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Bio-climatic Comfort and Climate Change Nexus: A Case Study in Burdur Basin

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Abstract

Aim of study: Climate change triggers many problems, such as loss of biodiversity on land and sea, destruction of forest areas, poverty, inequality, and economic development. One of the most vital indicators of quality of life and sustainable development is temperature, humidity, and wind conditions, which are in the range of bio-climatic comfort values. The changes in these parameters due to global warming threaten vitality and affect the use of space and quality of life in cities. The study aimed to model the evolution of bioclimatic comfort zones with the effect of climate change in the research area.

Area of study: The research was carried out in the Burdur Basin of Türkiye, which is an area that includes the underground and surface water bodies and the lakes region within its borders.

Material and Methods: Models were produced at 20-year intervals until 2100. The spatio-temporal variations are generated according to the IPCC's SSPs 245 and SSPs 585 scenarios. The discomfort index (DI) and Effective warming wind speed (ETv) were used to determine bioclimatic comfort.

Main Results: According to the DI, 87.4% of the area will be in the cold zone today, while in 2100, 50.5%, according to the SSP245, and 98.3%, according to the SSP 585 will be in the comfort zone. According to ETv, 92.7% of the area is quite cool today; by 2100, 90% of the site will be classified as slightly cool according to SSP 245, and 89.3%, according to SSP 585 will turn into mild areas.

Research highlights: The results of the research reflect the spatial impact of climate change and are significant in terms of holistic risk management at the basin scale

Keywords: Climate Risk, Sustainable Development, Geographic Information Systems, Global Warming, IPCC

Biyo-İklimsel Konfor ve İklim Değişikliği İlişkisi: Burdur Havzası'nda Bir Örnek Çalışma

Öz

Çalışmanın amacı: İklim değişikliği, karada ve denizde biyoçeşitliliğin kaybolması, orman alanlarının tahribatı, yoksulluk, eşitsizlik, ekonomik kalkınma gibi birçok sorunu tetiklemektedir. Yaşam kalitesinin ve sürdürülebilir kalkınmanın en güçlü göstergelerinden biri biyo-iklimsel konfor değerleri aralığında olan sıcaklık, nem ve rüzgar koşullarıdır. Küresel ısınmanın etkisiyle bu parametrelerde meydana gelen değişimler canlılığı tehdit etmekte ve kentlerde mekan kullanımını ve yaşam kalitesini etkilemektedir. Çalışmada, araştırma alanında biyoiklimsel konfor alanlarının iklim değişikliğinin etkisiyle değişiminin modellenmesi amaçlanmıştır.

Çalışma alanı: Araştırma, sınırlarında bulundurduğu yer altı ve yer üstü su kütleleri ile göller bölgesini kapsayan ve önlem alınması gereken bir alan olan Türkiye'nin Burdur Havzası'nda yürütülmüştür.

Materyal ve Yöntem: Modeller, 2100 yılına kadar 20 yıllık aralıklarla üretilmiştir. Zamansal-mekansal değişimler IPCC'nin SSPs 245 ve SSPs 585 senaryolarına göre üretilmiştir. Biyo-iklimsel uygunluğu belirlemek için rahatsızlık indeksi (DI) ve Etkili Sıcaklık alma rüzgar hızı (ETv) kullanıldı.

Sonuçlar: DI'ya göre bugün alanın %87,4'ü soğuk bölgedeyken, 2100'de SSP245'e göre %50.5'i ve SSP585'e göre %98.3'ü rahat bölgede olacaktır. ETv'ye göre ise alanın %92.7'si bugün oldukça serin, 2100'de alanın %90'ı SSP 245'e göre biraz serin sınıflandırmasında olacak ve SSP585'e göre %89.3'ü ılıman alanlara dönüşecektir.

Araştırma Vurguları: Araştırma sonuçları iklim değişikliğinin mekansal olarak etkisini yasnıtmakta olup, havza ölçeğinde bütüncül risk yönetimi açısından önemlidir.

Anahtar Kelimeler: İklim Riski, Sürdürülebilir Gelişme, Coğrafi Bilgi Sistemleri, Küresel Isınma, IPCC

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Introduction

The 21st century is a period in which rapid global changes are experienced in terms of people's preferences and lifestyles (Han & Lee, 2021; Olonade et al. 2021). Traditional production methods and social life have begun to change with effects such as the intensities in the flow of information, goods, and people, the relative disappearance of administrative and physical borders, and competition between cities and countries (Firmansyahet & Maulana, 2021; Noori et al. 2021). In particular, the acceleration of a consumption-based daily life with the change in production styles has led to a severe increase in energy demand worldwide (Zhang & Zhang, 2021). However, the increase in the use of private cars in urban areas, the rapid growth, and the spread of cities have increased the need for energy and raw materials (Razmjoo et al. 2021). The resulting emissions caused to environmental disasters, air, water, and soil pollution, while the amount of CO_2 accumulating in the atmosphere with the use of fossil fuels caused the greenhouse gas effect (Kazancoglu et al. 2021; Miller et al. 2021; Isinkaralar, 2022; Uddin, 2022; Yayla et al. 2022). The most basic reflection of climate change is the increase in temperature values. However, climatic parameters such as humidity, precipitation, and wind also change with temperature. These changes can also cause many environmental disasters, especially forest fires (Sevinc et al. 2020; Kucuk & Sevinc 2023).

Climate is a factor that affects living things multi-dimensionally (Felton et al. 2021; Lama et al. 2021). Considering that the urban population is increasing rapidly in present conditions, planning new urban development areas is inevitable. Climatic indicators should also be taken into account while managing the decisions of regional investment and development regions. It is an extreme necessity to determine the changes in cities and territories depending on climatic parameters to ensure that those living in urban areas can feel bio-climatically comfortable and that other living species can survive. The fact that living spaces are not in the bio-climatically comfortable range leads to energy consumption for heating or cooling. This situation creates a need for energy production again. From this point of view, proposing living spaces in areas that will be comfortable in the future provides a great deal of energy savings. CO_2, which comes out with the use of energy (Godil et al. 2021), is also a severe threat to health (Orach et al. 2021; Sillmann et al. 2021). Therefore, another purpose of determining bio-climatic comfort zones is to provide a healthy living space to society. The fact that the climatic values are not in the range where people feel comfortable brings many physiological and psychological diseases. If the place or area is unsuitable for parameters such as desired temperature or humidity, it causes thermal stress and causes circulatory and respiratory tract disorders. As a result, the working system of the metabolism may be damaged. Many diseases can be triggered or lead to the death of living things. Therefore, public health is at risk due to climate change (Thompson et al. 2018).

It is stated that many living species, biodiversity, forests, and agricultural lands are also damaged by climate change's impact and human health when viewed around the world. Therefore, there is a severe climate crisis that threatens sustainable development. From this point of view, it was aimed to investigate the change of bio-climatic comfort areas with climate change in the Burdur basin, which covers a large part of the country's lakes, and has excellent potential in terms of water bodies. The difference is modeled according to two pessimistic and more optimistic scenarios defined by the IPCC. Geographical information systems were used in the production of models.

Materials and Methods

Description of The Study Area of Simulation

The Burdur Basin is located between 29°51'01"-29°59'08" north latitudes and 29°28'27"-30°49'55" east longitudes in southwestern Türkiye. Afyonkarahisar, Burdur, Isparta, Denizli, and parts of Antalya are located within the boundaries of the Burdur Basin. The Burdur Basin's conservation areas are affluent and include wetlands, forest areas, wildlife development areas, nature parks, natural monuments, and unique environmental protection areas. The existence of water bodies in the area is rich in

drinking water resources and covers the "Lakeland" of Türkiye (Figure 1).

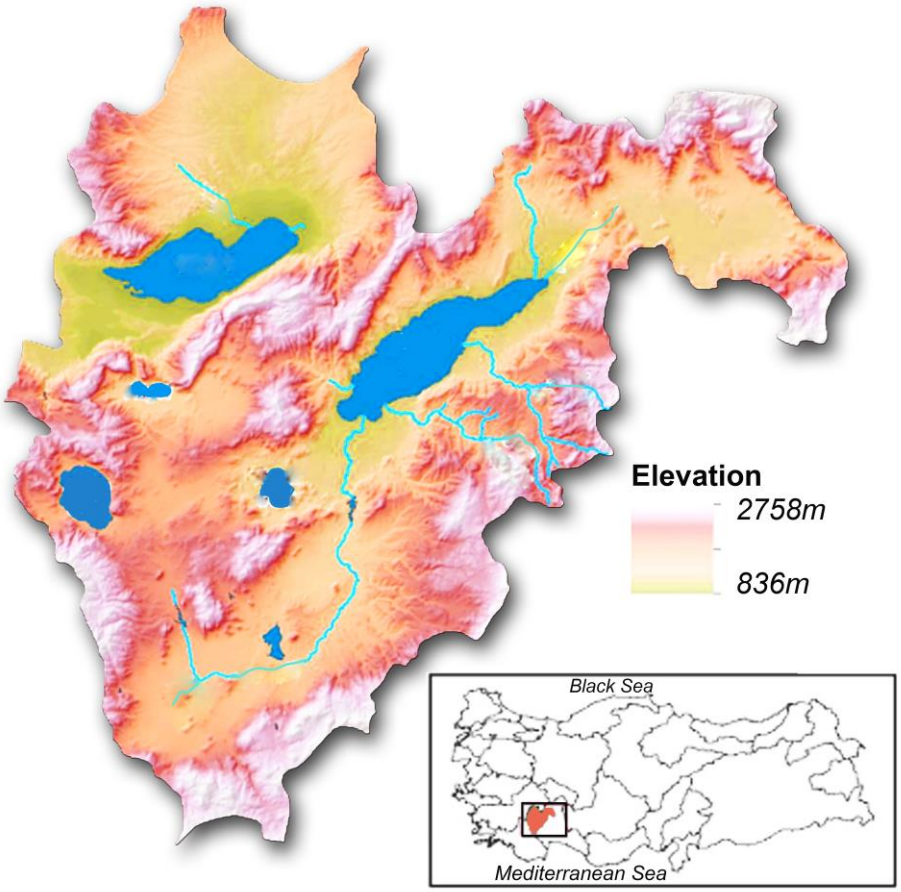

Figure 1. Location and DEM map of the study area

Methodology of Modeling

Data collection and scenario based modeling

This research produced models based on the SSP 245 and SSP 585 scenarios prepared by the IPCC. SSP 585 represents the most pessimistic scenario. SSP 245, on the other hand, has a relatively moderate approach. Climate parameters (temperature, humidity, and wind) were obtained from The National Department of Energy Lawrence Livermore National Laboratory at 50 km resolution. Obtained climate parameters were analyzed using ArcGIS 10.8 program. Geographic information systems are frequently preferred in current spatial research (Sağlam et al. 2008; Yahya et al. 2021; Zambrano-Asanza et al. 2021; Isinkaralar et al. 2022; Isinkaralar & Varol, 2023).

Mapping procedures and analysis using indexes

Two different indexes were used in the analyses. One of these is the discomfort index (DI) and the other is the Effective temperature-taking wind velocity (ETv). Spatial analyzes were performed using the Inverse Distance Weighted (IDW) method within the ArcGIS 10.8. All layers used were analyzed at 1x1 km spatial resolution. Various ranges are preferred in the interpretation of the values obtained under the DI. The contents used in this study are given in Figure 2. Accordingly, the range of 15.0-19.9 was accepted as comfortable. The increase in values is in the direction of extremely hot, and the decrease in values is in the order of extremely ice. Another preferred index in the study is Effective temperature-taking wind velocity (ETv). Temperature, humidity, and

wind speed data are used to classify the area according to the ETv index. ETv ranges are considered comfortable when they are 22-25°C.

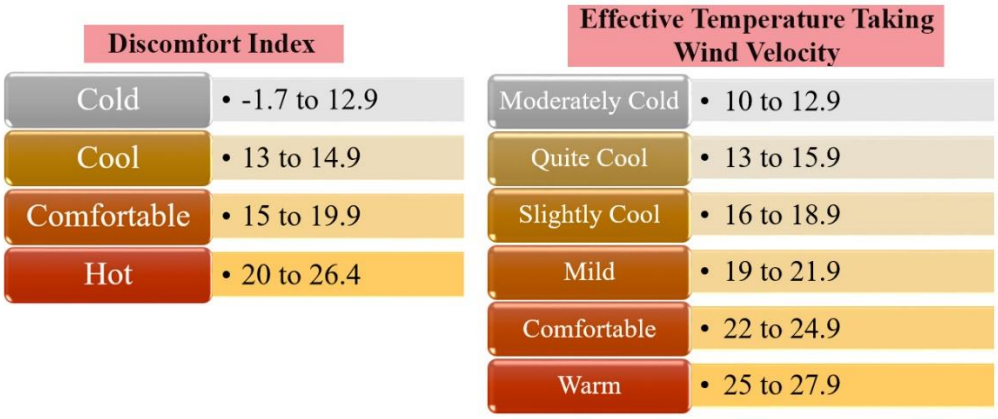

Figure. 2 Classification of Discomfort index and Effective temperature-taking wind velocity Index (Lucena et al., 2016; Isinkaralar, 2023)

In the case of the SSP 245 and SSP 585 scenarios for the Burdur basin, which is the study area, the temperature, humidity, and wind parameters also change. Bio-climatic comfort zones of the area were evaluated by grading according to DI and ETv indexes.

Bio-climatic comfort simulation

Regarding the change of bio-climatic comfort zones, it is seen that the minor difference is in the SSP 245 scenario, and the most change is in the SSP 585 scenario with an estimate of 2100. According to DI, 87.4% of the area is in the cold zone, and 12.6% is in the cool zone today. According to SSP 245, while areas in the cold zone decrease to 35.7% in 2040, the areas in the cool zone increase to 64.3%. In 2100, it was determined that the areas in the cold zone decreased to 4.6%, and the areas in the comfortable zone increased to 50.5%. According to SSP 585, cold spots will almost disappear by 2100 and will cover an area of 0.1%. Nearly all of the watershed boundaries (98.3%) will become areas in the comfortable zone in Table 1.

Table 1. The change of bio-climatic comfort zones

Index	Scenario	Class	Years				
			Present (2020)	2040	2060	2080	2100
DI	SSPs 245	Cold	87.4%	35.7%	18.9%	10.2%	4.6%
		Cool	12.6%	64.3%	73.8%	57.6%	45.0%
		Comfortable	0.0%	0.0%	7.3%	32.2%	50.5%
	SSPs 585	Cold	87.4%	30.1%	11.4%	1.3%	0.1%
		Cool	12.6%	69.9%	60.9%	22.0%	1.6%
		Comfortable	0.0%	0.0%	27.7%	76.7%	98.3%
			Present (2020)	2040	2060	2080	2100
ETv	SSPs 245	Cold	0.1%	0.0%	0.0%	0.0%	0.0%
		Moderately cold	7.2%	0.8%	1.0%	0.2%	0.1%
		Quite cool	92.7%	48.8%	49.8%	15.4%	9.9%
		Slightly cool	0.0%	50.4%	49.1%	84.4%	90.0%
		Mild	0.0%	0.0%	0.0%	0.0%	0.0%
	SSPs 585	Cold	0.1%	0.0%	0.0%	0.0%	0.0%
		Moderately cold	7.2%	0.2%	0.3%	0.1%	0.0%
		Quite cool	92.7%	23.3%	23.0%	4.9%	0.1%
		Slightly cool	0.0%	76.5%	76.7%	87.7%	10.7%
		Mild	0.0%	0.0%	0.0%	7.4%	89.3%

According to the ETv index, today, 0.1% of the area is in the cold zone, 7.2% in the moderately cold zone, and 92.7% in the exceptionally cold zone. According to SSP 245, there will be no cool areas in 2100. 9.9% of the area will be quite cool and 90% will be slightly cool areas. According to SSP 585, there will be no moderately cold areas in the area in 2100. 10.7% of the site turns slightly cool, and 89.3% turns into mild zone areas.

When the change in bio-climatic comfort areas is examined spatially, it is predicted that changes will take place primarily in terms of bio-climatic comfort in the center of Isparta and Burdur, and the districts of Afyonkarahisar, according to DI (Fig. 3). It is observed that the change in bio-climatic comfort zones will be relatively less in northern districts of Isparta such as Senarkent and Atabey, and western districts of Burdur such as Yeşilova, Karamanlı, and Tefenni. It is seen that the values will be lower since the high parts of Antalya, which has the smallest share in the Burdur basin, are located within the borders of the basin. According to ETv, it has been determined that Acıgöl Lake will be located in the high range and will turn into an area in the mild zone in 2080. The most remarkable change in the places in the slightly cool zone in the basin is observed between 2080-2100. It is observed that almost the entire basin will turn into a mild area (Figure 4).

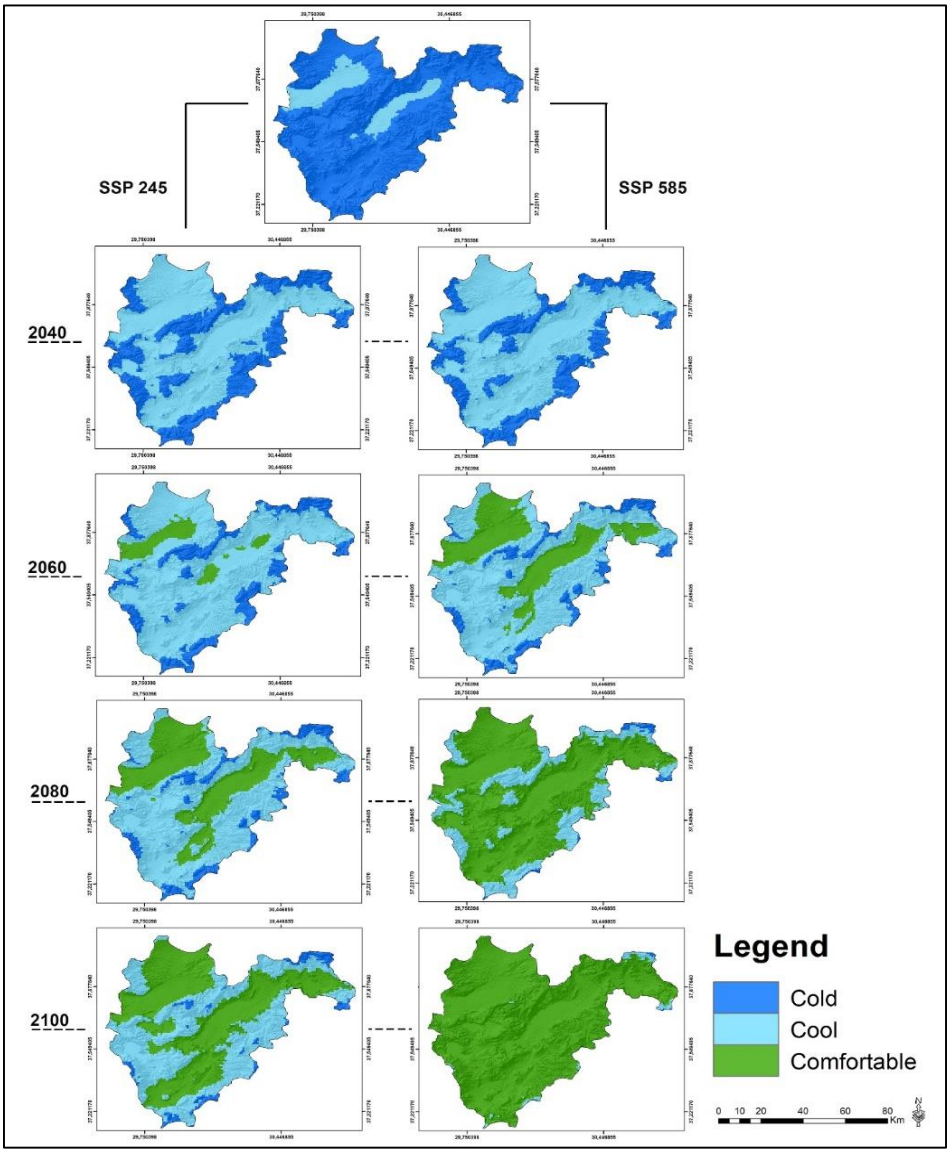

Figure. 3 Bio-climatic comfort zones change according to DI

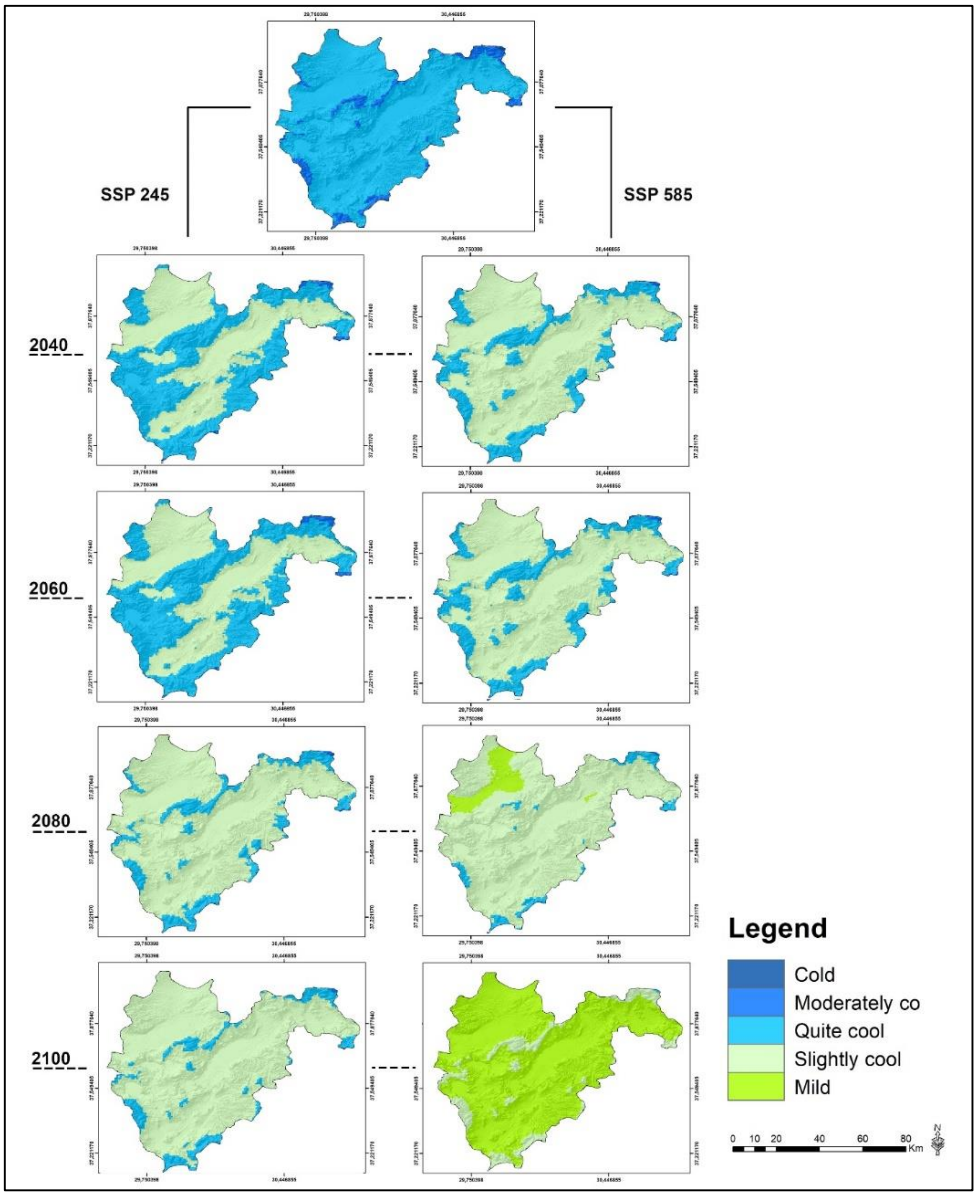

Figure. 4 Bio-climatic comfort zones change according to ETv

Discussion

The climate crisis is one of the most severe problems in the world. It is a very current issue to investigate the effect of changes in climate parameters on living things. Türkiye is one of the most sensitive and risky countries against climate change (Isinkaralar et al. 2023). It is revealed that the annual average temperature will increase in the whole country until 2100, and the average temperature, especially in the Aegean region, may rise up to 6 °C (Dalfes et al. 2007; UNDP, 2019).

Especially in recent years, there have been many studies on spatial modeling of bioclimatic comfort zones (Mansuroglu et al. 2021; Isinkaralar & Isinkaralar, 2023). Cetin et al. (2022) investigated the change in bio-climatic comfort areas due to global climate change in Mugla province borders. As it is a coastal area more than the Burdur basin, as a result of the research, it has been determined that warm regions will be formed at a rate of 16.11% according to the ETv index. Aricak (2020) modeled the change in bio-climatic comfort areas in Samsun using the summer simmer index. It was determined that 1.41% of the province in June and 16.65% in September remained in the cold zone. Koç (2022) determined the change of Antalya according to SSPs 245 and SSPs 585

scenarios. It has been determined that temperatures will shift from cold to warm.

The common feature of all these studies is that they cover provincial borders. This research presents a model with a holistic perspective of the whole basin. Thus, the change in the bioclimatic comfort zones in the natural land cover located at the basin borders can also be monitored. The research area represents a region rich in water resources, agricultural land, and forest ecosystems. Considering the change in comfort areas in the area, it can be stated that many vital sectors, such as health, tourism, agriculture, and energy, are under threat.

Conclusion

Bio-climatic comfort values are essential for maintaining the quality of life and vitality. Climate parameters are vital for plants, animals, and people to survive or lead a comfortable life. The change in climate values has been accepted by international organizations, governments, researchers, and local governments on a global scale. The multidimensional effects of the change in climate values are inevitable. However, especially in the production of strategic watershed management plans, defining the objectives of regional plans and estimating the spatial change in local decisions can be guiding. It can be used to monitor the zones at risk due to the effects of climate change. The determination of comfortable areas in terms of bio-climatic is very decisive in terms of spatial location selection and other suitability parameters for settlement.

Ethics Committee Approval

Not applicable.

Peer-review

Externally peer-reviewed.

Author Contributions

Conceptualization: O.I.; K.I., H.Ş.; Ö.K.; Investigation: O.I.; K.I., Material and Methodology: O.I.; K.I., H.Ş.; Visualization: O.I.; K.I., Writing-Original Draft: O.I.; K.I., H.Ş.; Ö.K.; Writing-review & Editing: O.I.; K.I., H.Ş.; Ö.K.; Other: All authors have read and agreed to the published version of manuscript.

Conflict of Interest

The author has no conflicts of interest to declare.

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