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Research Paper

Determination of Bioclimatic Comfort Zones by Geographic Information Systems: Karabük Province, Turkey**

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Abstract: Rapid increase in settlement areas with rapidly increasing population after the industrial revolution led to the formation of unplanned and irregular urbanization. By including climate data into city plans, comfortable spaces have been created to make people comfortable. Bioclimatic comfort is defined as the conditions in which a person adapts to the environment by consuming minimum energy. In order to determine the bioclimatic comfort status of a place, the temperature, relative humidity, and wind conditions must first be determined and evaluated. In this study, it is aimed to determine the bioclimatic comfort zones of Karabük province (Turkey). For this purpose, temperature, humidity, and wind data obtained from nine meteorological stations located within administrative borders of Karabük province are used. Temperature, humidity and wind maps are created by making a bioclimatic comfort analysis through this climatic data using ArcGIS 9.3 software, and Inverse Distance Weighting (IDW) technique is selected as a method. These maps are overlaid by classifying them according to the specified comfort values. At the end of the study, it is observed that June, July, August, and September are suitable for Bioclimatic comfort.

Keywords: *GIS, Inverse Distance Weighting Interpolation Technique, Karabük*

Introduction

It is a well-known fact that climate conditions are very important and determinant on human life, health, and activities. In particular, studies aiming to determine the most suitable climatic conditions for human life are quite new. Values related to climate elements have been identified, and some grades have been developed, especially through the studies on human comfort. Moreover, it is very important to determine these values in order to determine the deviation from the optimal values and to determine the current situation of the environment's climatic conditions with regard to average and optimal values (Evans, 2007; Güçlü 2008; Güngör & Polat, 2012).

As the return of living in an age, in which technological improvements are accelerating, increasing industrial activities are causing breaking down of the ecological balance and destroying of the natural resources swiftly. Bioclimatic comfort is defined as the conditions in which a person adapts to the environment by consuming minimum energy. The most important factor affecting people's comfort in the outdoor environment is the "climate". Although the climate parameters differ greatly, it is stated that the most important components of bioclimatic comfort are air temperature, air humidity, air wind, and additionally the short and long wave radiations. These components directly affect the physiological state of humans and are therefore a factor in human health. Creating a cozy and comfortable exterior design is ensuring comfort for the living through parks, gardens, and resting areas, recreational areas, aesthetic afforestation, augmenting agricultural crops with wind gouges *etc*., and thus, improving the climate (Marzarakis & Mayer, 1996; Tağıl & Ersayın, 2015; Aydın et al., 2017; Özyavuz, 2017; Öztürk & Kalaycı, 2018).

According to Mirza, 2014, Factors affecting bioclimatic comfort are environmental conditions and personal parameters. These are; air temperature, air humidity, air movement, radiation, and personal factors such as metabolism' regulating the temperature according to the activity, activity level, and clothing insulation (Çınar, 1999; Matzarakis, 2003; Nikolopoulou et.al., 2004; Toy et.al.,

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2005). Olgyay (1973) explains the values of climatic elements that need to be examined for bioclimatic comfort as a combination of 21-27.5 ° C temperature at open area, 30-65% relative humidity, and wind speed up to 5 m/s. These values have been used in many bioclimatic evaluations. (Topay & Yılmaz, 2004). Experts are evaluating which threshold values should be included in the ambient temperature in terms of bioclimatic comfort and what other meteorological parameters are there in addition to the weather temperature. For example, in a study on Turkey, it was found that the ideal temperature values to provide people a comfortable environment in terms of climate, should be between 16.7°C and 24.7 °C.It is also emphasized that the wind speed less than 6 m/sec and the relative humidity value between 30% and 70% must also be taken into account in the determination of the comfort zone beside the temperature values (Hobbs, 1995; Moran at al., 1997; Güçlü 2008; Güngör & Polat, 2012; Özyavuz, 2017).

Within the scope of this study, climatic maps of Karabük province were made using temperature, humidity, and wind data taken from climatic stations located in Karabük city center and districts (Eflani, Eskipazar, Merkez, Merkez-Kapullu, Merkez-Karatepe, Ovacık, Safranbolu, Safranbolu-Ovacuma, and Yenice) for many years. These maps were then overlapped according to their bioclimatic comfort values, and appropriate areas were identified.

Material and Methods

Study area

The Karabük province with a surface area of 4,145 km² and located in the Western Black Sea Region, is between 40° 57' and 41° 34' northern latitudes and 32° 04' and 33° 06' east longitudes. The main material of the study consists of the data taken from the meteorological stations located within the provincial administrative boundaries of Karabük (Figure 1).

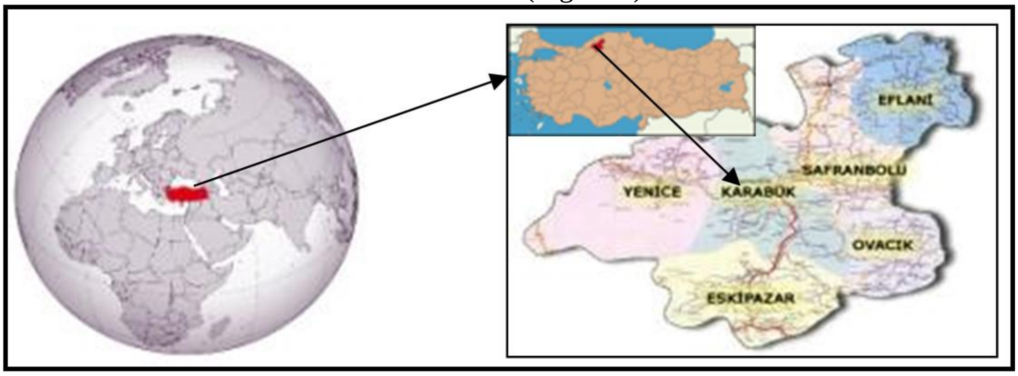

Figure 1. The location of Karabük

The long-term data of Karabük-Kapullu, Karabük-Kartepe, Eflani, Eskipazar, Ovacık, Safranbolu, Safranbolu-Ovacuma, Yenice, and Kastamonu-Araç stations, taken from the General Directorate of Meteorology are used. The information regarding these climate stations is given in Table 1.

Table 1. Meteorology stations and their features

No	Station No	Province	District	Station Name	Observation Type*
1	18159	Karabük	Eflani	Eflani	AMOS
2	17641	Karabük	Eskipazar	Eskipazar	AMOS
3	17078	Karabük	Merkez	Karabük	AMOS - Synoptic–Daily Climate
4	17077	Karabük	Merkez	Karabük Kapullu	AMOS
5	18261	Karabük	Merkez	Karatepe	AMOS
6	18266	Karabük	Ovacik	Ovacık	AMOS
7	17719	Karabük	Safranbolu	Ovacuma (H-SAF/Rainfall)	AMOS
8	17904	Karabük	Safranbolu	Safranbolu	AMOS
9	18262	Karabük	Yenice	Yenice	AMOS
10	18215	Kastamonu	Araç	Araç	AMOS

***AMOS:** Automatic Meteorological Observation Station. **Synoptic:** The basic observation type used for weather forecasting. All meteorological parameters are measured every 3 hours. **Daily Climate:** A type of climatic* *observation where rainfall, meteorological incident, evaporation, and sunshine duration are assessed every morning covering the last 24 hours.*

Methodology

Inverse Distance Weighting (IDW) InterpolationTechnique is used to evaluate and map the obtained data. Data of at least 10 points are required for this technique. The total number of stations in Karabük and its districts is nine. The data from the climatic station located at the border of Kastamonu province, neighboring Karabük province, is also included in the evaluation.

Inverse Distance Weighting (IDW) Interpolation Technique

It is an interpolation technique used to determine the cell values of points that are not sampled, with the help of known sample point values. The cell value is calculated according to the increase in distance and considering various points moving off the relevant cell. Estimated values are a function of the distance and magnitude of neighboring points and the increase in distance reduces the significance and impact on the cell to be estimated. In this method, properties of data such as general distribution, tendency, anisotropy, and clustering are not examined. The data are evaluated and compared only locally. It is a deterministic method (Başel et al. 2008). The IDW interpolation technique is often a preferred method of generating grids by interpolation from sampled point data. The IDW interpolation technique is based on the principle that adjacent points on the surface to be interpolated have more weight than distant points. This technique reduces the weight as it moves away from the point to be interpolated and makes a surface interpolation relative to the weighted average of the sample points (Tural, 2011). Although there are several IDW methods, the most known is the Shaperd's Method. Taking the number of scattered points on the surface as *n*, the function defining the sample points as *fi*, and the weights as *wi*, the Shaper's equality is formulating as:

$$f(x,y) = \sum_{i=1}^{n} w_i f_i$$

Wi weights are given below:

$$w_i = \frac{h_i^{-p}}{\sum_{j=1}^{n} h_j^{-p}}$$

p is known as the "power parameter" and it usually refers to a positive real number taken as 2. Whereas, *hi* defines the three-dimensional spatial distance in the equation between the sampling points and the point to be interpolated (Arslanoğlu and Özçelik 2005).

$$h_i = \sqrt{(x-x_i)^2 + (y-y_i)^2 + (z-z_i)^2}$$

Overlay

In this study, which aims to accurately determine the bioclimatic comfort values of the areas within the Karabük city center boundaries, the maps created in the GIS environment regarding the temperature, humidity, and wind elements, are classified and overlaid in terms of bioclimatic comfort values. The comfort values taken during the operation are given below.

Temperature 15-27 °C

Relative humidity 30% – 70%

Wind velocity 0 - 5 m/s

Results

<u>*Temperature*</u>

The long-term temperature values of 10 districts calculated according to their average climate values are given in Table 2. In this table, the values of the climate stations in neighboring provinces are also given in order to make the interpolation technique more accurate. However, they are not used in the evaluation. When the temperature values are examined, it is seen that the coldest regions are

Eflani, Karabük-Kartepe, and Ovacık. The temperature maps generated according to these values are given in Figure 2.

Table 2. Long-term average temperatures (°C)

No	Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	Eflani	-1.6	4.9	5.4	9.7	11.5	17.2	18.4	20.3	14.2	9.3	4.1	-4.7
2	Eskipazar	0.4	6.2	6.8	12.1	12.9	19.0	21.0	21.9	16.3	11.3	5.6	-1.8
3	Merkez	4.3	6.7	9.3	14.4	17.9	20.9	25.2	25.7	20.0	14.7	8.7	6.2
4	Kapullu	1.8	7.9	9.0	14.1	15.2	21.9	23.4	24.5	18.8	13.4	6.5	-0.3
5	Karatepe	-3.2	3.4	3.0	9.2	8.9	15.1	16.7	17.6	12.4	7.9	4.5	-5.1
6	Ovacık	-1.1	5.8	5.6	10.9	11.0	17.3	18.6	19.9	14.5	9.9	6.1	-2.9
7	Safranbolu	1.3	7.4	8.3	13.3	14.2	20.7	22.2	23.3	17.8	12.6	6.6	-0.9
8	Ovacuma	2.3	8.6	9.1	13.7	14.9	20.9	22.0	23.4	17.9	12.8	7.7	0.3
9	Yenice	3.0	8.6	9.9	14.1	15.8	21.7	23.1	24.3	18.8	13.7	7.4	0.9
10	Araç	-0.7	4.9	6.5	11.8	13.0	18.6	20.2	20.6	15.1	10.4	3.9	-1.6

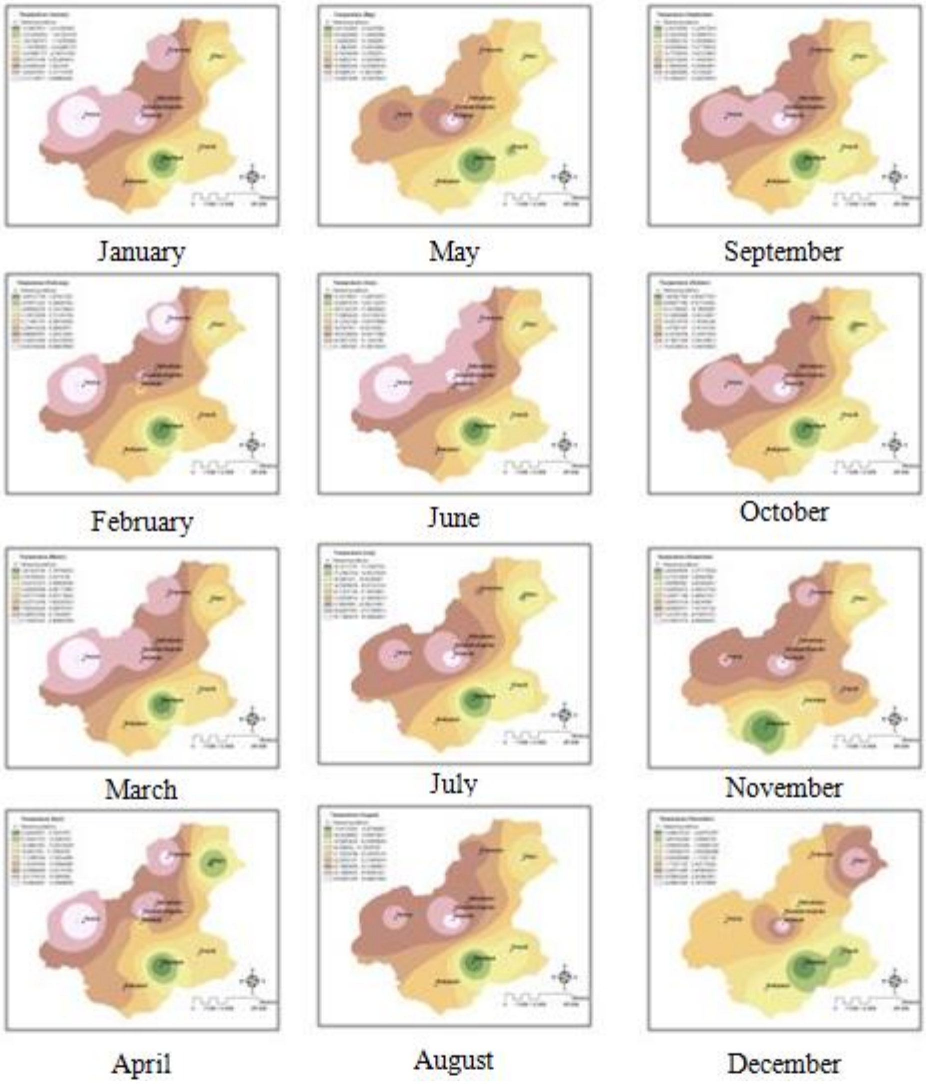

Figure 2. Monthly dispersion of temperature values

Humidity

Average monthly humidity values for Karabük province are given in Table 3. In December, January, and February, humidity levels are found to increase up to 80-90%. The district centers with high humidity values are; Eflani, Safranbolu-Ovacuma, Merkez-Kapullu, and Merkez-Karatepe. The values in the other districts are observed to be lower and closer to each other.

In March, April, and May these values are observed to vary between 60-78%. The provinces where these values are measured high are Merkez-Kapullu, Safranbolu, and Karabük-Merkez.Humidity maps generated according to these values are given in Figure 3.

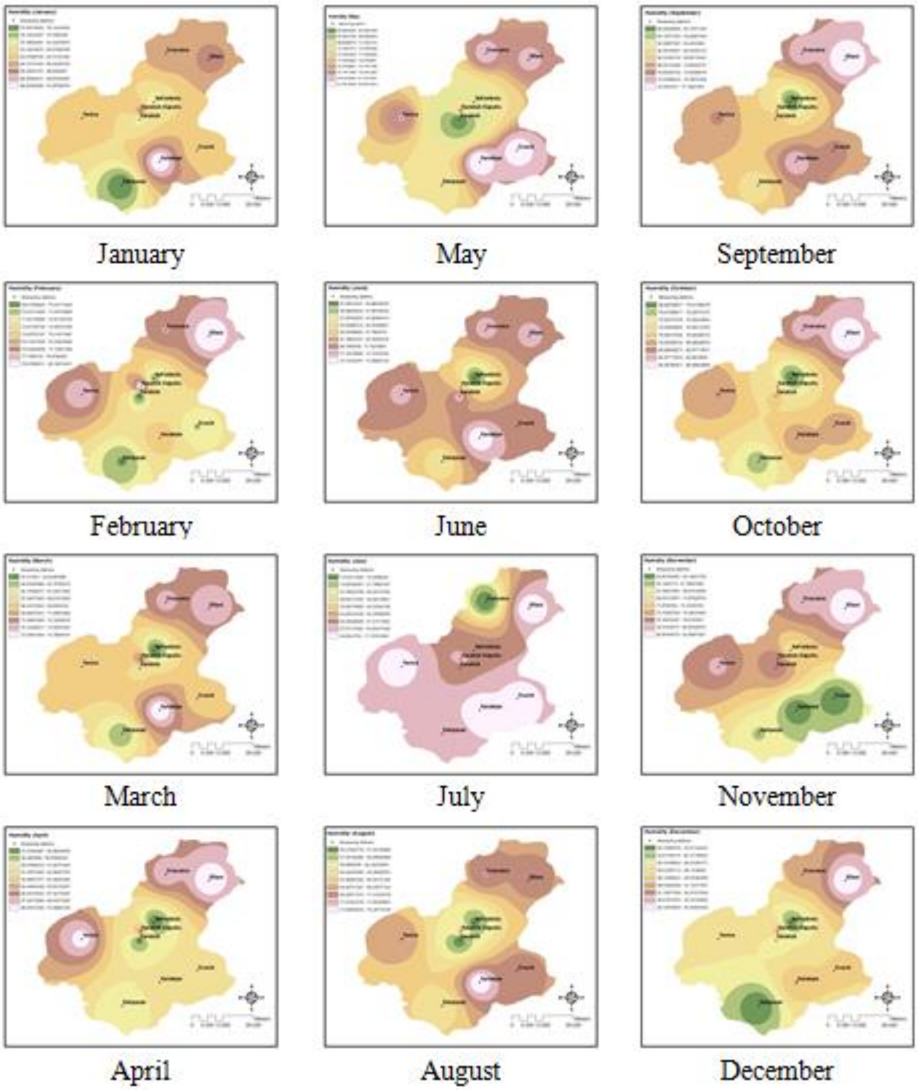

Figure 3. Monthly dispersion of humidity values

Wind: Long-term average wind values are given in Table 4. When the wind values are examined, it is seen that Karabük is not a province with too much wind due to its geographical location. It is determined that the highest values are found in Eskipazar and Ovacık in January and February, whereas the lowest values are found in Karabük-Merkez, Ovacuma, and Yenice, which are located upcountry. The wind maps generated according to these values are given in Figure 4.

Table 3. Average monthly humidity values (%)

N	Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	Eflani	86.9	80.2	73.4	70.4	80.3	72.2	70.6	70.7	77.2	86.1	83.1	95.7
2	Eskipazar	76.5	70.3	65.3	60.1	73.9	64.1	58.3	62.7	65.2	71.1	67.2	82.1
3	Merkez	81.2	68.9	67.6	64.4	66.7	66.2	56.3	56.4	68.2	77	78.3	85.4
4	Kapullu	85.9	80.2	71.5	65.4	78.3	65.6	60.7	63.7	66	74.4	78.1	89.2
5	Karatepe	91.3	75	74.8	61.9	83.7	75.7	71.8	76.3	74.8	79.6	62.9	89.7
6	Ovacık	83.8	71.6	69.4	62.3	82.9	71.5	68.5	71.4	71.1	78.5	63.2	88.3
7	Safranbolu	80.1	71	63.7	57	71.4	57.9	52.2	56.6	58	68	69.7	82.9
8	Ovacuma	86.1	77.6	72.6	68.5	80.7	72.4	70.5	71.7	74.2	83.1	79.7	90.5
9	Yenice	84.3	78.7	69.2	69.6	79.9	72.2	68.5	69.3	71	80.1	79.1	86.8
10	Araç	82.9	78.1	68.9	64.4	77	66.1	60.6	69	71.8	77.4	75.2	81.1

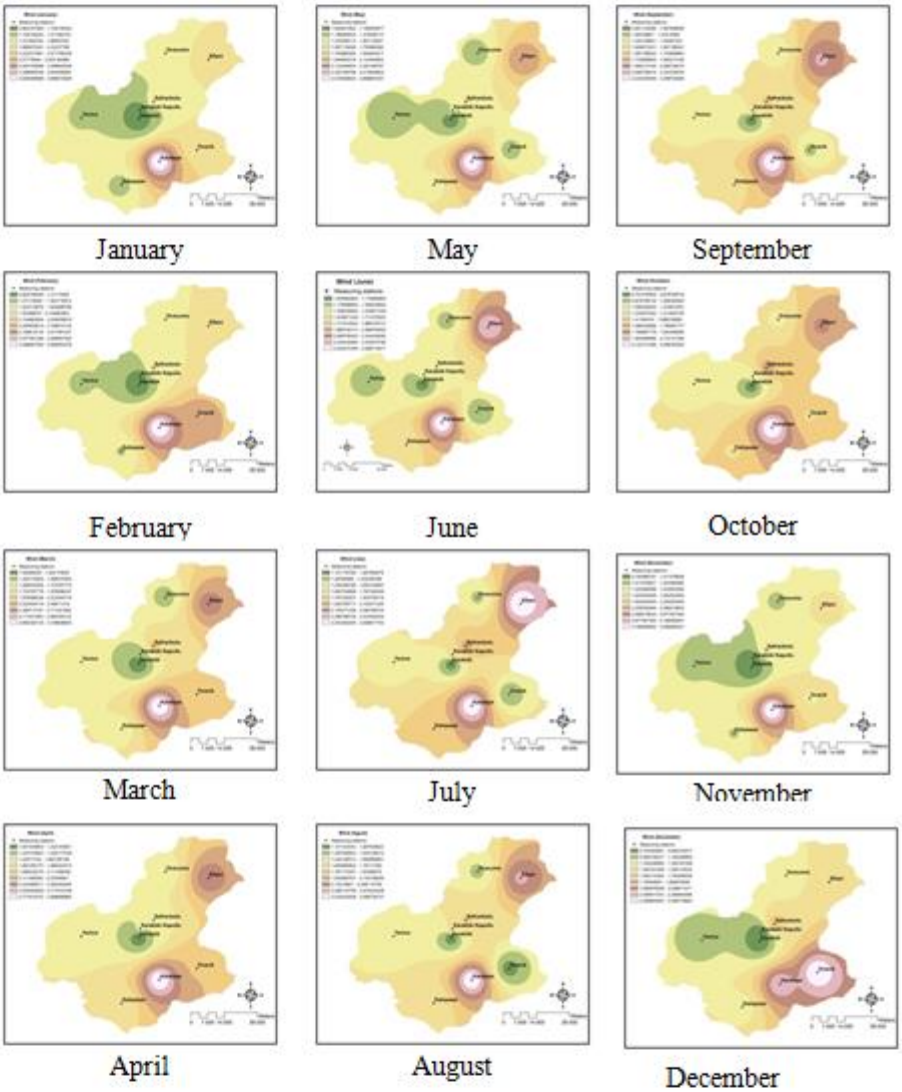

Figure 4. Monthly dispersion of wind values

Table 4. Monthly average wind values (m/sec)

No	Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	Eflani	2.1	2	2.6	2.5	2.1	2.4	2.6	2.3	2.1	1.8	1.7	1.5
2	Eskipazar	3.1	3.9	3	4	2.7	2.4	3.3	2.6	2.5	2.7	2.2	2.6
3	Merkez	0.8	0.9	1	1	1	1	1.1	1.1	0.9	0.7	0.7	0.7
4	Kapullu	1	1.1	1.3	1.5	1.4	1.5	1.7	1.7	1.5	1.2	0.8	0.7
5	Karatepe	4	3.7	3.2	3	2.7	2.6	2.6	2.6	2.4	2.3	3.5	2.3
6	Ovacık	4.7	4.1	3.3	3.2	2.9	2.5	2.5	2.3	2.4	2.1	3.3	2.7
7	Safranbolu	1.7	2.1	2.2	2.3	2.1	2.6	2.9	2.6	2.3	1.8	1.6	1.4
8	Ovacuma	1.4	1.5	1.7	1.5	1.5	1.3	1.4	1.5	1.5	1.4	1.5	1.5
9	Yenice	1.5	1.5	1.5	1.5	1.3	1.3	1.5	1.5	1.3	1.1	1.3	1
10	Araç	1.7	1.7	2	2.6	2.8	2.1	2.5	2.3	2.6	1.4	1.3	1.3

Discussion and Conclusions

Maintaining the bioclimatic comfort must be aimed, as all planning and design studies are realized in order to serve human life. These values, which are classified in the GIS environment, are overlapped. The comfort values used in the process are given below.

Temperature 15-27 °C
Relative humidity 30 – 70%
Wind velocity 0 - 5 m/s

When overlapped areas and values are examined, it is determined that comfort areas in general are May, June, July, August, and September according to climate values (Figure5).

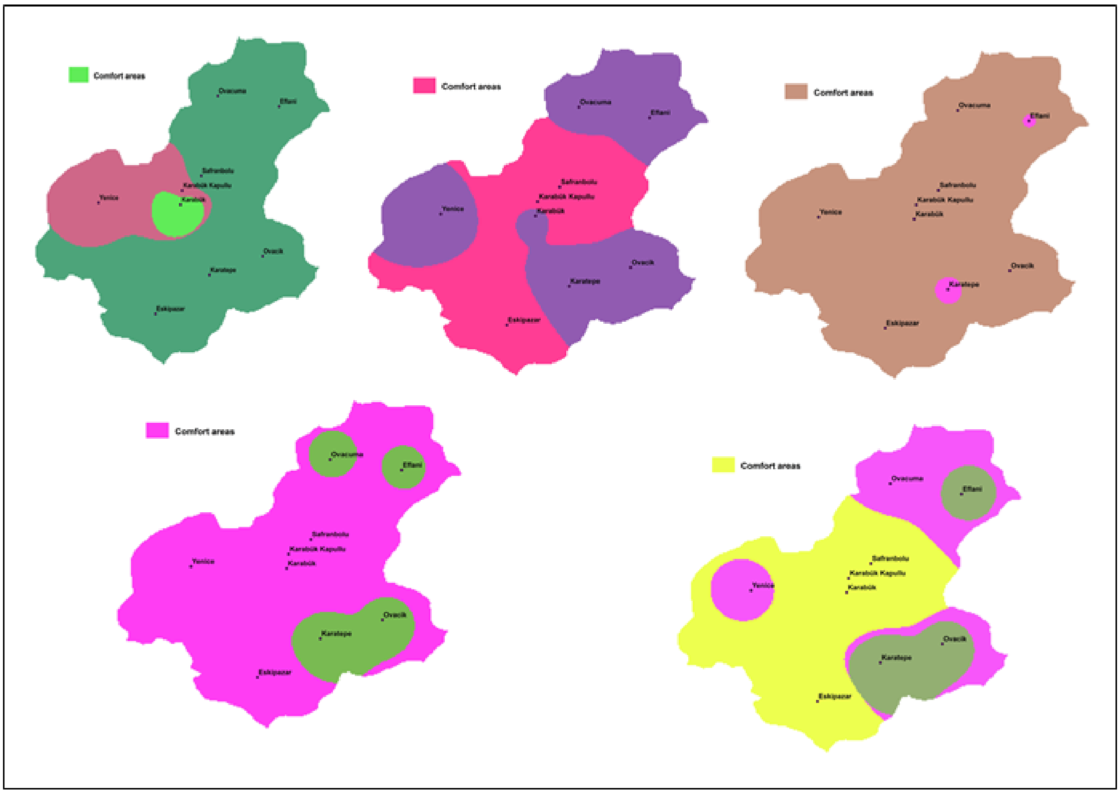

Figure 5. Karabük Province Bioclimatic Comfort Zones

The most important of today's environmental problems is the climate change issue due to the increase of greenhouse gas emissions in the atmosphere. This change in the climate is a growing threat to human life, bringing along many problems. This change, which is expected to have effects in different fields, has also attracted the interest of many professional disciplines (Coşun & Karabulut, 2009).

Bioclimatic comfort is completely or partially overlooked in planning and design of urban areas. Establishment of urban environments, which is very important in terms of bioclimatic comfort, is only possible with urban planning and design to be performed as a result of knowing and evaluating the bioclimatic comfort values of outdoor areas. The open-green areas to be formed as a result of planning and design, can prevent the formation of extreme hot and cold environments due to their microclimate effect on the urban climate (Toy and Yılmaz, 2009).

Since climatic data is related to geographical location and land, Geographical Information Systems is one of the basic information technologies and tools in bioclimatic comfort studies, used for updating, processing, and combining national, regional, and local data and making different analyses, as well as generating data regarding bioclimatic comfort. The aim in planning should be to develop and change the climate in a positive way for the identification of climatic data affecting planning and for the comfort of living creatures. Most of the effects of human activity on nature are due to climatic events and plays a decisive role in the lives of the living things. Since all planning and design activities are realized to serve human life, ensuring the bioclimatic comfort must be the primary purpose (Çetin *et al*., 2010).

In studies on human bioclimatic comfort, generally, the region's monthly dispersion of comfort conditions is sought for. Besides, during the times appropriate in terms of comfort, outdoor activities such as tourism and recreation are advised. Since outdoor planning and design is primarily the interest of the landscape architecture discipline, it is necessary to know the comfortable periods of the area that landscape planning and design will be conducted, in order to know the seasons with highly used.

Another advantage of knowing comfortable periods is that outdoor activities can be performed. Thus, the use of space can be shaped according to these comfortable periods (Toy and Yılmaz, 2009).

Karabük is located at 0-850 m height. In the northern part, it has the typical (rainy) black sea climate type. When the climate data of Karabük province are examined, it is determined that the average temperature is 13.4, the average humidity is 74%, and the average wind velocity is 2.6.

It is possible to say that many natural and cultural factors effect the change in the climatic values of Karabük. The reason for temperature values being higher in the months remaining in the pit areas such as Karabük-Merkez and Safranbolu can be attributed to the formation of urban surfaces that occur due to intensive urbanization and the urban heat islands that occur in parallel with these surfaces. It is estimated that Yenice and Ovacık are less cold in winter due to their altitude and overcast rainfall.

Assessment and use of climate and bioclimatic values are among the most important components for sustainable studies of planners and designers together with other parameters. However, considering the formation of different types of microclimate in a city, detecting these values spatially is important in practical work. The areas, which are important in terms of bioclimatic comfort, are crucial for planners and designers to create outdoor public spaces. In particular, the green areas resulting from the wrong area selection in the development plans do not provide sufficient ecological and social contribution to the cities. For this reason, in the work to be done, climatic values together with other criteria to be considered will provide significant contributions to the plans and projects of planners and designers.

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