below 21°C will decrease by approximately 27% between 2026 and 2050 under the RCP8.5 scenario (as disclosed in Supplementary Table 3). Between 2051 and 2075, this rate is expected to decrease by 51% under the RCP8.5 scenario. For the RCP4.5 scenario, the number of comfortable days is predicted to fall by 27% between 2026 and 2050 and 35% between 2051 and 2075 (as disclosed in Supplementary Table 3). A decrease in the number of days suitable for human comfort is expected for 2051–2075 under the RCP8.5 scenario. Kemer is expected to see the least amount of decrease with about 14 days less during the summer months, while Alanya is expected to see the most drop with about 38 days less during the summer months (as disclosed in Supplementary Table 1). Naturally, it is estimated that there will be an increase in the number of days above 32°C DI, which is considered a medical emergency. The highest increase is expected in Aksu, with an average of 2.3 days per year. For detailed information about the increase in other destinations, please refer to the supplementary material.

Six human comfort categories were defined for 10 destinations based on DI, and the expected number of days in each category was calculated. Then, the changes in averages for 10 destinations according to the reference years were calculated (Fig. 4). Among these categories, the most significant decrease occurred in the number of days below the 21°C DI. A decrease in the number of days between 21 and 24°C was projected for all scenarios and periods. On the other hand, the number of days with DI values 24–27, 27–29, 29–32, and above 32°C will increase under RCP4.5 and RCP 8.5 scenarios. It is predicted that there will be a significant decrease in the number of days under 21°C in all destinations.

Under both optimistic and pessimistic scenarios, an average of 13 days of decrease is expected in the number of days under 21°C in the near future. This value will be as high as

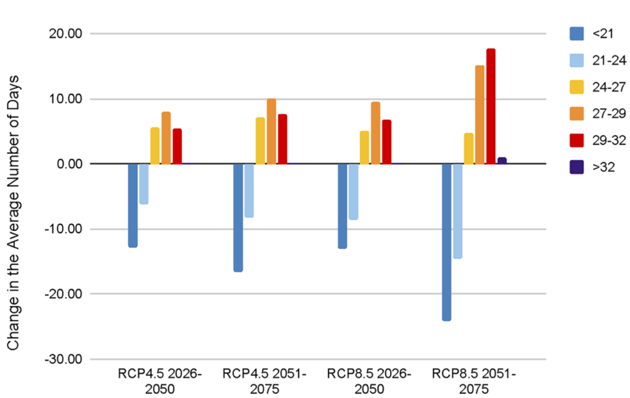

Fig. 4 Changes (day) in the average number of days belonging to given DI categories of 10 provinces examined for the near and far future according to the reference period

17 days for Alanya. In the mid-future, the number of days expected below 21°C DI will be 17 days less in the optimistic scenario and 24 days less in the pessimistic scenario. This value goes up to 32 days for Alanya. A similar decrease is predicted in all provinces in the 21–24°C DI category. While a decrease of 6 days is expected for the optimistic scenario in the near future, this value increases to 9 days for the pessimistic scenario. In the mid-future, an average of 8 to 15 days less is predicted to be in this category for the optimistic and pessimistic scenarios, respectively. In the 27–29°C DI category, an increase of more than 10 days is expected in Fethiye, Kemer, Manavgat, and Serik in the near future under optimistic and pessimistic scenarios, while a milder increase is expected in other destinations. While the average is 3 days in this category for reference years in Alanya, it is predicted that this value will be between 7 (RCP4.5) and 10 (RCP8.5) days in the near future. In the mid-future, 10 to 20 more days are expected to fall into this category.

In the destinations of interest, it is estimated that there will be a significant increase in the number of days with the 29–32°C DI category, in which everyone feels severe stress. The number of days in this category will triple on average in the near future. In Kemer, which had an average of 2 days in this category during the reference period, the average number of days is expected to increase to 11 in the near future. While only 7.7 days fall into this category during the reference period in Aksu, it is predicted that this number will jump to 20 days in the near future, and 24 to 40 days a year will be spent in this category in the mid-future. The last category, where DI is higher than 32°C, refers to a level of discomfort that causes conditions that require medical attention. Serik is the only destination that experiences such days with any regularity, with one in 8 years on average during the reference period, and it is estimated that Serik will experience days in this category once every 6 to 3 years depending on the scenario. In the near future, it is predicted that a day in this category will be experienced every 10 years in Aksu, Bodrum, Kuşadası, and Marmaris on average. In the mid-future RCP8.5 scenario, it is estimated that there will be more than a day annually in the DI category of above 32°C in Aksu, Bodrum, Kemer, Kuşadası, Marmaris, and Serik.

In the monthly analysis (Table 2), monthly average DI values were examined. The results show that people may feel discomfort in Aksu and Kemer under all RCP scenarios and future periods in July and August. In addition, it is predicted that people may feel discomfort in the RCP8.5 scenario between 2051 and 2075 in Bodrum, Fethiye, Kuşadası, Manavgat, Marmaris, and Serik. In most of the analyzed regions throughout June, July, August, and September, it is estimated that more than 50% of the population may feel uncomfortable under all scenarios and future periods. Given that the regions under study are important summer tourism destinations, it may be concluded that this rate will have

Table 2 Comparison of monthly projected DI scores

Province	Model	Period	May	Jun	Jul	Aug	Sep	Oct
Aksu	Historical	1976-2000	21.49	24.49	26.41	26.22	24.25	21.03
	RCP 4.5	2026-2050	22.76	25.50	27.23	27.11	25.07	21.69
		2051-2075	22.79	25.73	27.45	27.30	25.53	22.30
	RCP 8.5	2026-2050	22.78	25.44	27.29	27.48	25.22	21.66
		2051-2075	23.35	26.49	28.26	28.36	26.11	22.97
Alanya	Historical	1976-2000	19.07	21.99	24.02	23.88	21.95	18.72
	RCP 4.5	2026-2050	20.25	23.01	24.77	24.78	22.74	19.37
		2051-2075	20.29	23.29	25.03	24.88	23.26	20.01
	RCP 8.5	2026-2050	20.30	23.05	24.86	25.19	22.96	19.43
		2051-2075	20.91	24.13	25.91	26.01	23.85	20.72
Bodrum	Historical	1976-2000	19.80	22.93	25.08	25.32	23.78	20.92
	RCP 4.5	2026-2050	21.05	23.86	26.03	26.08	24.15	21.27
		2051-2075	20.89	24.08	26.19	26.29	24.62	21.88
	RCP 8.5	2026-2050	20.80	23.98	26.03	26.40	24.47	21.44
		2051-2075	21.42	24.92	27.04	27.26	25.26	22.49
Çeşme	Historical	1976-2000	19.48	22.64	24.58	24.89	23.23	20.37
	RCP 4.5	2026-2050	20.72	23.52	25.67	25.62	23.56	20.72
		2051-2075	20.58	23.84	25.76	25.82	24.12	21.32
	RCP 8.5	2026-2050	20.51	23.75	25.58	26.08	23.97	20.91
		2051-2075	21.06	24.61	26.70	26.75	24.57	21.94
Fethiye	Historical	1976-2000	20.35	23.23	25.17	25.11	23.36	20.33
	RCP 4.5	2026-2050	21.55	24.18	26.07	25.93	23.87	20.79
		2051-2075	21.50	24.46	26.25	26.08	24.43	21.44
	RCP 8.5	2026-2050	21.46	24.24	26.10	26.26	24.13	20.88
		2051-2075	22.04	25.26	27.05	27.12	24.97	22.10
Kemer	Historical	1976-2000	21.56	24.56	26.43	26.30	24.04	20.46
	RCP 4.5	2026-2050	23.00	25.62	27.41	27.28	24.94	21.18
		2051-2075	22.98	25.92	27.59	27.39	25.40	21.72
	RCP 8.5	2026-2050	22.98	25.56	27.37	27.58	25.01	21.13
		2051-2075	23.57	26.68	28.51	28.45	25.89	22.48
Kuşadası	Historical	1976-2000	20.50	23.57	25.67	25.88	24.12	20.95
	RCP 4.5	2026-2050	21.80	24.51	26.71	26.70	24.49	21.32
		2051-2075	21.63	24.81	26.78	26.83	25.03	21.98
	RCP 8.5	2026-2050	21.53	24.78	26.65	27.00	24.80	21.49
		2051-2075	22.11	25.61	27.67	27.81	25.60	22.62
Manavgat	Historical	1976-2000	20.05	23.04	25.04	24.96	22.84	19.44
	RCP 4.5	2026-2050	21.33	24.09	25.91	25.84	23.66	20.07
		2051-2075	21.40	24.40	26.15	26.00	24.17	20.71
	RCP 8.5	2026-2050	21.39	24.10	25.96	26.19	23.82	20.08
		2051-2075	21.95	25.19	27.05	27.08	24.68	21.43
Marmaris	Historical	1976-2000	20.44	23.57	25.69	25.82	24.13	21.03
	RCP 4.5	2026-2050	21.71	24.49	26.65	26.64	24.59	21.44
		2051-2075	21.57	24.74	26.82	26.82	25.06	22.06
	RCP 8.5	2026-2050	21.51	24.61	26.66	26.94	24.87	21.52
		2051-2075	22.14	25.58	27.68	27.87	25.71	22.72
Serik	Historical	1976-2000	21.04	24.05	26.01	25.83	23.77	20.39
	RCP 4.5	2026-2050	22.33	25.08	26.83	26.71	24.57	21.02
		2051-2075	22.37	25.33	27.06	26.87	25.05	21.65
	RCP 8.5	2026-2050	22.37	25.04	26.90	27.08	24.72	21.00
		2051-2075	22.92	26.12	27.90	27.93	25.57	22.35

DI<21	21≤DI<24	24≤DI<27	27≤DI<29	29≤DI<32

a detrimental impact on regional tourism. Moreover, it is foreseen that the summer season will be lengthened until September, in addition to June, July, and August. While days with DI values above 32°C are expected in the daily calculated DI values, the results differed since the monthly analysis was calculated with the average of the DI values throughout the month.

In the present study, an analysis of trends was conducted, employing the Mann-Kendall test for this purpose. In comparison to the reference period of 1976–2000, for both scenarios, there is an observed upward trend in the number of days where the Discomfort Index (DI) exceeds the specific threshold of 21°C, potentially intensifying the stress or discomfort experienced by people across all districts (Table 3). To put it in other words, in addition to the increase in the average DI values of the locations, it is seen that there is an increasing trend in the number of uncomfortable days. The observed trend exhibits statistical significance, indicating that variations in weather conditions have a discernible impact on human comfort.

4 Conclusions

Changes in the frequency and intensity of extreme climate events can negatively impact vital economic sectors such as tourism (Kostopoulou and Jones 2005) and significantly impact local communities in the Mediterranean region (Giannakopoulos et al. 2011). Considering the damages of extreme climatic events to human comfort and health and the economic importance of tourism for Turkey, their effects on human comfort and health may cause significant damage to the sector. DI was employed in this research, and the changes that climate change will make in human comfort levels were revealed.

For all the destinations examined in the study, it is expected that the number of days in the intervals evaluated as favorable (comfortable conditions) in terms of DI values will decrease, and the number of days in which the intervals are considered unfavorable (uncomfortable conditions) will increase. From a spatial perspective, it was observed that DI variation is higher in high-elevation areas compared to low-elevation areas (see Figs. 1 and 2). It shows that the future projections point to a faster increase in regions where DI value was low in the past. According to these findings, regions with relatively high comfort levels may not be designated as alternative tourism destinations due to the increase in DI values, as extreme temperatures endanger coastal tourism destinations. Secondly, research findings showed that the comfort level will decrease in the future, not only in coastal areas but also in interior areas, which indicates that urban tourism will also be damaged.

An increasing trend in DI values is expected in the near and mid-future for 10 destinations (i.e., Manavgat, Çeşme, Alanya, Kemer, Serik, Bodrum, Marmaris, Kuşadası, Aksu, and Fethiye). In addition, the number of days requiring a medical emergency and the number of days when a substantial portion of the population feels uncomfortable will increase significantly. This situation indicates the necessity of adaptation for the medical emergency needs in those coastal areas. One of the findings in the literature is that the maximum values of DI are observed during the daytime in summer months, and increasing temperatures are highly effective in the levels of thermal discomfort (Poupkou et al. 2011). Studies in literature also state that extreme temperatures negatively affect human comfort (Katavoutas and Founda 2019; Pantavou et al. 2011; Tselepidaki et al. 1992; Kambezidis 2021). The future state of thermal sensitivity with the effect of global warming was investigated, and it was concluded that DI trends will increase in summer, and almost half of the society will be disturbed by temperature in the distant future (Kambezidis 2021).

According to the results of our research, the number of tourists coming to Manavgat, Çeşme, Alanya, Kemer,

Table 3 Mann-Kendall test results for DI

	P value		Tau		Trend	
	RCP4.5	RCP8.5	RCP4.5	RCP8.5	RCP4.5	RCP8.5
Aksu	0.00	0.00	0.4050	0.6321	↑	↑
Alanya	0.00	0.00	0.4483	0.6494	↑	↑
Bodrum	0.00	0.00	0.4155	0.6072	↑	↑
Çeşme	0.00	0.00	0.4148	0.6209	↑	↑
Fethiye	0.00	0.00	0.3968	0.6047	↑	↑
Kemer	0.00	0.00	0.3593	0.6043	↑	↑
Kuşadası	0.00	0.00	0.4043	0.5993	↑	↑
Manavgat	0.00	0.00	0.4252	0.6468	↑	↑
Marmaris	0.00	0.00	0.4004	0.6086	↑	↑
Serik	0.00	0.00	0.4004	0.6025	↑	↑

*Statistically significant at 95% confidence level

Serik, Bodrum, Marmaris, Kuşadası, Aksu, and Fethiye may decrease during the summer months in the next 25 years with the decrease in the comfort level. This is an expected result, given that coastal heatwaves may cause more than half of the tourists to change their travel plans (Becken and Wilson 2013; Rutty and Scott 2010). For example, Giannakopoulos et al. (2009) indicate that due to the extremely high summer temperatures in the region, there may be a gradual decrease in summer tourism in the Mediterranean, and seasonal shifts may occur in the tourism season. The increase in DI in the surveyed coastlines compared to previous years will cause people to prefer regions where they feel comfortable. It will negatively affect the local business owners (e.g., hotel operators) and the locals whose economic livelihood is the tourism sector (e.g., shopping stores). In addition, rising prices because of increasing costs may indirectly cause tourists to search for alternative destinations. The results indicate that summer tourism may be adversely affected by the expected decrease in the number of tourists and tourism revenues due to the decrease in human comfort level (Kum and Gönençgil 2018). Taking necessary measures in this direction and developing state strategies can reduce the negative economic consequences. The analysis of our study can be improved by including more regions whose economy is heavily dependent on summer tourism.

Research on human comfort that was carried out in fields other than tourism also suggests that there will be difficulties in ensuring thermal comfort in the not-too-distant future. The findings indicate that there may be challenges in maintaining thermal comfort in the future, particularly in buildings with high insulation levels. The energy requirement for cooling is projected to exceed the demand for heating by a maximum of 5% (Ferdyn-Grygierek et al. 2021). Furthermore, according to a study conducted by Summa et al. (2020), it is projected that there will be a reduction in the duration of thermal comfort within buildings by the 2050s. Research on thermal comfort offers valuable insights for the design of environments that promote well-being and productivity, considering a range of factors and industries. A recent study conducted by Lima et al. (2023) examined climate indices pertaining to Portugal across three consecutive 30-year intervals encompassing the years 2011–2100 (i.e., 2011–2040, 2041–2070, and 2071–2100), in addition to the reference period of 1971–2000 under three distinct emission scenarios, namely RCP2.6, RCP4.5, and RCP8.5. The findings of the study indicate that industries such as agriculture, forestry, coastal management, and human health may face potential threats in the future due to thermal comfort conditions. Since heat stress is also a health hazard, such research results are important in terms of preventing loss of labor productivity and regulating decent work conditions. In particular, the assessments to be made by the National Weather and Climate Services can be effective in warning the risky sectors in terms of heat stress and taking precautions against the increasing heat stress threat, and implementing adaptation studies.

Adaptation is seen as the appropriate response to reduce the tourism industry's vulnerability to climate change (Patterson et al. 2006). The need to adapt to climate change is imperative, but it cannot be said that this need is fully understood in the tourism sector (Weaver 2011). When the potential impacts of climate change are known, it may be easier and more efficient to focus on adaptation strategies. The difference between an impact study and an adaptation study lies in this threshold. Examining the effects of climate change on a system is important for studies to evaluate and understand vulnerabilities and related adaptation measures (IPCC 2022). The importance of our research comes to the fore at this point.

The most cited adaptation responses are efforts to diversify products or change destinations. The diversification of tourism products has been put forward as a possible adaptation mechanism and is generally accepted as an effective adaptation strategy that can limit susceptibility to economic and other crises (Dubois and Ceron 2006; Gómez-Martín et al. 2014). On the other hand, it is argued that turning to alternative products or diversifying may create significant difficulties in many destinations due to limited resource capacity. These are obviously needed (Moen and Fredman 2007; Scott and McBoyle 2007); however, this is more difficult to do in summer tourism because summer activities are found in many other parts of Europe and are therefore not as unique and attractive.

Better surveillance and control systems are needed for people who are particularly vulnerable to the effects of climate change on comfort. Educational programs are needed to inform about the risks of exposure to high temperatures and how to deal with them, especially for the most vulnerable (Linares et al. 2020). It is important to work with other sectors and institutions to promote urban green infrastructure suitable for Mediterranean Basin countries and to reduce heat and sun exposure and associated discomfort, i.e., increase thermal comfort (Shashua-Bar et al. 2012). In a nutshell, the health, environmental, and ecological threats that increasing temperatures may cause in the relevant locations should be developed in an integrated manner by acting jointly not only with the tourism sector but also with other sectors related to the tourism sector, especially health. For example, the capacity of the health system, which will have to serve a capacity above the normal population during the summer tourism season, is a field that needs to be enhanced primarily.

Making the alternative cool regions in the north suitable for tourism can be a unique measure to protect the economic balance. Given the risks of climate change, planned adaptation may be the most appropriate response. On the other hand, the planned adaptation process should include risk management planning, financing the compliance process, prioritizing research and development activities, training and effective communication, and taking responsibility for each stakeholder, from local people to government agencies.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s00704-023-04613-y.

Code availability The code used during the current study is available from the corresponding author upon reasonable request.

Author contributions MTT and NA conceptualized the project and designed the methodology. BB, EB, ZD, MTT, and NA conducted the steps that included formal analysis, investigation, and visualization. BB, EB, MTT, and NA prepared the original draft and wrote the manuscript. BB, MTT, and NA reviewed and edited the written paper. The project was administrated and supervised by MTT, NA, and MLK. All authors have read and agreed to the published version of the manuscript.

Data availability The climate data used in the study were produced by Boğaziçi University Center for Climate Change and Policy Studies (iklimBU) using RegCM4.4 for Turkey. The datasets generated and/or analyzed during the current study are available from the corresponding author or iklimBU (http://climatechange.boun.edu.tr/en/) upon reasonable request.

Declarations

Ethics approval Not applicable

Consent to participate Not applicable

Consent for publication Not applicable

Conflict of interest The authors declare no competing interests.

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