Theoretical and Applied Climatology (2025) 156:543
https://doi.org/10.1007/s00704-025-05804-5

RESEARCH

The far-reaching impacts of bioclimatic comfort change and sustainable tourism development for western black sea basin: a spatiotemporal study in the context of climate adaptation

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Received: 29 November 2024 / Accepted: 13 September 2025 / Published online: 30 September 2025

Abstract

This study investigates the impact of climate change on bioclimatic comfort zones in the Western Black Sea basin, a region known for its natural touristic resources. Using global climate change scenarios and two bioclimatic indices (Discomfort Index and Effective Temperature-taking wind Velocity), we analyze potential shifts in the spatial distribution of comfortable areas. Findings of the Discomfort Index (DI) simulations reveal significant changes by 2100: cold areas, currently covering 88.5% of the region, will decrease to 4.3% under the SSP 585 scenario, while comfortable zones will emerge, covering 54.9% of the area. Effective temperature taking wind Velocity (ETv) simulations indicate dominance of moderately cold (43.9%) and slightly cool areas (44.4%). Additionally, comfort zones (7.9%) will increasingly emerge. These results suggest that the Western Black Sea basin, characterized by a short tourism season and below-average sea temperatures, may develop a more favorable bioclimatic structure, particularly for coastal tourism. This research provides valuable insights for regional development strategies and upper-scale planning, highlighting the potential for increased bioclimatically comfortable areas throughout the basin due to climate change.

Keywords Adaptation strategies · Climate change scenarios · Cold regions · Geographic information systems · Spatial planning

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1 Introduction

The rapid urbanization and economic development worldwide, occurring in increasingly complex and dynamic urban environments (Baz et al. 2021; Zhang et al. 2023), has transformed urban lifestyles into consumption-driven patterns (Hu et al. 2022; Andres et al. 2022; Sun et al. 2022). Urban growth has significantly increased energy and raw material demands across various sectors, including production, transportation, and tourism (Avtar et al. 2019; Kulińska and Dendera–Gruszka 2019; Elavarasan et al. 2022; He 2022). These human activities, centered on mass production and consumption, have not only degraded urban air quality (Isinkaralar and Isinkaralar 2025) but also contributed to climate change through increased greenhouse gas emissions (López-Pacheco et al. 2021; Halder et al. 2021; Mortoja and Yigitcanlar 2021; Kafy et al. 2022). Climate change, in turn, affects various aspects of urban life and significantly impacts tourism preferences. Tourists seek destinations where temperature, humidity, and weather conditions fall within comfortable ranges (Indraganti and Humphreys 2021; Li et al. 2022; Tang et al. 2022), as deviations can lead to discomfort, irritability, and fatigue (Lam et al. 2021; Campbell et al. 2022). Moreover, climate change can trigger serious health issues, particularly respiratory and circulatory diseases among vulnerable groups (Demain 2018; Mayrhuber et al. 2018), further influencing tourist movement patterns. As a result, understanding the relationship between climate change and tourism, especially in cold regions, has become crucial for predicting and adapting to shifting tourist preferences and ensuring sustainable tourism development.

Temperature and thermal comfort influence human movement patterns and tourism preferences. Various indices have been developed to estimate land surface temperature (LST) (Khalil and Kumar 2025a, b) and quantify microclimatic conditions. The Physiologically Equivalent Temperature (PET) is widely used for both indoor and outdoor thermal comfort assessments (Sulzer et al. 2023), while the Discomfort Index (DI) is employed explicitly for outdoor evaluations (Fotso-Nguemo et al. 2022; Kishta et al. 2022). Other steady-state assessment indicators include the Effective Temperature taking wind Velocity (ETv) (Lucena et al. 2016) and the Predicted Mean Vote Index (PMV) (Fanger 1970). These indices provide numerical representations of local microclimates and human perception of thermal conditions. Some comprehensive studies have combined multiple indices, such as analyzing thermal comfort using DI and ETv (Suping et al. 1992), to provide a more holistic understanding of thermal comfort in various environments.

However, research on thermal comfort (ThC) within the tourism framework and climate risks/scenarios is limited. Current research on ThC encompasses various domains, including the building scale (Arowoiya et al. 2024; Babich et al. 2023; Ouanes and Sriti 2024), urban design (Darbani et al. 2023; Deng et al. 2023), and urban and regional planning strategies (Cárdenas-Jirón et al. 2023; Yuan et al. 2023). The literature on ThC primarily focuses on adaptive ThC (López-Pérez and Flores-Prieto 2023), ThC assessment (Abd Rahman et al. 2022; Elnabawi and Hamza 2019), and indexing (Kim et al. 2022). At the building scale, studies explore natural ventilation (Izadyar et al. 2020; Gilvaei et al. 2022) and material selection (Nicolalde et al. 2022; Imghoure et al. 2021) for energy-saving purposes (Ma et al. 2021). Urban design research investigates issues related to building orientations and design, street canyon geometry, and the impact of various design strategies on microclimate and outdoor comfort (Boyer 2022; Khraiwesh and Genovese 2023; Yenigun et al. 2025). On a macro scale, ThC is linked to comprehensive energy and transportation investments and a sustainable regional economy (Khan et al. 2022). Achieving specific standards that move beyond individual thermal perception requires managing the combined effects of these components.

Despite the growing body of research on climate change impacts, a significant gap exists in understanding its specific effects on tourism. This study aims to address this gap by presenting a comprehensive analysis of how climate change could affect tourism in colder climates, focusing on Türkiye. We concentrate on the Western Black Sea basin, a region in northern Türkiye known for its relatively colder climate, examining potential impacts towards the end of the century. This research makes a significant contribution to the field by utilizing climate scenarios and spatial models to map areas of bioclimatic comfort. By doing so, we provide an approach to understanding the complex interplay between climate change and tourism preferences in cold regions. These indices must guide us regarding changes and sensitive areas in the region rather than providing deterministic information. This analysis enhances our understanding of future tourism patterns in Türkiye. It offers valuable insights that can be applied to similar cold regions globally, thus advancing the broader field of climate change impacts on tourism.

2 Review of representative works: progress and opportunities

Climate change is a major global issue that is having impacts around the world. As temperatures rise and extreme weather events become frequent, the tourism industry faces challenges and opportunities (Enríquez and Bestard 2020). Despite the adverse effects of climate change on infrastructure and natural landscapes, there is a growing trend of tourists seeking out destinations that offer unique and memorable experiences in the face of changing climate patterns (Siddiqui and Imran 2019; Scott et al. 2012). For instance, Semenza and Ebi (2019) reported that as temperatures increase and ice cover reduces, previously inaccessible regions become more accessible, creating new prospects for tourism. Yang et al. (2023) and Shijin et al. (2020) reported that ice thawing is uncovering ancient artifacts and structures, attracting tourists interested in cultural heritage and archaeology. Climate change poses severe risks, including unpredictable weather patterns and natural disasters, impacting tourism infrastructure and visitor safety (De Urioste-Stone et al. 2016; Arabadzhyan et al. 2020; Scott and Gössling 2022). It is important to implement sustainable tourism practices and adaptive management strategies to mitigate the adverse impacts of climate change on the sector and promote responsible tourism to address these challenges and risks.

Numerous studies conducted worldwide have extensively examined the effects of climate conditions on tourism. Wilkins et al. (2018) argued that warmer temperatures could lead to increased tourism during the summer and fall seasons.

This suggests potential opportunities for colder destinations like Maine and the United States to capitalize on the warmer months. The researchers concluded that Maine and other relatively colder destinations could benefit from higher tourist activity during warmer months. In another study, Zhong et al. (2019) demonstrated climate change's significant impact on Tibet's tourism industry. They found that climate comfort levels have increased in northwestern Tibet but declined in its southeastern parts. The researchers emphasized the need for different regions to adopt alternative tourism products, energy conservation, and green infrastructure to adapt to and mitigate the effects of climate change on tourist destinations (Gebre and Gebremedhin 2019). These findings align with Amelung et al. (2007) and Amelung and Nicholls (2014) perspectives, who suggested that climate change could alter the most desirable conditions for the tourism industry, thus requiring investment in indoor amenities and infrastructure to accommodate potential increases in visitor numbers.

During shoulder seasons (i.e., spring and autumn) in Mediterranean regions, Köberl et al. (2016) reported that climate change may lead to revenue gains in Sardinia (Italy) and Cap Bon (Tunisia). However, they also found that losses could be incurred in the summer due to increased heat stress, which may deter tourists from visiting the region. They concluded that significant climate-induced reductions in total available water may somewhat counteract the positive direct impacts of climate change by placing additional water costs on the tourism industry. Similarly, Filho (2022) reported that climate change is intensifying the already challenging effects of COVID-19 on the tourism sector. They emphasized the need for a strategic approach to address immediate impacts and support local livelihoods. These studies also highlighted the limited preparedness of the sector to handle the harsh conditions posed by climate stressors. Further, Zhang et al. (2021) suggested that climate change will improve thermal comfort conditions in high-income regions but worsen them in low-income regions due to the increase in warm and uncomfortable days. They concluded that prioritized support for climate mitigation and adaptation in developing nations is justified and urgently needed.

Climatic parameters should stay within the optimum range for survival and thermal comfort (Brousse et al. 2019; Ravindra et al. 2020; Psomas et al. 2021). Under optimum conditions, overall mood disturbance is minimal, and an average temperature of 23.5 °C increases human performance (Sharma et al. 2024). Feeling comfortable while living in an urban area increases our quality of life. Regional city plans, which aim to determine the most suitable areas for spatial location selection and are produced for specific targets, are developed through this approach, and comprehensive analyses are conducted considering natural, economic, and social aspects. Existing research has contributed to determining the heat and cold stress levels in cities and exploring potential impacts on human health and well-being. These have enabled decision-makers to propose effective planning strategies (Nouri et al. 2023). Current studies have also shown a proven relationship between thermal comfort conditions, air temperature, and respiratory diseases (Sun et al. 2021; Fan et al. 2022). There is a need to do more case-specific studies due to unique climatic conditions in different parts of the world. Several recent studies, including those mentioned above, have primarily focused on limited areas or scales to determine the suitability of bioclimatic conditions for tourist destinations (Cokola et al. 2020). Regional spatial research on this subject has widely utilized geographic information systems (Bouras et al. 2019; Korpilo et al. 2022).

According to the Final Report of the Future of Türkiye Project conducted by WWF- Türkiye, temperatures are expected to increase significantly after the 2030s. The region, rich in forest assets and forestry-related sectors, has experienced a noticeable decline in winter precipitation. In the literature, local and urban studies have revealed changes in bioclimatic conditions. As the impacts of climate change become increasingly evident worldwide, the tourism industry in Türkiye must adapt and innovate to meet the evolving needs of tourists who seek unique and sustainable experiences. By prioritizing environmental conservation, promoting eco-friendly practices, and embracing the opportunities that arise from the changing climate, Türkiye can establish itself as a leading destination for tourists interested in exploring the effects of climate change on the natural world. This study aims to comprehensively analyze how climate change could enhance tourism in cold regions, focusing on insights from Türkiye to build on the existing knowledge. The study investigates the effects of climate change in the Western Black Sea basin, a region in the northern part of Türkiye known for its relatively colder climate. It considers the impacts of various climate parameters on the entire basin and makes future predictions (2020–2100) using two different indices. What sets this study apart is its innovative approach of utilizing a spatial model to map areas of bioclimatic comfort under different scenarios. This approach aims to capitalize on the potential benefits that the changing climate could bring to the tourism industry because of changing demands due to extreme conditions.

3 Materials and methods

3.1 The area of study

The Western Black Sea Basin is located between 40°34'42"-41°27'52" northern latitudes and 30°52'33"- 35°12'12" east longitudes in the Black Sea Region of Türkiye in

Fig. 1. The area has various climate types due to its location in the Western Black Sea Basin, lying horizontally along the coast and rising towards the interior. A predominantly mountainous terrain characterizes the region. The region's climate exhibits a distinct gradient as one moves inland from the coastline. Closer to the sea, the area experiences a more moderate maritime climate. However, as the distance from the coast increases, the climatic conditions gradually transition to resemble those of Central Anatolia. This transition is marked by decreased precipitation throughout the year and more pronounced temperature variations between seasons. The Black Sea climate prevails in the northern part of the basin, while the transitional climate between the Black Sea climate and the Central Anatolian climate prevails in the southern part. The Bolu and Karabük regions, which are located in the Filyos sub-basin, are influenced by the Black Sea and Central Anatolian climates. This results in winters that are cold and rainy and mild summers. There are a total of 81 weather stations in the area that provide specific climate data. The basin is also characterized by a dense network of rivers and tributaries that flow northward into the Black Sea. This abundant water resource has led to the development of numerous hydroelectric power plants throughout the region.

The Western Black Sea basin constitutes 3.7% of Türkiye's surface area. The research area includes the coastal cities of the Western Black Sea basin, which experience some of the lowest average sea water temperatures in Türkiye, contrasting sharply with the warmer southern coastlines. The basin in Fig. 2 is located within the borders of Ankara, Bartın, Bolu, Çankırı, Düzce, Karabük, Kastamonu, Sakarya, Samsun, Sinop, and Zonguldak provinces. Between 1970 and 2023, the average seawater temperature in the Black Sea was recorded at 15.3 °C, with 2019 Marking the warmest year in 53 years at 18.5 °C. This aligns with the warming sea temperatures observed in Türkiye's coastal waters. Despite the relatively cool waters, the region boasts an average annual air temperature of 13.0 °C and is rich in geographical features attractive to tourists, including numerous valleys, canyons, and waterfalls.

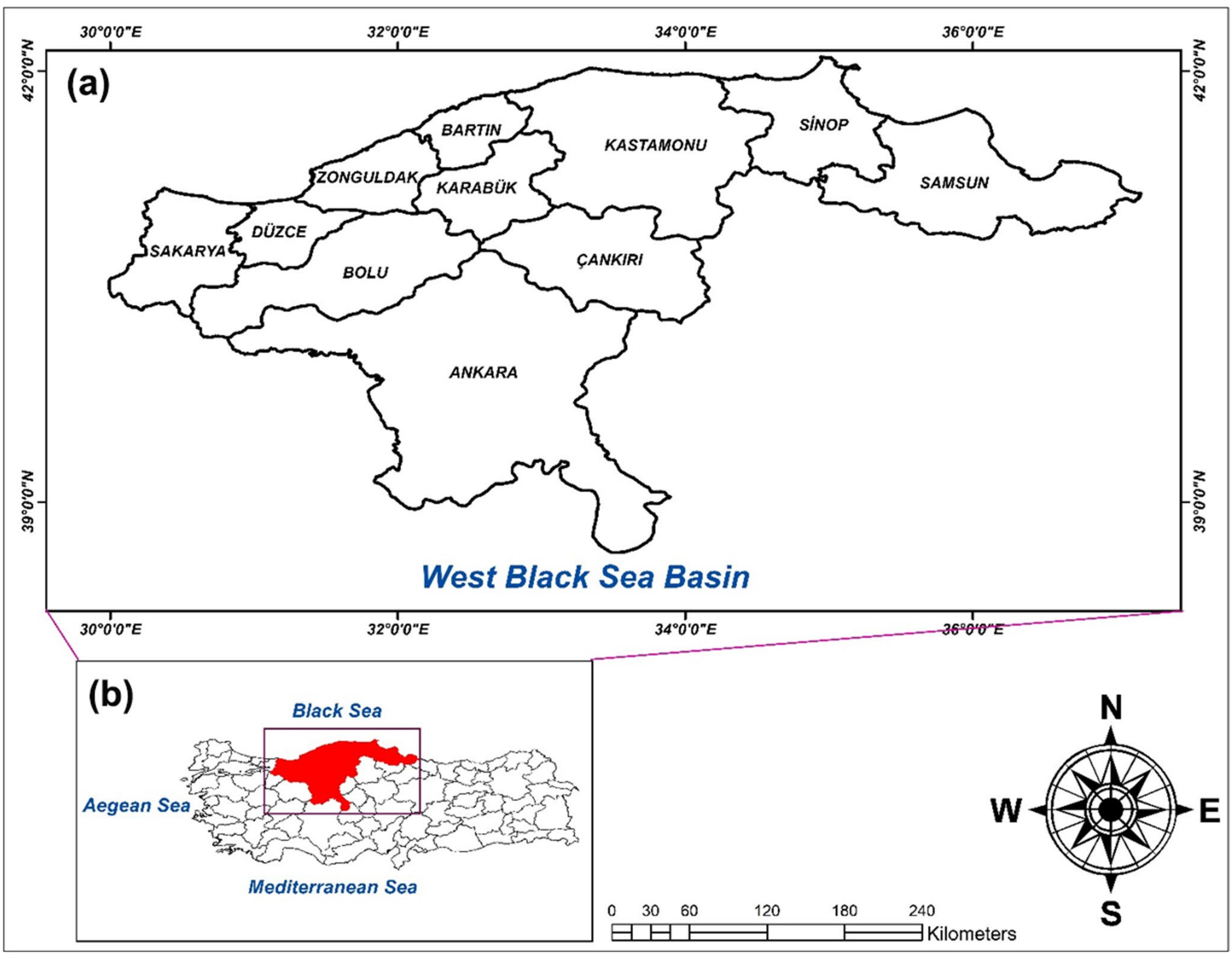

Fig. 1 Study area **a**: the cities of the region and **b**: the location of the West Black Sea basin in Türkiye

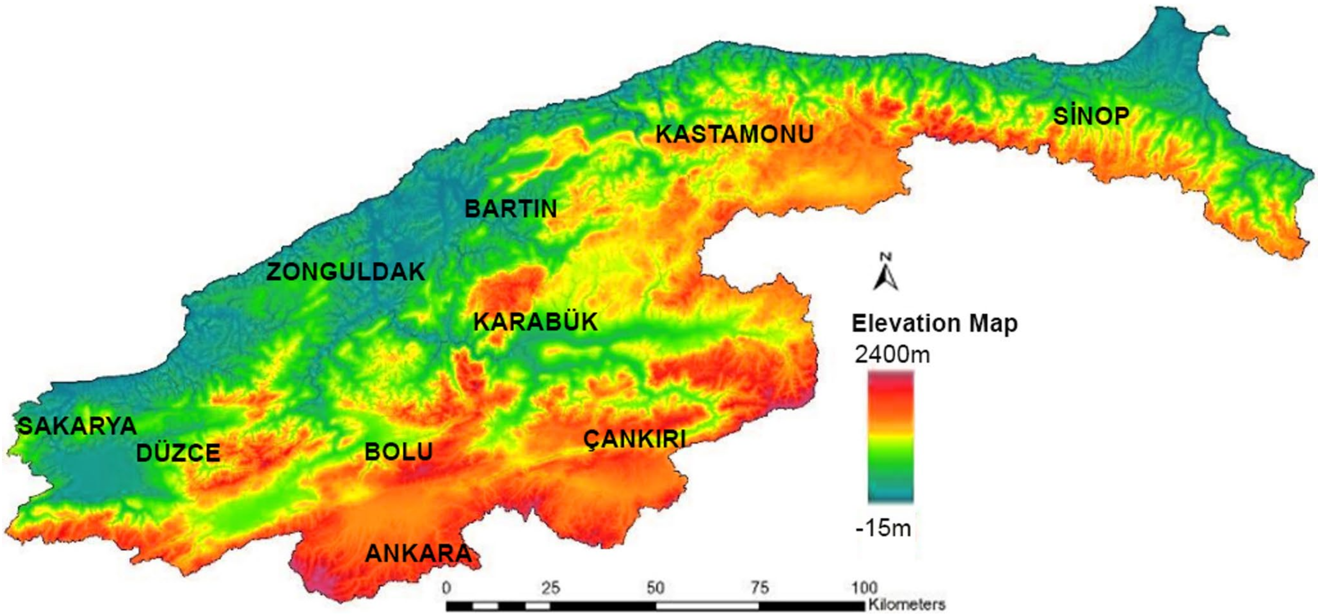

Fig. 2 Digital elevation model and the provinces within the borders of the basin

However, the region's northern location, rugged topography, and high altitude contribute to a shorter tourism season than other parts of the country. This unique combination of cool waters, diverse landscapes, and a compressed tourist season makes the area particularly interesting for studying the potential impacts of climate change on tourism patterns.

3.2 Methodology of the modeling

The climate parameters of the Lawrence Livermore National Laboratory's National Department of Energy were modeled for regional or local areas using the SSP 245 and SSP 585 scenarios of the CNRM-CM6-1 model. The purpose of choosing these models is to reveal the most adverse conditions and an average level of change. The values used in the index formula were obtained from spatial data downloaded from 'WorldClim 2'. These data were processed in the ArcGIS 10.8. Simulation maps were created using the "Inverse Distance Weighted (IDW)" method, based on the climate data obtained after applying the transformation process in the software, at a resolution of 30 m x 30 m. The data were calculated according to Eq.1 using the ArcGIS program:

$$z(x_o) = \frac{\sum_{i=1}^{n} z(x_i).d_{i0}^{-r}}{\sum_{i=1}^{n} d_{i0}^{-r}} \tag{1}$$

Where the estimation location X_0 is determined by neighboring measurements n [$z(X_{0i})$ and i = 1, 2, …, n], as well as by the top *r* that defines the range assigned to each observation, and the distance d that separates the observation location X_i from the prediction location X_0.

We used the DI (Thom 1959) and ETv to classify the area regarding bioclimatic conditions. All layers were in 1 × 1 km spatial resolution, and DI as follows (Giles et al. 1990):

$$DI = (T_{dbt}) - 0.55 \\ [1 - (0.01)(RH)] * [T_{dbt} - 14.5] \tag{2}$$

where T_{dbt} is the dry bulb temperature (°C), *RH* is the Relative humidity (%), and *v* is wind speed (m/s).

Equation 3 is used to calculate the Effective temperature-taking wind Velocity (ET*v*) (Lucena et al. 2016):

$$\mathrm{ET}_v = 37 - \left[\frac{(37-T_{dbt})*(1.76+1.05v)}{(0.68-0.0014RH+1)}\right] \\ -(0.29)*(T_{dbt})*\left[1-\frac{RH}{100}\right] \tag{3}$$

The change in the bioclimatic comfort areas of the basin was analyzed using DI and ET*v* indexes during 2021–2040, 2041–2060, 2061–2080, and 2081–2100. According to DI, −1.7 to 12.9 means cold, 13 to 14.9 is cool, 15 to 19.9 is comfortable, and 20 to 26.4 is hot (Benaddi et al. 2024). While interpreting the ETv, 10 to 12.9 moderately cold, 13 to 15.9 quite cool, 16 to 18.9 slightly cool, 19 to 21.9 mild, 22 to 24.9 comfortable, and 25 to 27.9 warm (Lucena et al. 2016).

4 Results

The bioclimatic comfort status in the Western Black Sea basin from 2020 to 2100 was determined using the DI technique based on SSP 245 and SSP 585 scenarios, as depicted in Figs. 3 and 4. Presently, 88.5% of the study area is classified as cold, while 11.5% is considered cool. No areas are currently deemed bioclimatically comfortable or hot. However, projections after 2040 indicate that 3.3% of the area will become comfortable under SSP 245 and 5.5% under SSP 585. To the east lies Sinop, a coastal province, and the west the Çaycuma district in the Zonguldak region. These regions encompass vital pulp and paper mills of the country. The climate's impact on this forest-rich production area may have significant sectoral implications.

Today, the elevation model states that cool areas are prevalent near sea level. By 2080, SSP 585 projects a balanced distribution of cold (33.9%), cool (33.3%), and comfortable (32.8%) areas. SSP 245 suggests these areas will become more suitable for comfort classification until 2100, while SSP 585 indicates the emergence of hot areas. Cold regions constitute 88.5% but are projected to decrease to 4.3%. Conversely, the comfortable zone is modeled to become the most extensive, covering 54.9%, as depicted in Fig. 5.

In models produced with ET*v* technique according to SSP 245 and SSP 585 scenarios, in present conditions, 43.9% of the area is moderately cold, 29.3% is cold, 24.2% is quite cool, and 2.1% is slightly cool. Accordingly, the place is generally cold/cool, and there is no comfortable area regarding bioclimatic conditions, as shown in Fig. 5. Mild regions, which have a rate of 0.5% today and are starting to appear, will reach 1.8% by 2100 according to SSP 245 and 35.1% according to SSP 585, as shown in Fig. 6. Bioclimatically comfortable areas will appear for the first time in the SSP 585 scenario before 2100, constituting 7.9% of the site. These areas include Sinop, Sakarya, Düzce, Zonguldak city center, and Kozlu and Ereğli district centers.

5 Discussion

5.1 Potential effects of climate change in the region

The change in bioclimatic comfort zones in the Western Black Sea basin, located in the northernmost part of Türkiye, was investigated using two climate change scenarios. According to the Discomfort Index (DI), no area is currently suitable for bioclimatic comfort. However, the SSP 585 scenario, which is more pessimistic, predicts the emergence of hot areas. In contrast, the Effective Temperature-taking wind Velocity (ETv) does not forecast hot regions but models a gradual shift towards a milder and more comfortable climate structure over time. The models derived from field data indicate that the area's cold climate is changing towards more comfortable conditions according to the DI approach. The ETv simulations show a transition from a predominantly moderately cold spatial distribution to one dominated by slightly cool and mild areas. These findings demonstrate a shift in the research area from colder conditions to more suitable bioclimatic comfort ranges.

Wilkins et al. (2018) argued that warmer temperatures could lead to increased tourism during summer and fall seasons in colder destinations. One possible ramification of climate change involves a decrease in energy consumption within regions that typically experience significant heating demands (Cassarino and Barrett 2022; D'Agostino et al. 2022; Fortes et al. 2022). This provides opportunities for tourism investment in these areas since studies in the southern parts of Türkiye emphasize the emergence of a warmer geography beyond bioclimatic comfort values (Shah and Lone 2022). Such changes could potentially deter tourists from visiting the currently popular southern areas during peak summer months, as noted by Köberl et al. (2016) in their study of Mediterranean regions. The study area can then benefit from this shift.

Overall, our results suggest that the local climate of the Western Black Sea basin may become more attractive for tourism in the near future due to its changing climate parameters. This aligns with the findings of Zhong et al. (2019) in Tibet, where climate comfort levels increased in some regions. The Western Black Sea basin boasts diverse geological and geomorphological formations, including canyons, waterfalls, streams, and caves, combining high-altitude geography with a sea coast. In this context, there could be opportunities to invest in nature-based tourism activities such as sea, highland, and winter tourism, which are widely practiced due to the region's natural values, especially its forests and water resources. Moreover, many studies already emphasize that regional climate change, which is often overlooked in coastal tourism development strategies, can have positive and negative effects (Kostianaia and Kostianoy 2021). Especially in regions at risk from the climate crisis, the adverse effects of changes in parameters (Isinkaralar et al. 2025) and the emphasis on many extreme weather events come to the fore.

5.2 Limitations and future research

This study set out to investigate the impact of climate change on bioclimatic comfort zones in the Western Black Sea basin of Türkiye, with a particular focus on its implications for tourism. By utilizing climate scenarios and indices to map areas of bioclimatic comfort, we have addressed a significant gap in understanding the specific effects of climate change on tourism in cold regions. Using the DI and ETv indices, our analysis revealed significant changes in the region's bioclimatic comfort zones by 2100. The DI simulations showed a dramatic decrease in cold areas from 88.5% to 4.3%, with comfortable zones emerging to cover 54.9%

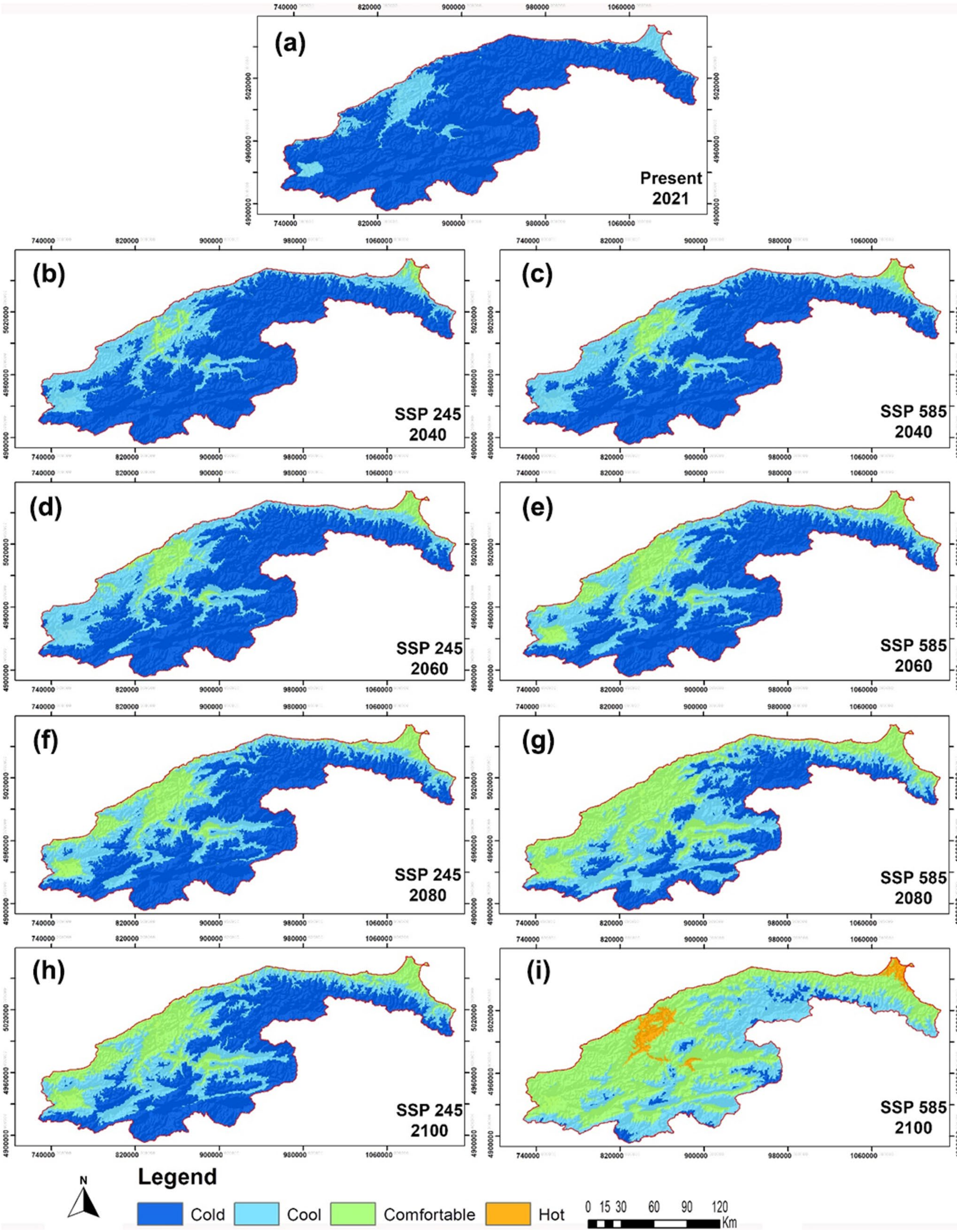

Fig. 3 Simulations of bioclimatic areas according to discomfort index (**a**): 2021; (**b**): 2040 for SSP 245, (**c**): 2040 for SSP 585, (**d**): 2060 for SSP 245, (**e**): 2060 for SSP 585, (**f**): 2080 for SSP 245, (**g**): 2080 for SSP 585, (**h**): 2100 for SSP 245, (**i**): 2100 for SSP 585

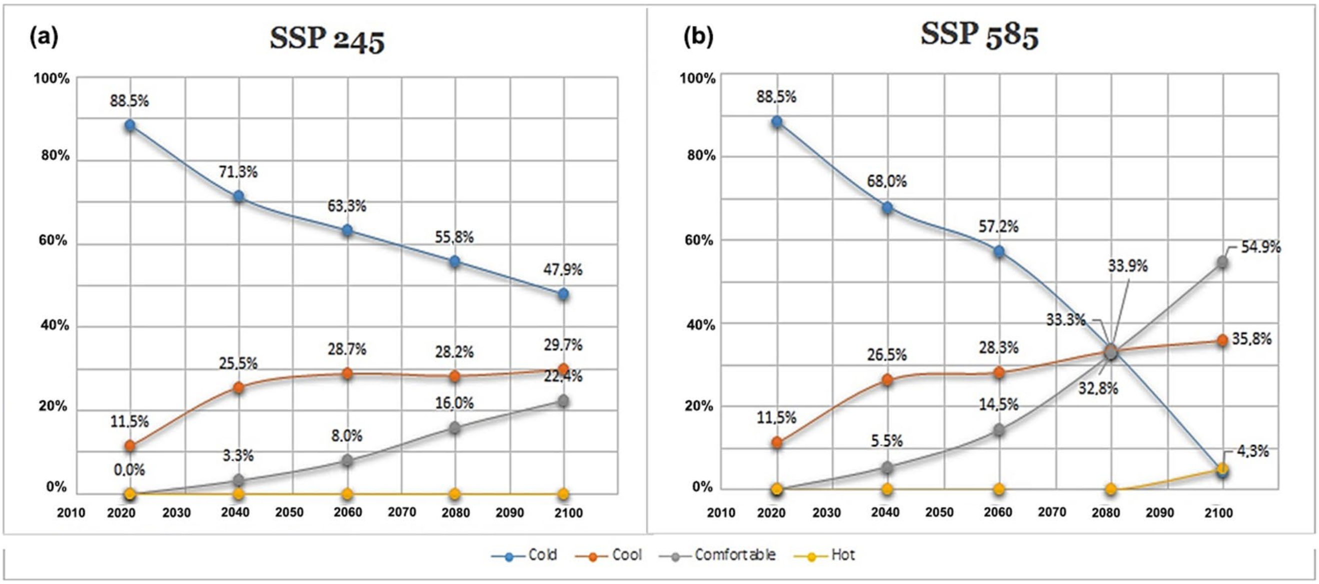

Fig. 4 Variation of bioclimatic comfort areas according to the scenarios via the DI technique a: SSP 245, b: SSP 585

of the area under the SSP 585 scenario. The ETv simulations indicated a shift from predominantly moderately cold areas to a mix of slightly cool and mild zones, with the emergence of comfortable areas (7.9%) by 2100.

In our study, extreme weather events are neglected due to their unpredictable nature. It is crucial to note that future climate change may also result in uncertainties and extreme events that could threaten the region's tourism industry and socioeconomic sustainability. Such potential risks have been highlighted by Dogru et al. (2019) in their studies on the compounded effects of climate change and COVID-19 on the tourism sector. Therefore, policymakers in the study area should also explore solutions for dealing with potential risks. Also, a study in Amasya (Çağlak and Matzarakis 2023) revealed a strong negative correlation between thermal comfort conditions (PET), air temperature, and respiratory diseases. These findings offer insights into public health implications, particularly regarding respiratory tract diseases in the region. Numerous studies have observed similar results, indicating that global climate change can cause significant and far-reaching modifications worldwide (Zhou et al. 2019; Piao et al. 2019; Clarke et al. 2019). Overall, climate change could present opportunities and challenges for the region, requiring adaptive strategies and sustainable tourism practices to capitalize on the potential benefits while mitigating the risks associated with climate change.

While this study provides valuable insights, it's important to acknowledge its limitations. The analysis was constrained by the data available from existing sources and weather stations. The spatial and temporal resolution of the climate data may not capture all local variations in climate conditions, which could be particularly significant in a region with diverse topography like the Western Black Sea basin. Furthermore, the study focused on two specific bioclimatic indices (DI and ETv) and climate scenarios (SSP 245 and SSP 585). While these provide a robust foundation for analysis, incorporating additional measurements and indices could add new dimensions to the research. For instance, including indices that account for factors such as precipitation patterns, extreme weather events, or sea level rise could provide a more comprehensive picture of the region's future climate conditions and their implications for tourism.

Several issues could be explored in future studies to build upon this research. Comparing the analysis results with basins that have warm climate characteristics could provide valuable insights into the differential impacts of climate change on various tourism regions. Applying other climate scenarios beyond SSP 245 and SSP 585 could help create a more granular understanding of potential future outcomes. Also, integrating economic models to quantify the potential economic impacts of the projected changes in bioclimatic comfort on the tourism sector would provide valuable information for policymakers and investors. Further, incorporating qualitative research on stakeholder perceptions and adaptive capacities could enhance the practical applicability of the findings. Expanding the analysis to include the potential impacts of changing bioclimatic conditions on local ecosystems and biodiversity could help develop more holistic tourism and conservation strategies.

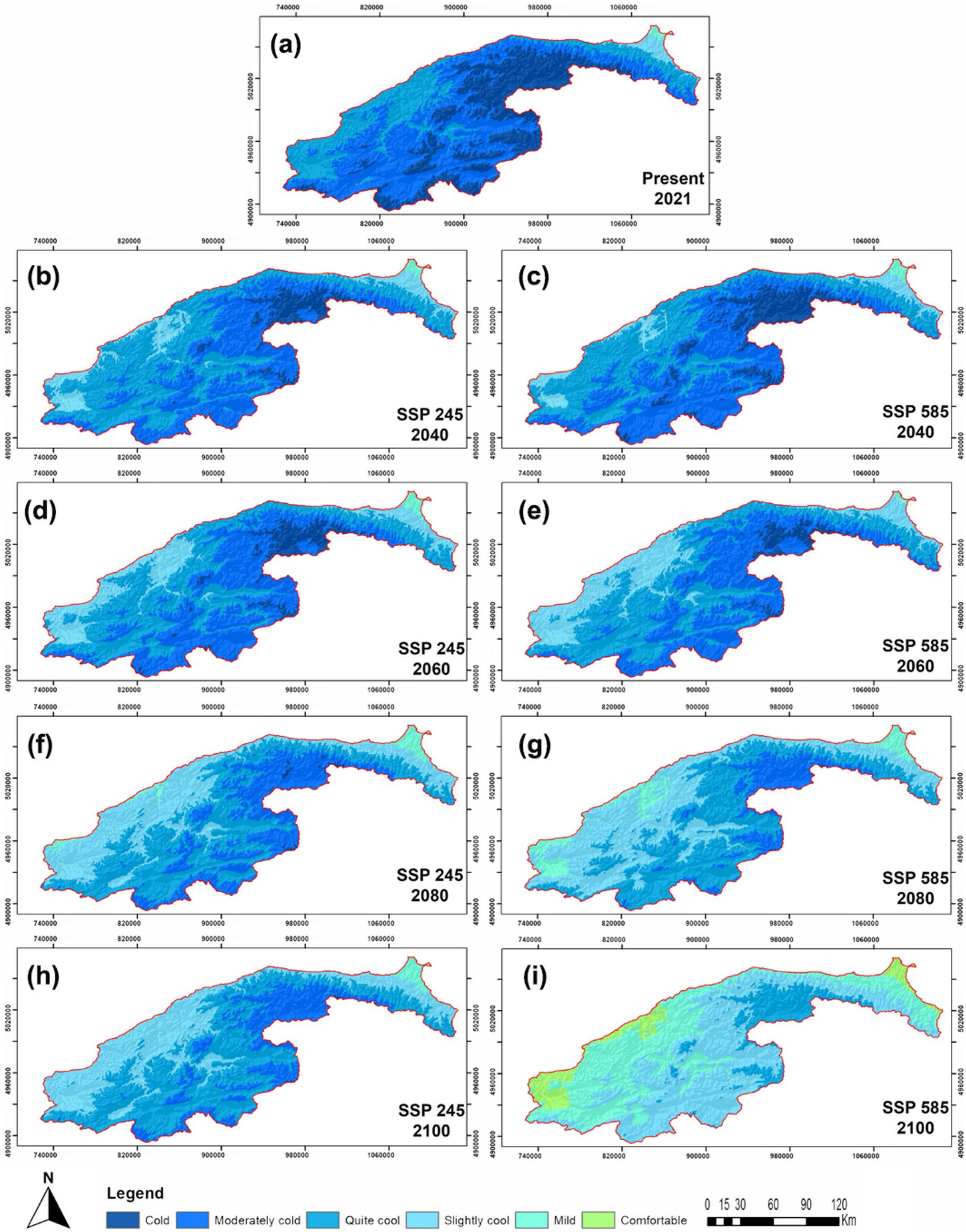

Fig. 5 Simulations of bioclimatic areas according to ET*v* (**a**): 2021, (**b**): 2040 for SSP 245, (**c**): 2040 for SSP 585, (**d**): 2060 for SSP 245, (**e**): 2060 for SSP 585, (**f**): 2080 for SSP 245, (**g**): 2080 for SSP 585, (**h**): 2100 for SSP 245, (**i**): 2100 for SSP 585

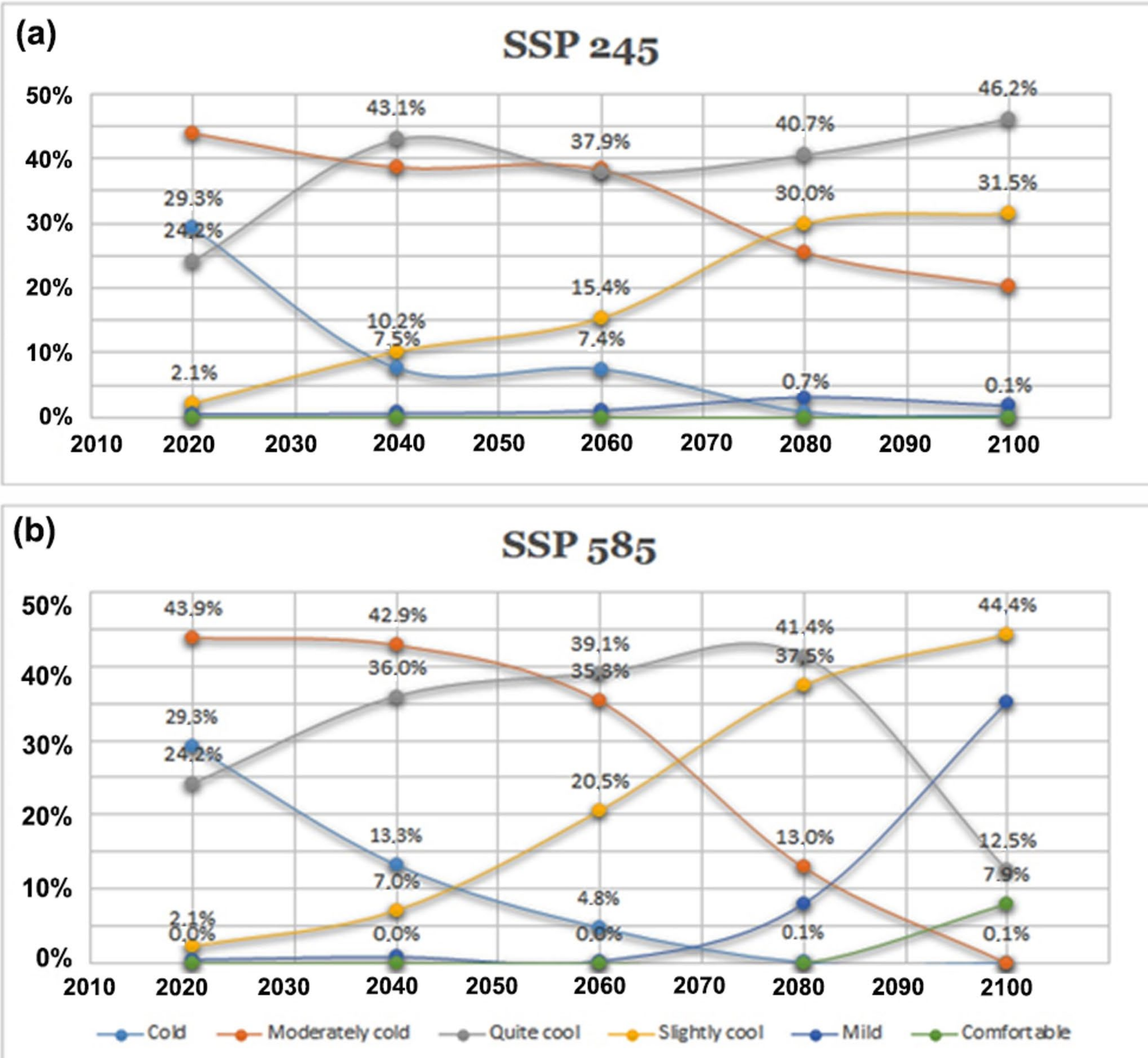

Fig. 6 Variation of bioclimatic comfort areas according to the scenarios via the ET*v* technique (**a**): SSP 245, (**b**): SSP 585

6 Conclusions

These findings have several important policy implications for regional development and tourism planning in the context of climate adaptation strategies. Local and regional authorities should develop adaptive strategies to capitalize on the potential extension of the tourism season due to more favorable bioclimatic conditions. This could include investments in sustainable and low-carbon infrastructure and services to accommodate increased tourist numbers during shoulder seasons. As the climate becomes more suitable for a broader range of activities, there's an opportunity to diversify tourism offerings. Policymakers should encourage the development of new tourism products that take advantage of the region's unique combination of mountainous terrain and coastal areas. Despite the potential benefits of tourism, it is crucial to implement policies that protect the region's rich natural resources, including forests, rivers, and coastal ecosystems, from the potential negative impacts of increased tourism and climate change. Also, given the potential health implications of changing climate conditions, policies should be developed to address public health concerns, particularly respiratory diseases and heat-related illnesses. Further, as heating requirements may decrease, energy policies should be adjusted to reflect changing demand patterns and to promote sustainable energy use in the tourism sector. The predicted changes will likely affect multiple sectors beyond tourism, including forestry and agriculture. Integrated, cross-sectoral planning approaches will be necessary to manage these changes effectively.

In conclusion, this study contributes to the growing body of literature on climate change impacts on tourism by providing a detailed analysis of potential changes in bioclimatic comfort in a cold region of Türkiye. The findings suggest that while climate change poses significant challenges, it may also create opportunities for extending and diversifying tourism activities in the Western Black Sea basin. However, capitalizing on these opportunities will require careful planning, sustainable practices, and adaptive management strategies.

Acknowledgements na

Author contributions Oznur Isinkaralar: Processing analysis, data interpretation, writing original draft, data curation, processing analysis, and interpretation. Kaan Isinkaralar: Processing analysis, data interpretation, writing original draft, and data curation. Emmanuel Yeboah: Processing analysis, interpretation, validation, review and editing. Isaac Sarfo: Formal analysis, validation, review and editing. Ayyoob Sharifi: writing original draft, review and editing.

Funding There is no financial support and commercial support.

Data availability No datasets were generated or analysed during the current study.

Declarations

Ethics approval Not applicable.

Consent to participate Not applicable.

Consent to publish Not applicable.

Competing interests The authors declare no competing interests.

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