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Determination of Indoor Climate Requirements of Greenhouses in Samsun Provinces with –GIS assisted

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ABSTRACT: In this study, the most suitable growing period was explored in order to continue production economically in greenhouses. Based on the climatic data gathered from 9 different district of Samsun provinces the time periods for cooling, heating and natural ventilation were determined and compared with each other. Spatially distributions of mean daily outside temperature in region of Samsun determined using DEM (Digital Elevaluation Model) and spatial distributions of heating requirements of greenhouses determined using IDW(Inverse Distance Weight), with support of GIS (Geographic Information system). Research results showed that the central district of Samsun had more advantages in aspects of greenhouse production compared to other districts and Çarşamba, Bafra, Kolay, Taflan and Vezirköprü followed it. Unlikely Ladik, Havza and Kavak had several disadvantages for production in greenhouses.

Key words: Greenhouses, climatologic requirements, ventilation, heating, cooling, GIS

Samsun İl Ve İlçelerinde Seraların İklimsel İhtiyaçlarının Cografi Bilgi Sistemleri İle Belirlenmesi

ÖZET: Bu çalışmada, Samsun il ve ilçelerinde ekonomik olarak seracılık yapılması için iklim parametreleri göz önüne alınarak en uygun yetiştirme periyotları belirlenmiştir. Çalışmada, 9 ilçenin iklim verileri kullanılmış, ısıtma, doğal havalandırma, soğutma gerektiren aylar belirlenmiş ve Samsun merkez ilçe ile karşılaştırılmıştır. Samsun il ve ilçelerinin seracılık açısından günlük ortalama sıcaklık değerlerin uzaysal dağılımı Sayısal Yükseklik Modeli (DEM) kullanılarak, ısı gereksinimleri ise Ters Mesafe Ağırlıklı Enterpolasyon Tekniği (IDW) ile belirlenmiştir. Seracılık açısından en avantajlı ilçe merkez ilçe olup bunu, Çarşamba, Bafra, Kolay, Taflan ve Vezirköprü izlerken seracılık açısından diğerlerine göre dezavantajlı Ladik, Havza ve Kavak ilçeleri bulunmuştur
Anahtar Kelimeler: Seralar, iklimlendirme istekleri, havalandırma, ısıtma, soğutma, CBS

INTRODUCTION

GEOGRAPHICAL INFORMATION SYSTEMS (GIS) facilitate the storage, manipulation, analysis, and visualization of spatial data. GIS technology integrates common database operations such as query and statistical analysis with the unique visualization and geographic analysis benefits (Hartkamp, 1999; Burrough, 1990; Yomralıoğlu, 2000; Aranoff 1989). This technology is an expansion of Cartographic Science, which takes advantage of computer science technologies, enhancing the efficiency and analytic power of traditional methodologies (Ballestra et al., 1996).

GIS recently is becoming an essential tool in the effort to understand complex processes at different scales; local, regional and global. In GIS, the information coming from different disciplines and sources, such as traditional or digital maps, database and remote sensing can be combined in models (such as agronomic models) that simulate the behavior of complex systems (Mueksch, 1996).

Greenhouses are highly sophisticated structures, which aim at providing ideal conditions for satisfactory plant growth and production throughout the year. Over the ages, growers have developed ways of altering the environmental conditions for their crops with a view to hastening earliness and improving the quality of production (von Elsner *et al.,* 2000).

In addition to the Mediterranean coasts of Turkey, greenhouses are widely extended in Aegean, Marmara and Black Sea Regions. As far as the production of early vegetables and ornamental plants exported are concerned the regions where the cost of energy is relatively low, are more becoming more advantages. Suitable climate, the availability of irrigation and the structure of soil are some of the critical factors which determine the suitability for greenhouse production in a specific region in terms of the production of early fruits. The parameters of temperature, rainfall and radiation especially in the peak greenhouse production season between December and March show that the Mediterranean coast is one of the most suitable production areas in Turkey. However, the greenhouse production in the Black Sea Region is more advantages compared to Mediterranean region, because there is no cooling requirement for the greenhouses in the Black Sea both in the spring and summer. This provides comparative economic advantages to Black Sea Region in terms of late production in spring and early production in autumn.

The general crop needs and the local climatic conditions impose specific requirements on the greenhouse structure. However, national traditions have a strong and sometimes misleading influence on the greenhouse design. A simple and efficient method for checking the suitability of a region for protected cultivation is the comparison of its climatic data to those of other regions where greenhouse production of the same crop has been successful. Most of the plants grown in greenhouses are warm season species. Their climatic requirements for plant growth can be defined and summarized as follows (Sirjacobs, 1989; Baudoin *et al*., 1990; Verlodt, 1990; Krug, 1991; Baytorun, 1996; von Elsner *et al.,* 2000).

(1) Plants can be killed by frost. It is generally accepted that the risks of sub zero air temperatures occurring for a period long enough to destroy the crop can be neglected when the monthly average minimum temperature exceeds 7°C.

(2) Plants grown under protected cultivation are mainly adapted to average temperatures ranging from 17 to 27°C. Taking into account the warming-up effect of solar radiation in greenhouses, one can define the climatic limits of suitability between 12 and 22°C mean daily outside temperature if the greenhouses are not heated.

(3) If the mean daily outside temperature is below 12°C, greenhouses have to be heated, particularly at night. When mean daily temperatures above 22°C are common (summer in Mediterranean countries), artificial cooling may be necessary or cultivation in greenhouses has to be stopped (depending also on the relative humidity outside). With mean temperatures between 12 and 22°C natural ventilation is sufficient.

(4) The absolute maximum temperature for plants should not be higher than 35-40°C.

(5) A minimum of 500-550 h of sunshine for the three winter months (November, December and January) is desirable. This corresponds to a daily insolation of about 2300Wh/m2d. The limit for effective production is 1000Wh/m2 d (Krug, 1991). Artificial lighting may be used for intensive production.

(6) The minimum threshold for soil temperature is 15°C.

(7) Verlodt (1990) suggests a threshold of the average night temperature as 15-18.5°C for heat-requiring plants such as tomato, pepper, cucumber, melon and beans.

(8) Relative humidity of 70-90% is regarded as being within a safe range. Different climatic conditions impose different design requirements on the greenhouse structure as is demonstrated by the following example. This study evaluated the need of weather conditions in aspect of greenhouse activities by means of GIS. Suitable time period and zone for cooling, heating and ventilation was also explored.

MATERIALS AND METHODS

Study area

Samsun is situated between two river deltas jutting out into the Black Sea, and between the geographic coordinates of 34° 52’ -37° 10’ east longitudes and 40^0 52’-41° 45’ north latitudes in Turkey. Samsun has an area of 957888 hectares. Except the Çarşamba and Bafra Plains (approximately 160 000 ha), most areas in this region have precipitous, sloping and complicated topography. Elevation of the area varies from sea level to 2000 m. The means of annual total precipitation, temperature and relative humidity are 648.7 kg, 15.5 ^{0}C and 74.4 %, respectively (Anonymous, 2004). The location of the study area, and the locations of weather stations in a topographical map are presented in Figure 1. Further information on weather stations is indicated in Table 1.

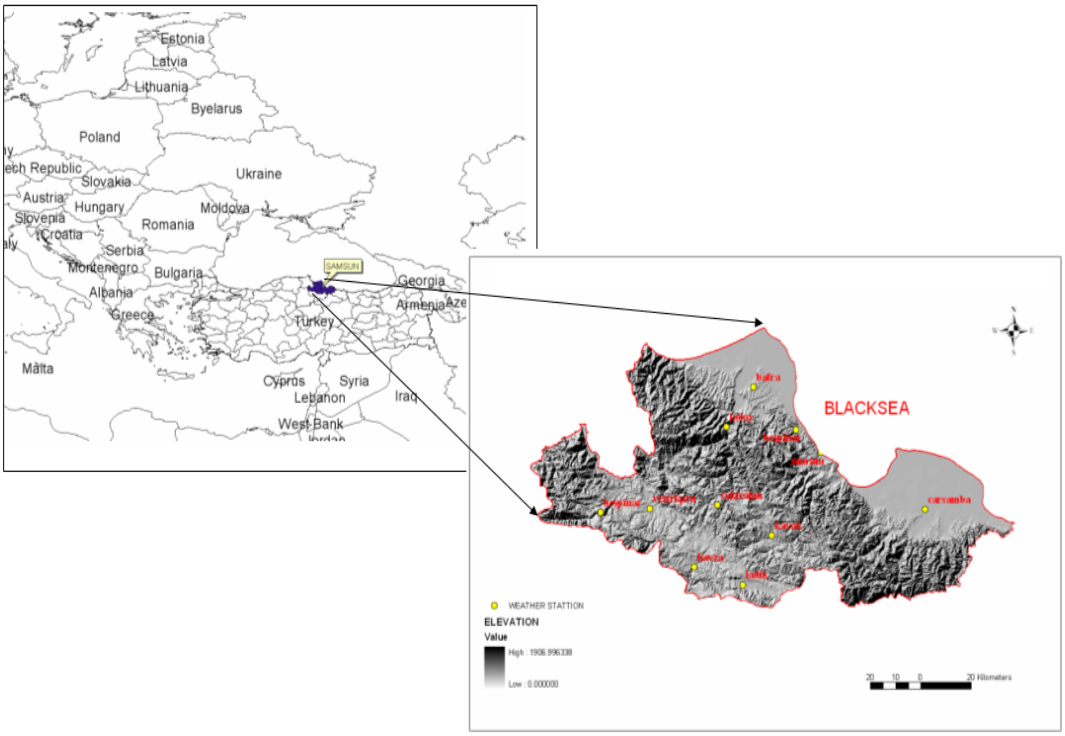


Figure 1. The location of the study area and the locations of weather stations.

Table 1. The sources and amounts of meteorological data used to examine the techniques for estimating temperature, relative humidity and precipitation.

Location	Latitude (N)	Longitude(W)	Elevation (m)	Data record[a]
Samsun	41^0 21’	36^0 15’	4	75
Havza	40^0 58’	35^0 40’	750	33
Kolay	41^0 25’	35^0 48’	70	31
Ladik	40^0 55’	35^0 54’	950	35
Taflan	41^0 25’	36^0 08’	150	27
Vezirköprü	41^0 09’	35^0 27’	260	39
Bafra	41^0 35’	35^0 56’	20	50
Çarşamba	41^0 11’	36^0 45’	35	23
Kavak	41^0 05’	36^0 02’	600	42

[a] Data record from 1 January of first year to 31 December of last year.

Meteorological data used in this study was obtained from 9 different weather stations located within the study area. The elevations of the meteorological stations varied from 4 to 950 meters. The location of study area and these weather stations are given in Fig.1. It is clear from upper evidence that available station data does not span the complete range of elevations in the study area, especially in mountainous regions. Therefore, vertical extrapolation is required.

Our research adapts the assumption that, for a localized region, elevation is the most important factor in the distribution of weather data. Observations from many parts of the world showed that the altitudinal variation of weather data is to be approximately a linear form (USDA, 1998).

In this study grid cell (termed the target grid cell) at each DEM are accomplished through a simple linear climate-elevation regression. This regression function serves as the main predictive equation in this study. A linear regression was chosen rather than that of nonlinear (e.g. polynomial regression) and curve-fitting functions. A simple, rather than multiple, regression model was preferred because it is difficult to control and interpret the complex relationships between multiple independent variables and dependent one. The meteorological data was used as dependent variables, whereas elevation was considered as independent variable in both methods. The regression analysis was performed with SAS (SAS inc, 1999) following the procedure of Gomez and Gomez, (1984). Climate-elevation regression is estimated from x, y pairs of elevation and climate observations. Curve fitting processes were continued until the least sum of squares of the residuals was obtained.

The digital elevation model of the area which was used in the study was built up using the elevation data on the topographic maps at the scale of 1:25000 with using well-known GIS software package ArcGIS 8.3.

RESULTS AND DISCUSSION

The parameters and determination coefficients for the models estimated for the mean, temperature layers and the maps of these data layers were presented in Table 2 and Figure 1.

Table 2. The coefficients, their standard errors and r^2 values of the new produced equation predicting the monthly mean temperature based on models and regression analysis result of monthly mean temperature $T = \beta_1 h + \beta_0$

Month	β_0 (s.e)	β_1 (s.e)	r^2
1	5.68 (0.57)***	-0,00559 (0.001002)***	0,80***
2	6.27 (0.58)***	-0,00682 (0.001014)***	0,85***
3	8.21 (0.34)***	-0,00477 (0.000594)***	0,89***
4	11.84 (0.31)***	-0,00242 (0.000548)***	0,71***
5	15.91 (0.36)***	-0,00399 (0.00063)***	0,83***
6	20.59 (0.31)***	-0,00542 (0.000538)***	0,93***
7	23.45 (0.36)***	-0,00666 (0.000626)***	0,94***
8	23.17 (0.26)***	-0,00504 (0.000457)***	0,94***
9	19.64 (0.16)***	-0,00543 (0.000289)***	0,98***
10	15.62 (0.43)***	-0,00578 (0.000754)***	0,88***
11	11.18 (0.52)***	-0,00661 (0.000902)***	0,87***
12	8.03 (0.58)***	-0,00744 (0.001006)***	0,87***
Mean	14.12 (0.20)***	-0,00551 (0.000351)***	0,97***

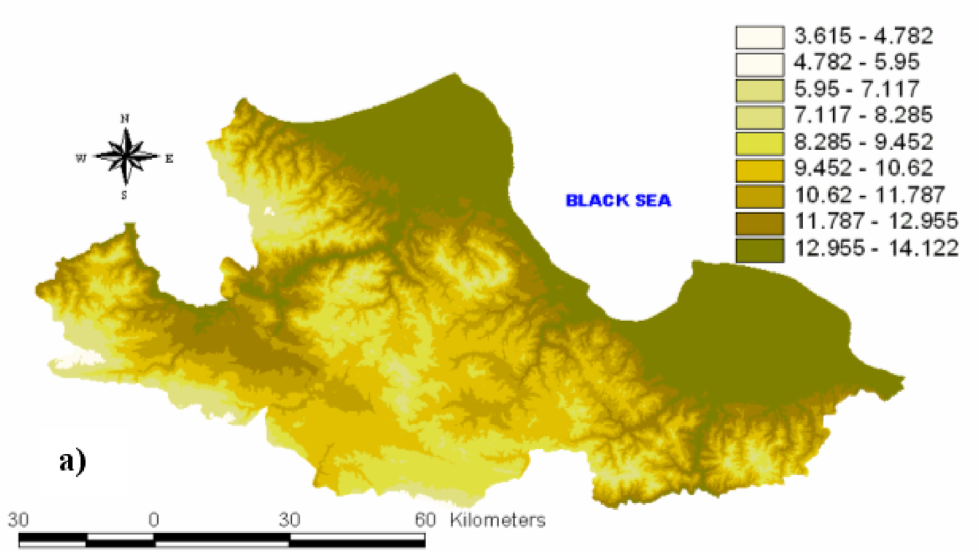


Figure 2. Monthly mean temperature of temperature layers developed for Samsun province

The results of the regression analysis showed that there is a linear relationship between monthly mean temperature values and elevation values. This confirmed the results of the previous studies (Yazdanpanah, 2001; Silva and Blanco, 2003; Greene *et al.,* 1999; USDA. 1998; Daly, 1999; Philips *et al.,* 1992; Chuanyan *et al.,* 2004).

The models estimated for the monthly mean temperature values were statistically significant ($p<0.001$). All slope coefficients and constant term in these models were found statistically significant ($p<0.001$).

Maps of the yearly temperature values were depicted in Figure 2. It was observed from the maps that temperature was getting lower through the south and the highest temperature values have occurred in the coastal areas, depending on the topographic characters of the region. In addition, temperature values in valleys located in this region were high.

Some adverse effects of lower temperature arise in case of the level of daily minimum outside temperature is below 7 °C. The risky area for greenhouse activities in January, February, March, April, November and December was determined by means of distribution of temperature, which is below 7 °C. In addition the most risky month was January and February (Figure 3).

The coastal part of Samsun had the several advantages compared to other parts. Generally the optimum temperature for growing plant in greenhouses is between 17-27 °C. This temperature range varies from 12 °C to 20 °C for growing plant in greenhouses economically. Since the temperature fall below the 12 °C in Havza, Kavak and Ladik in May, growing plant in greenhouses was not suggested.

Economic greenhouses zone for Samsun was depicted in Figure 3. In this region natural ventilation was not a serious problem during the period a between May and October. However, especially in July and August, temperature reached the 24 °C. In coastal part of Samsun and cooling system was necessary to combat higher temperature.

In Çarşamba, Kolay, Bafra, Taflan and central district of Samsun, average daily temperature is below 12 °C from November to first week of April. Whereas this cases is valid for Havza, Ladik, Kavak and Ladik from October to April (Figure 3). During this period heating is necessary in greenhouses in order to increase yield and quality of crops. To stabilize the inside temperature at the level of 17 °C, the distribution of heating requirements from November to April is needed in January and February. In January maximum monthly heating requirement is 130-140 W for areas of 605722 hectares around the Ladik and Havza While that of February is the some but for the areas of 56692 hectares. Heating requirement is also higher in the coastal part of Samsun compared to mountain part (Figure 4).

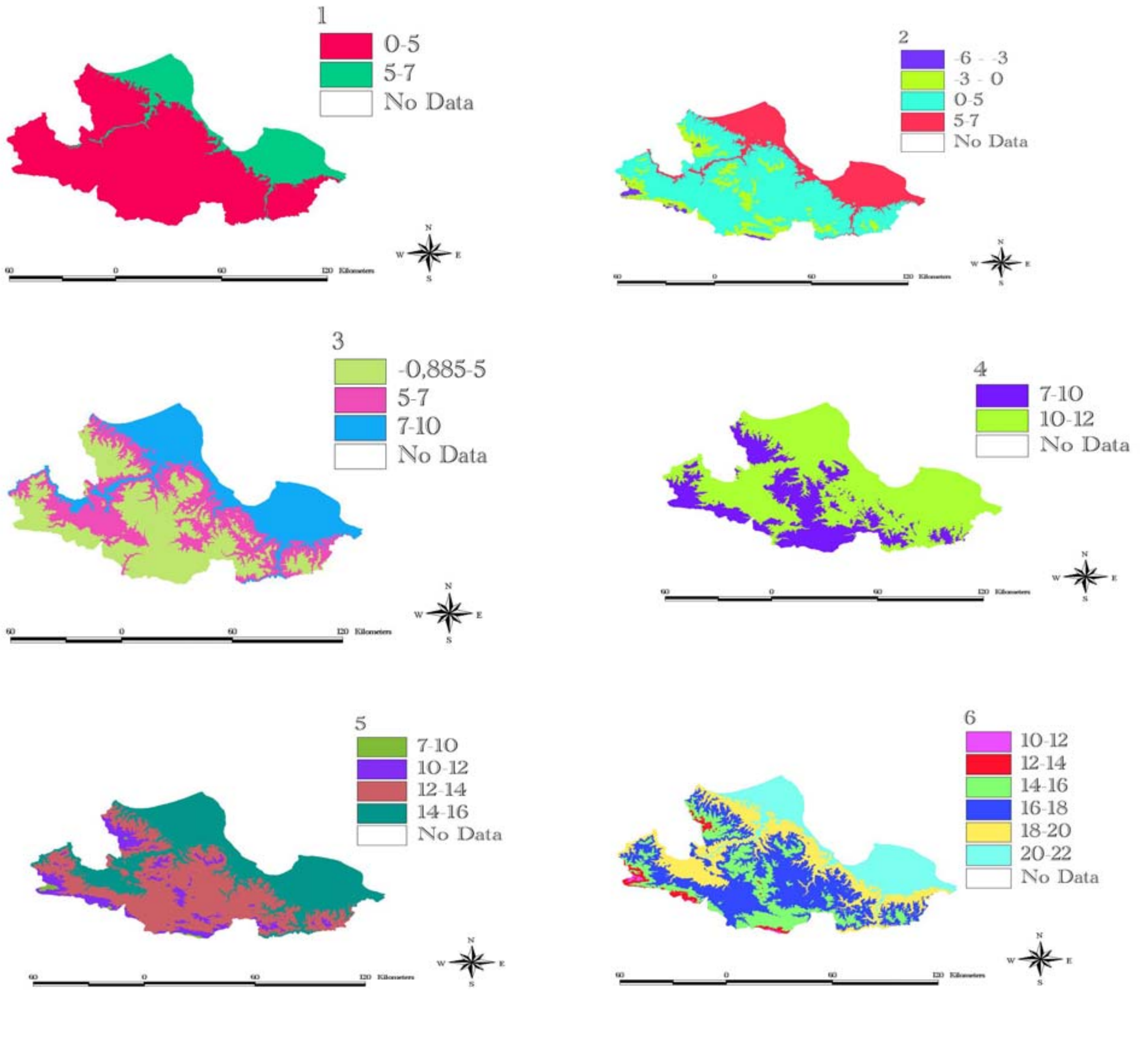
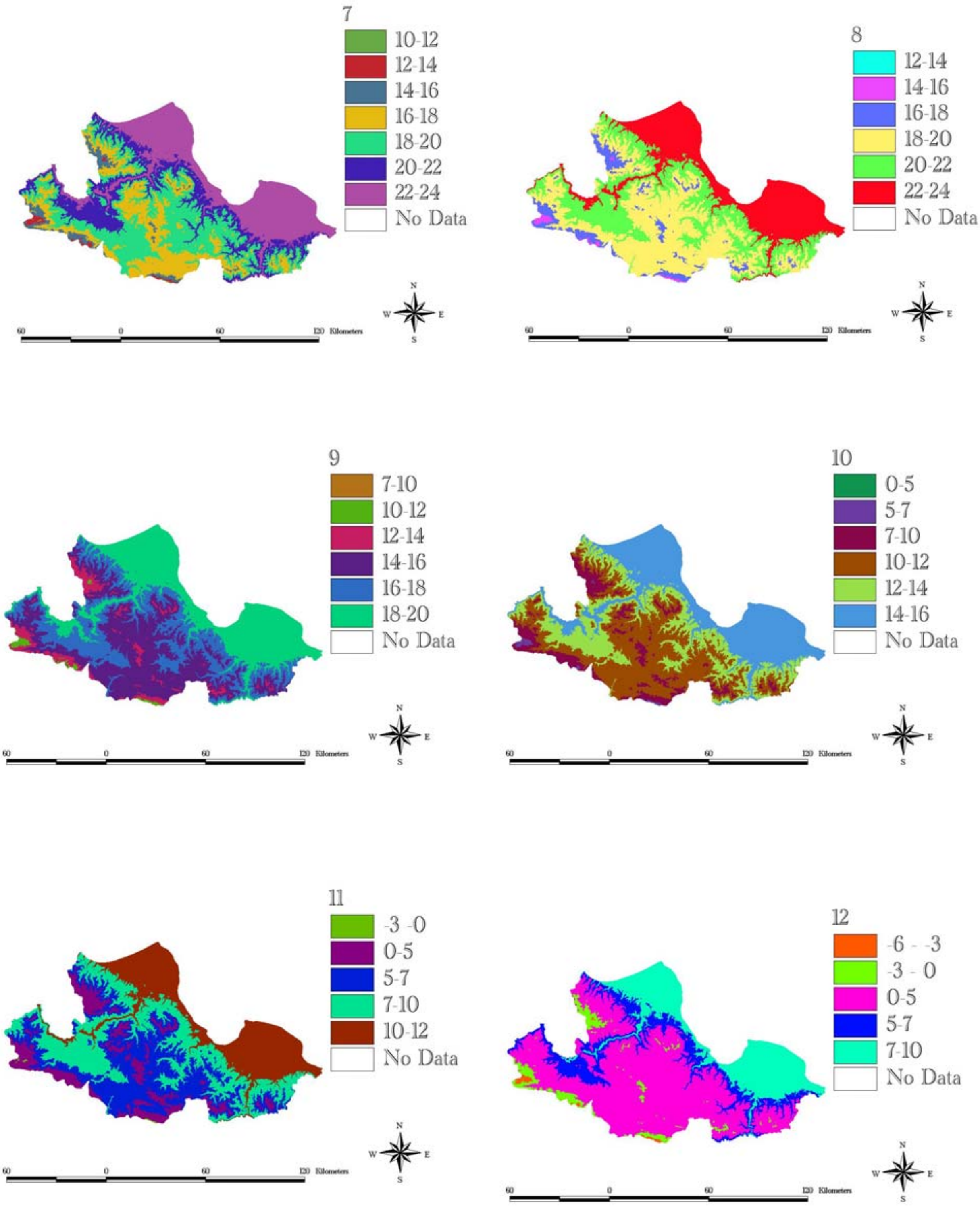


Figure 3. Spatial variability of climatic suitability for greenhouses in Samsun province form the average monthly air temperature



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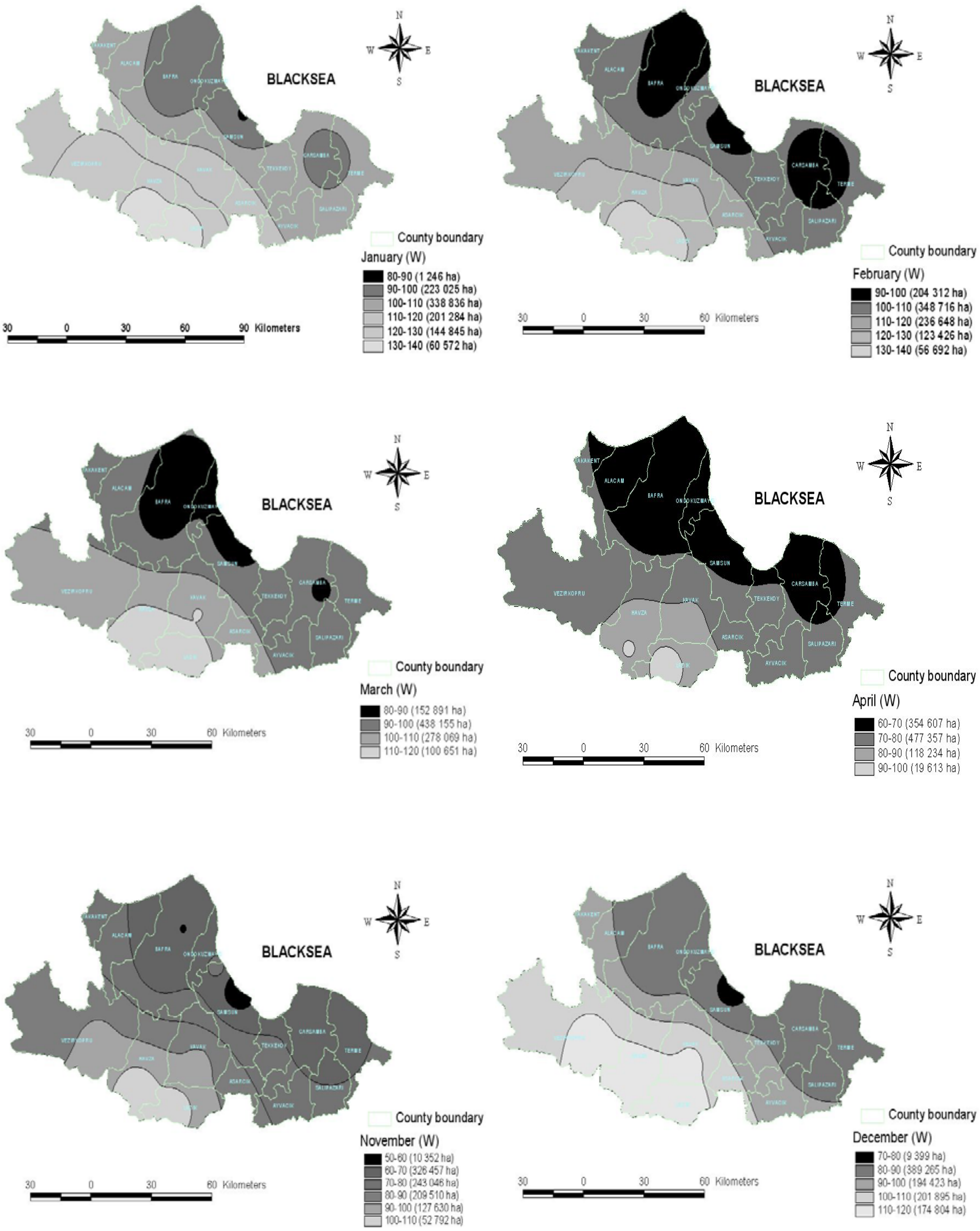

Figure 4. Spatial variability of heat requirements for greenhouses in Samsun province

CONCLUSION

This study evaluated the need of weather conditions in aspect of greenhouse activities by means of GIS. Suitable time period and zone for cooling, heating and ventilation was also explored. The threshold value for heating assumed 12°C and the distribution of the areas that need to heat between November and April was determined. In greenhouses, there is in need of artificial light together with heating from November to January in order to continue the production activities in optimum conditions in the research area. It was clear based on the research results that natural ventilation is more suitable for the greenhouses in the research area, and suitable areas was fixed. Even if same part of Samsun the temperature reaches the 24 °C, establishing mechanical cooling system is not necessary. Determination suitable ventilation gap, shading and artificial cooling systems may help to combat this problem. Conducting production activities in greenhouses without mechanical cooling system is big opportunities for the farmers in the research area. The most suitable economic production period is from April to December. Farmers Who conduct their activities in greenhouses have the big advantages late autumn growing.

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