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Investigation of Bioclimatic Comfort Structure in Muğla with the help of Geographical Information Systems

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ABSTRACT

In places and times where the climate is not comfortable for people, people have adapted their clothing habits according to the situation and developed heating and cooling systems in their buildings and cars. On the other hand, until the last century, research on climate comfort remained in the form of philosophical description rather than experimentation. The studies in the last century, on the other hand, remained mostly local, seasonal/spatial continuity and difference have just begun to take their place in the literature. This deficiency in the literature creates an obligation for academics interested in the subject to work on this subject and produce examples. It is aimed to determine the areas where climate comfort is suitable or not for human life and activities in Muğla province and its surroundings. For this purpose, climate data for the period 1975-2017 of 9 meteorology stations were obtained from the MGM in the province. These stations were digitized transferred in the CBS environment using by GIS. The transferred data were interpolated with the Co-Kriging method using the seasonal elevation factor. Thus, temperature and humidity substrates were obtained. By calculating Thom's temperature-humidity index with raster data created by interpolation, seasonal and spatially continuous felt temperature values were produced. The calculated values were classified according to the Temperature Equivalent Psychology scale and the seasonal and spatial determination of the climate comfort. The relationship between climate comfort and land cover/classes was determined.

Anahtar Kelimeler:
Biyoklimatik Konfor,
CBS,
Co-Kriging,
Hissedilen Sıcaklık,
Muğla.

ÖZ

İklimin insanlar için konforlu olmadığı yerlerde ve zamanlarda insanlar giyim alışkanlıklarını duruma göre uyarlamışlar ayrıca binalarında ve arabalarında ısıtma ve soğutma sistemleri geliştirmişlerdir. Diğer yandan son yüzyıla kadar iklim konforuna yönelik araştırmalar deneysellikten öte felsefi betimleme şeklinde kalmıştır. Son yüzyıldaki çalışmalar ise daha çok lokal özellikte kalmış mevsimsel/mekânsal süreklilik ve farklılık literatürdeki yerini henüz almaya başlamıştır. Literatürdeki bu eksiklik konuyla ilgilenen akademisyenler için bu konuda çalışmalar yapma örnekler üretme zorunluluğu oluşturmaktadır. Bu çalışmada Muğla ili ve çevresinde insan yaşamı ve aktiviteleri için iklim konforunun uygun olduğu ya da olmadığı alanların belirlenmesi amaçlanmıştır. Bu amaç için ildeki MGM'den 9 meteoroloji istasyonuna ait 1975-2017 dönemi iklim verileri (sıcaklık ve nemlilik) elde edilmiştir. Ayrıca bu istasyonlar CBS ortamında sayısallaştırılmıştır. Daha sonra istasyonların iklim verileri Coğrafi Bilgi Sistemleri (CBS) ortamına aktarılmıştır. Aktarılan veriler mevsimsel olarak yükselti faktörü kullanılarak Co-Kriging yöntemiyle enterpole edilmiştir. Böylece sıcaklık ve

nemlilik altlıkları elde edilmiştir. Enterpolasyon ile oluşturulan raster veriler ile Thom'un Sıcaklık-Nemlilik İndisi (DI) hesaplanarak mevsimsel ve mekânsal süreklilik arz eden hissedilen sıcaklık değerleri üretilmiştir. Hesaplanan değerler Sıcaklığa Eşdeğer Psikoloji (SEP) skalasına göre sınıflandırılarak iklim konforunun mevsimsel ve mekânsal olarak belirlenmiştir. Ayrıca iklim konforu ile arazi örtüsü/sınıfları arasındaki ilişki de tespit edilmiştir.

1. Introduction

According to Maslow's hierarchy of needs theory, human needs are ranked according to their priorities. These needs are to eat, drink, sleep, breathe and protect oneself against physical dangers that people have to do to survive. From past to present, people have established settlements in safe areas to protect themselves. In recent years, comfortable areas where climatic conditions are suitable for human life have started to be preferred as residential areas [1-9] For people to continue their lives, they need to establish a heat balance with the environment they live in. To establish this balance, heat exchange takes place between humans and the environment. If the temperature of the environment is higher than the temperature of the human body, the body takes the heat. However, if the body's temperature is too high, it sends heat to the environment with various activities (shivering, sweating, etc.) [10-14]. Thus, people feel comfortable in their environment. If the temperature is 26°C and the relative humidity is above 70%, it cannot give heat to the environment and therefore causes human beings to be under thermal stress [15-19]. Cities with the rapidly increasing population of today's world are among the places where people do not feel comfortable in terms of thermal comfort. Among the main reasons for these are the rapid population growth and the scarcity of green areas in urban areas that are increasing rapidly in an uncontrolled manner. The location of the buildings built in the cities, dense and high buildings, increased traffic density due to overpopulation and air pollution cause warmer environments than the natural areas around the cities. This situation is called an urban heat island [20-26]. To prevent the formation of urban heat islands, it is tried to be eliminated by observing the city-green area relationship in the cities and by designing the settlements by the air currents [27-36].

Since the bioclimatic comfort situation, changes according to time, place, and person, different approaches have emerged. These approaches are the psychological approach, thermophysiological approach, and body temperature balance approach. How the human brain perceives the temperature in the environment in which it lives is a psychological approach. In the thermophysiological approach, the temperature has less effect on the nervous system so that the environment is comfortable. In the last approach, the body temperature balance approach, the heat entering and leaving the body is in balance [37-50]. Two factors, environmental and personal factors, affect human comfort. The first of these are environmental factors: air temperature, humidity, wind, and solar radiation. Personal factors other than environmental factors and resulting from the influence of humans are metabolic heat, activity level, and the wrapping effect of clothing [40-55] In the study, air temperature and relative humidity, which are environmental factors, were taken into account. However, personal factors affecting bioclimatic comfort were not the subject of this study.

This study, it is aimed to determine the bioclimatic comfort status of Muğla province and to reveal its maps. The study was carried out in the following stages. In the first stage, climate data for the years 1975-2017 were obtained from 9 stations from the General Directorate of Meteorology and these data were arranged as monthly averages. The edited climate data was transferred to the Geographic Information Systems (GIS) environment. The temperature and relative humidity data at the stations were made into a continuous surface with the co-kriging model in the GIS environment and disseminated to the area. As a result, pixel-based monthly temperature and relative humidity maps were produced. In the next step, the Temperature-Humidity Index (Discomfort Index) produced by Thom was used. Thus, monthly and average values were obtained on a pixel basis. The classification was made using the Temperature Equivalent Psychology (PET) scale and the felt temperature values were revealed. In the last stage, to examine the relationship between bioclimatic comfort and land use in the province; land classes and annual average felt temperature data were overlapped.

2. Material and Method

2.1 Study area and Data

Muğla province, located in the southwest of Anatolia, is between 36º 07' and 37º 30' north latitudes and 27º 20' and 29º 40' east longitudes [56]. Covering the south of the Menteşe region and the west of the Teke region, the province is surrounded by the Aegean Sea to the west and the Mediterranean Sea to the south (Figure 1a). There are Antalya in the east, Burdur in the northeast, Denizli, and Aydın in the north (Figure 1b).

Temperature and relative humidity data for the years 1975-2017 were obtained from 9 meteorology stations, including Milas, Yatağan, Muğla, Bodrum, Köyceğiz, Marmaris, Dalaman, Fethiye, Datça, located within the borders of Muğla province, from the General Directorate of Meteorology. monthly averages were obtained by arranging the data and transferring it to the GIS environment (Figure 1d).

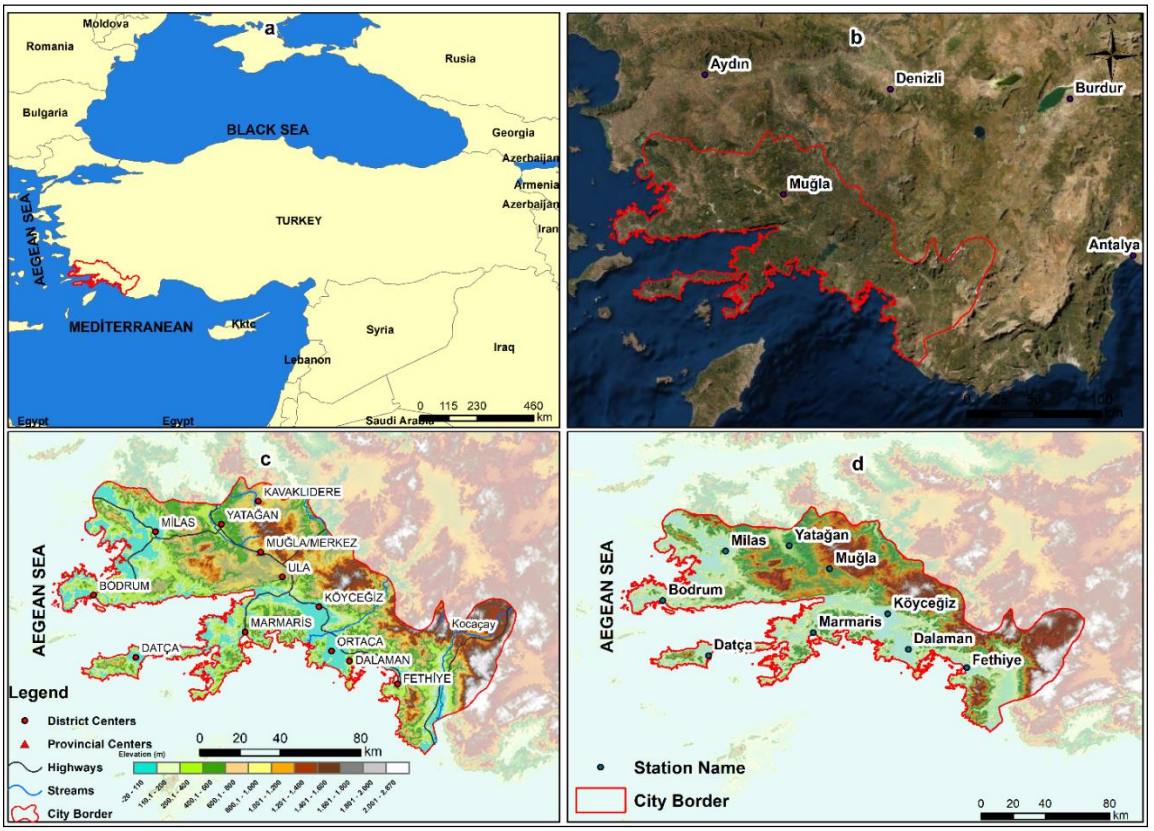

Figure 1. :(a and b= Location, c= Topography of the study area, d= Stations used in the study).

2.2 Method

In the study, the interpolation method was used to obtain continuous surface data from point data. At this stage, pixel-based continuous surface data were created by using the co-kriging technique [5,9,10,14,15, 19, 26,17,24,31,32, 33, 38] , which is one of the interpolation methods of two-dimensional temperature and relative humidity data obtained from MGM stations [57]. Co-kriging method:

$$Z_1(s) = \mu_{1+} \epsilon_1(s)$$

$$Z_2(s) = \mu_{2+} \epsilon_2(s)$$

calculated by the formula.

Here, ϵ_1 and ϵ_2 show random errors, with the unknowns μ_1 and μ_2 fixed. To predict the relationships between variables with the help of other variables, the relationship between them must be strong. There is autocorrelation between Z_1 and Z_2 and co-kriging predicts $Z_1=(s_0)'_1$. [58, 5,9,10,14,15, 19, 26,17,24,31,32, 33, 38]

The Discomfort Indices values based on the temperature and relative humidity relationship produced by Thom on the pixel-based raster data obtained by the co-kriging method were revealed. Index prepared according to temperature and relative humidity;

DI = T – (0,55 – 0,0055 * RH) * (T – 14,5)

Here;

DI=Temperature-Humidity Index (Discomfort Indices)

T=Monthly Average Temperature (C°)

Expressed as RH=Relative Humidity (%) [59, 5,9,10,14,15, 19, 26,17,24,31,32, 33, 38]

With the Discomfort Indices formula, the temperature values felt for 12 months have been produced. However, Physiological Equivalent Temperature (PET) has been adapted to SEP, as DI does not classify climate comfort. Using the SEP classification scheme, it was determined how people perceive temperature (Table 1).

Table 1. Temperature Equivalent Psychology Classification (SEP)

Index Values (DI)	**Thermal comfort classes**
< 4	Very cold
5 – 7.9	Cold
8 – 11.9	Mild cold
12 – 14.9	Cool
15 – 19.9	Comfortable
20 – 21.5	Warm
21.6 – 24.9	Hot
25 >	Very hot

As a result of the index calculations for Muğla province and its surroundings, climate comfort maps were produced following the SEP scheme. It has been revealed how the research area is in terms of thermal comfort for 12 months.

3. Result

3.1 Temperature and Relative Humidity in the Study Area

Temperature data of Muğla province were evaluated using the co-kriging method and monthly average temperature maps were prepared (Figure 2). When the temperature maps obtained were evaluated, it was observed that there were differences according to the months depending on the effect of factors such as temperature values, altitude, proximity, and distance to the sea.

Average monthly temperatures in the study area vary between 5.1°C and 30.1°C. These values are between 5.2°C and 14.1°C in December, January, and February. In January, temperatures are between 6°C - 10°C as you go south from the city center. In February, temperatures in high areas decrease depending on the altitude. While the lowest temperatures prevail in the city center in March, the temperatures reach high values along the coastline. It is seen that the temperature conditions begin to change with April and May. In June, July, and August, the lowest temperatures are seen in the north of the city center with 26°C, while the highest temperatures reach 30°C in places where the altitude is low. When compared to August in terms of average temperature values in September, it is seen that the temperature values decrease. While the temperatures in the east of the province are around 16°C in October, this value drops to 10°C in November.

Since the study area is located by the sea and is exposed to the effect of the maritime, it is seen that there are no extreme winter temperatures in the region, and the temperatures reach maximum values in the spring and summer months. It is observed that changes in climate comfort conditions occur due to the increase in altitude and the emergence of terrestrial conditions as you go from the sea coast to the inner parts. This situation affects people and causes spatial changes.

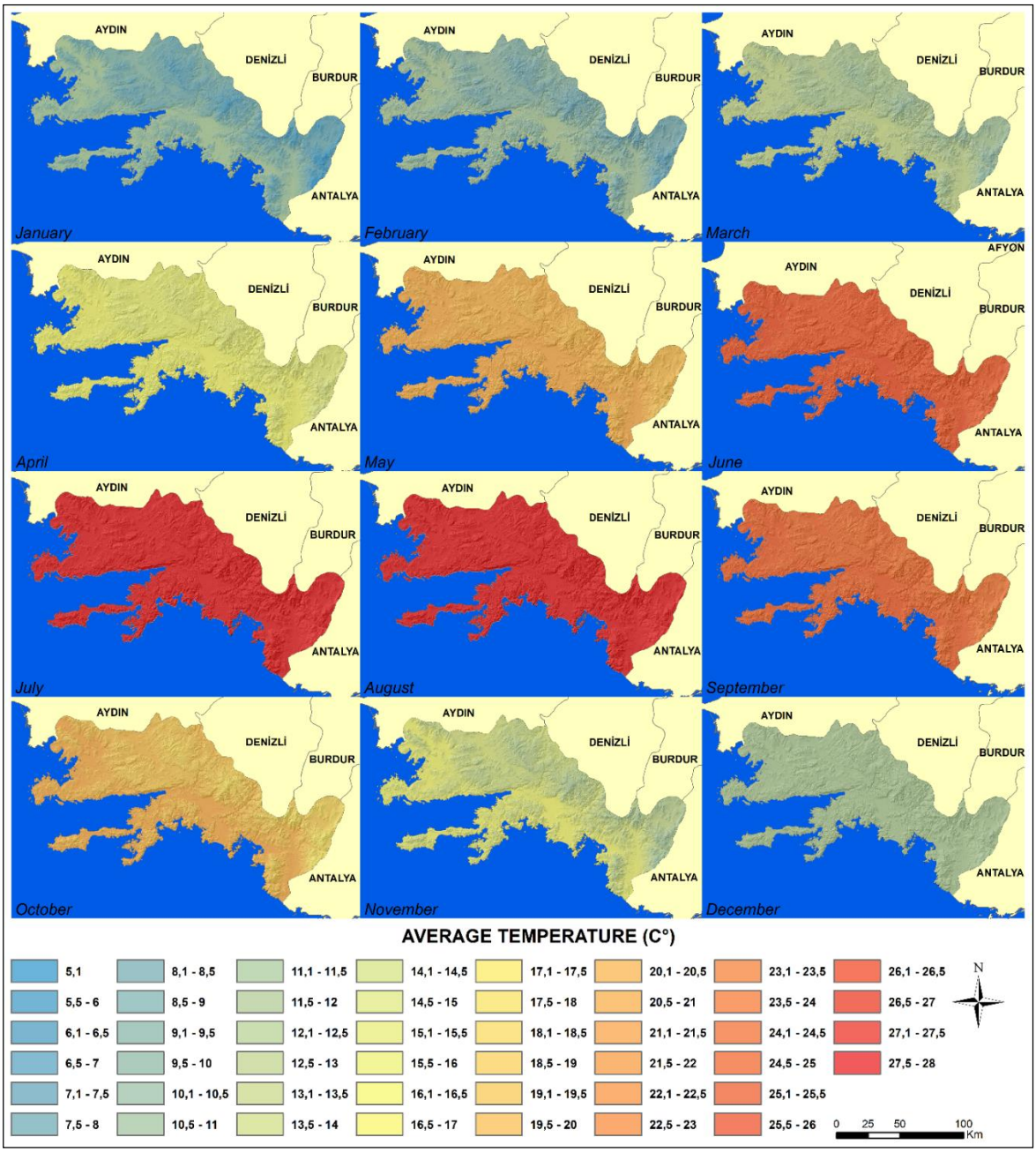

Figure 2: Monthly average temperatures of the study area

When the relative humidity values are examined, it reaches the highest value (79.9%) in the winter months, especially in December. In January, while it is 77% in the city center, the lowest values are seen in the coastal areas. Relative humidity values in February vary between 66% and 73%. When February and March are compared, it is seen that the humidity values are similar. It is observed that the relative humidity values have changed with June. In July, relative humidity values decrease to 52%. In August and September, it reaches 60%. Relative humidity values rise above 70% as of November. Although the relative humidity values rise above 65% in winter (December, January, February), it falls below 60% in summer (June, July, August). In addition, it is observed that the relative humidity is generally low in the coastal areas and the relative humidity values increase in the high areas (Figure 3).

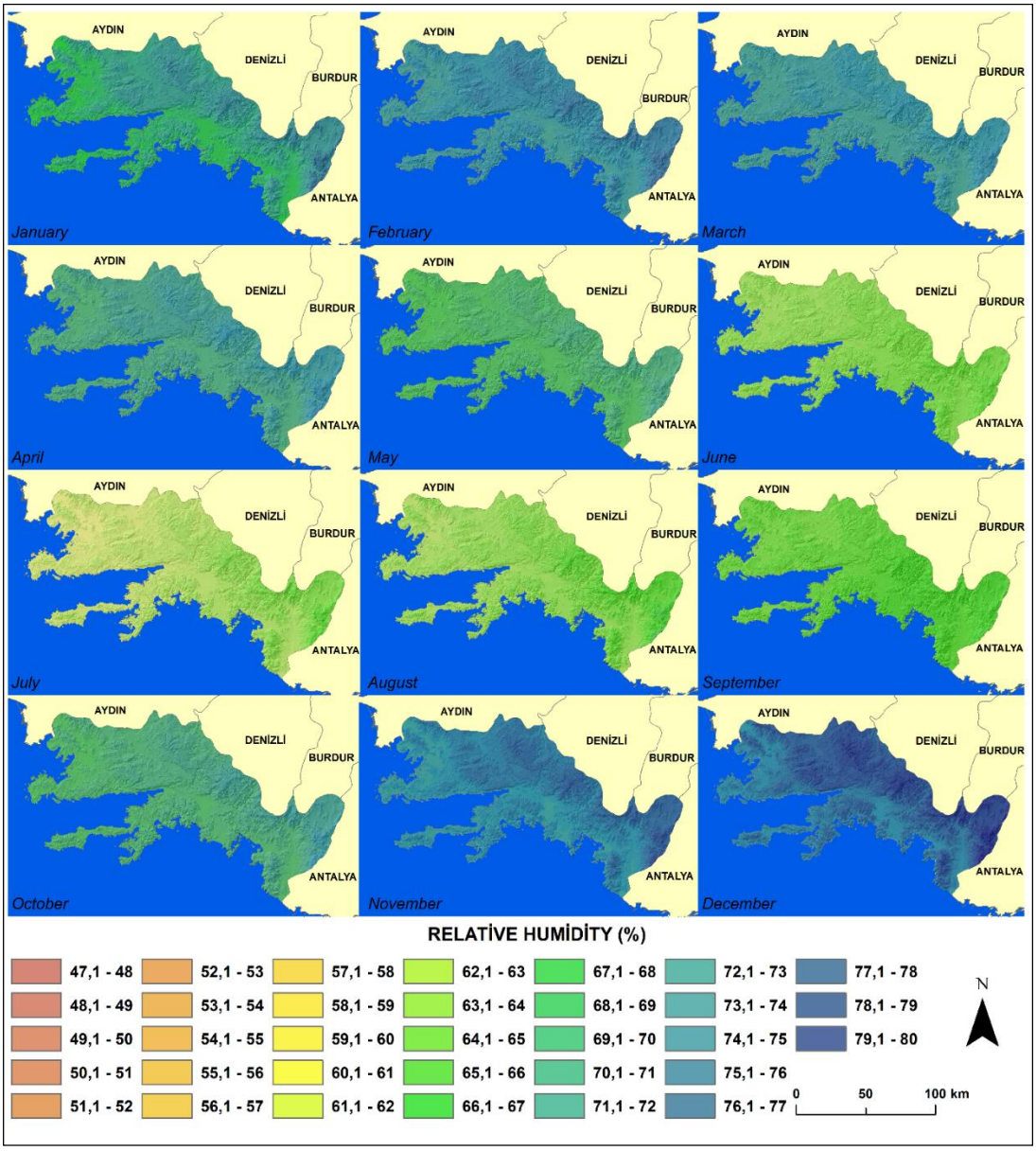

Figure 3: Monthly average relative humidity values of the study area

3.2 Temperature - Humidity Index (Discomfort Indices)

Temperature - Humidity Index was used to determine the climate comfort characteristics in the study area located in the Aegean Region coastal zone. When the index values are examined, the temperature values felt during the winter months (December, January, February) vary between 6°C and 14°C. While the temperatures felt in the high areas in the north and northeast of the study area are low, the temperatures felt in the coastal areas increase. In March, it is 10°C in high areas and around 14°C in lowland areas. In April and May, the temperatures felt increase and reach 22°C.

The temperatures felt in the summer months (June, July, August) do not exceed 25°C. While the felt temperatures are 21°C in the high areas, it is 24°C in the coastal areas. The temperatures felt in July reach the maximum value. This situation continues in August as well. In September, it decreases below 24°C. While the temperatures felt in October are 20°C in the plains, it drops to 15°C in the higher parts (Akdağ, Babadağ and Oyuklu Mountains).

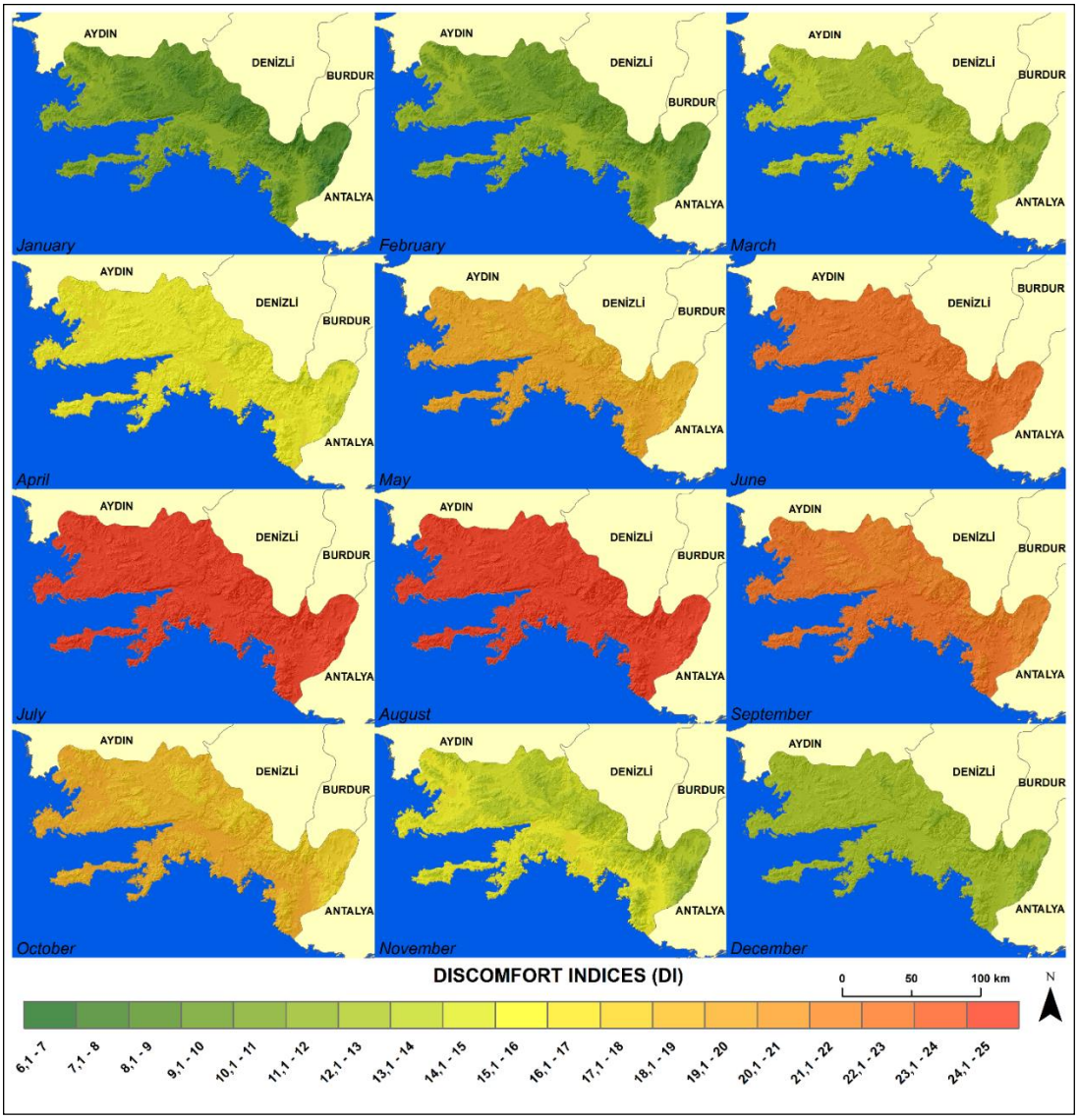

Figure 4: Study area of the temperature-humidity index (DI)

In November, it drops below 8°C in the east of the province. While the felt temperature values are minimum in the high parts of the research area, they reach the maximum values in the low parts of the coast (Figure 4).

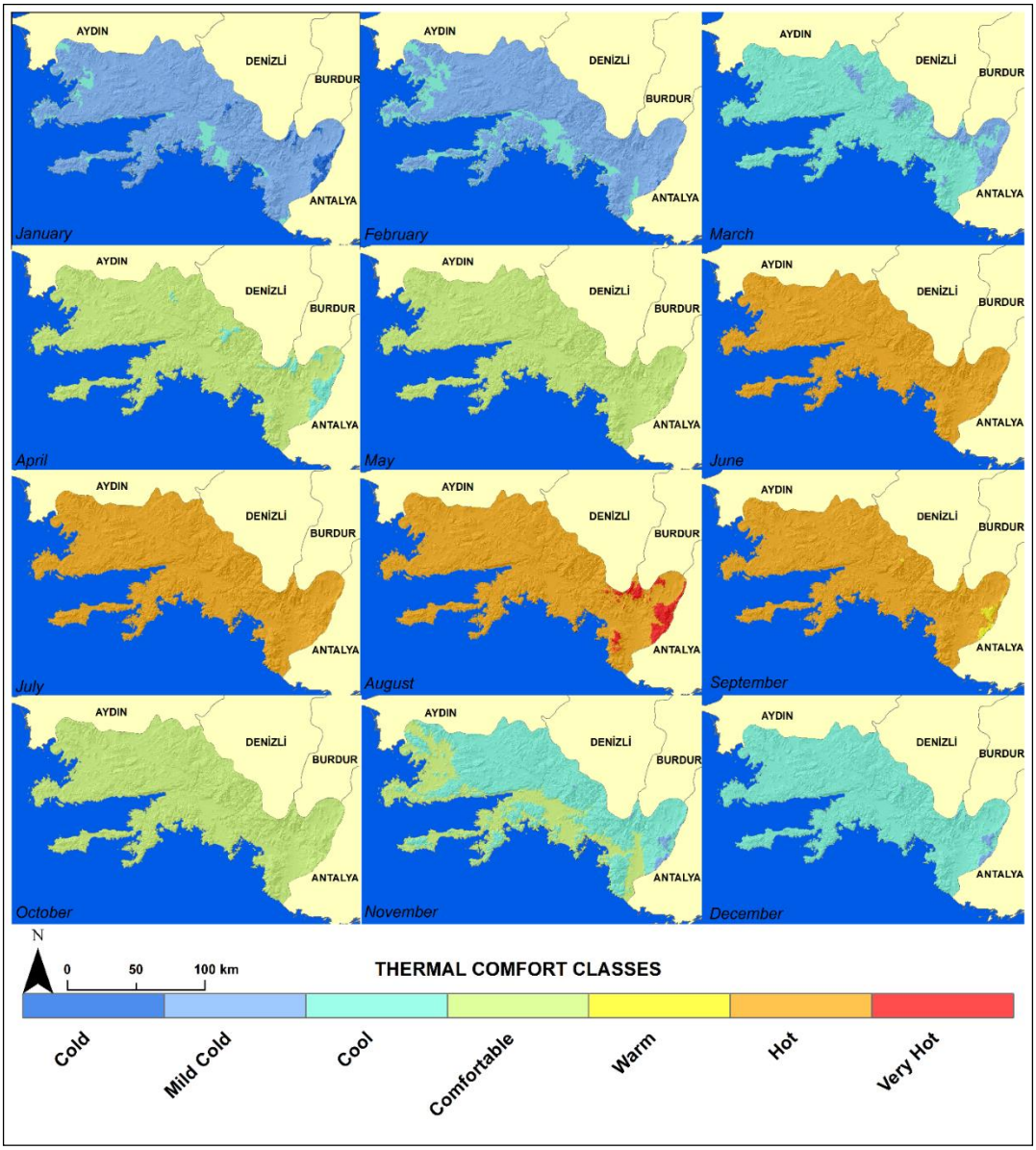

Figure 5: Study area of thermal comfort classes

When the discomfort index values of Muğla are examined; The temperatures felt in January range from cold to cool. While cold is felt in the high parts of Akdağlar, which is located in the east of Fethiye, a slight cold is felt in the west of Köyceğiz, Dalaman, and Milas. While the temperatures felt cool in the coastal areas in February, the temperatures felt from the west to the east changed and the cool comfort class left its place to the mild cold class. There was a big change in the temperature sensation in March. While the temperature feeling is cool throughout the province, it is felt slightly cool in the Akdağlar located in the west and the Oyuklu Mountains in the northeast of the city center. With April, the temperatures started to feel comfortable. In April, comfortable conditions prevail in almost the entire province, and the temperature felt in the high parts of the east is cool. On the other hand, it is felt comfortable in all of the low and high parts of Muğla in May. While the felt temperatures are comfortable in May, they change with June. The temperatures that felt comfortable in May left their place to the warm comfort class in June and July. While the temperatures felt in August are hot in the study area, it is felt very hot in a narrow area in the south and southwest. The temperature felt in September is similar to August. There is a feeling of warmth in all plains and foothills of the study area, but only in the higher parts

of the east. With October, it is felt comfortable in the whole of Muğla. In November, the low areas are comfortable and it is felt as cool at the foot of the mountains and slightly cold at higher altitudes. The temperatures felt vary between slightly cold and cool in December. While it is felt as cool in all plains and mountainous areas of Muğla, it is felt as slightly cold in the high parts of Akdağlar, located in the east of the province. In Muğla province, it is generally slightly cold and cool in December, January, and February, cool in March, comfortable in April and May, warm and cool in June, July, August, September, comfortable again in October, and cool in November and December. and slightly cold (Figure 5).

As a result of the analyzes made, the average Discomfort Index (DI) values were produced by using the temperature and relative humidity values. These values vary between 15.9°C and 18.2°C throughout the province. The minimum temperatures are seen in and around the high parts of the mountains, while the maximum temperatures are seen in the low parts of the coast.

Temperature Equivalent Psychology (SEP) classification was applied to the mean discomfort index values in Muğla province. As a result, it has been determined that the whole of the province is comfortable climatically.

4. Discussions and Conclusions

To determine the bioclimatic comfort characteristics of Muğla province, monthly average temperature and relative humidity data obtained from 9 meteorology stations were arranged and transferred to the GIS environment. Temperature and relative humidity data were evaluated by months using Co-Kriging methods and maps were created. The monthly average temperature values of the study area were examined and it was determined that it was in the appropriate range in terms of bioclimatic comfort. Considering the humidity values, it has been determined that the other parts of the province have suitable values in terms of bioclimatic comfort, except for the regions in the eastern and southeastern parts of the province with a relative humidity of over 70%.

In the study, the Temperature-Humidity Index (DI) produced by Thom using the climate parameters was calculated and the temperature values felt were determined according to the months. It has been observed that the temperatures felt in the winter season are low in the north, northeast of the province, and high in the coastal areas. The perceived temperatures do not exceed 25°C in summer. As a result of calculating the Discomfort Index values, the temperatures felt were classified by using the Psychology Equivalent to Temperature (SEP) scale.

The change in the bioclimatic comfort situation is in months and what kind of spatial distribution it exhibits are examined. When the variation of bioclimatic comfort according to the months is examined, it is felt as slightly cold and cool due to the low temperatures in December, January, February, and March. In April, May, and October, comfort conditions without any thermal stress cover a wide area throughout the province. Due to the high temperatures in June, July, August, and September, it feels hot. To make the temperatures felt in summer comfortable, it is necessary to increase the green areas in the city and to plan the streets in a way to ensure air circulation in the newly planned residential areas.

In Muğla Province, no discomfort was observed depending on the monthly average temperatures. Due to the lack of discomfort, it may cause tourists to prefer this area more. Before making investments for tourism purposes, it will help to determine the climate comfort characteristics and to reveal unused potentials in areas where comfort is appropriate.

Competing Interest / Conflict of Interest
The authors declare that they no conflict of interest. None of the authors have any competing interests in the manuscript.

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We declare that all Authors equally contribute.

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