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ARAŞTIRMA MAKALESİ / RESEARCH ARTICLE

DETERMINATION OF SUITABLE BEEKEEPING PLACES BY WEIGHTED OVERLAY ANALYSIS: A CASE STUDY OF BOLU, TÜRKİYE

Weighted Overlay Analizi İle Uygun Arıcılık Yerlerinin Belirlenmesi: Bolu, Türkiye Örneği

Şule YAMAN[1*], Mustafa YAMAN[2]

[1*]Department of Geomatics Engineering, Faculty of Engineering, Karadeniz Technical University, 61080, Trabzon, TÜRKİYE, Yazışma Yazarı / Corresponding author E-posta: suleyaman98@hotmail.com, ORCID No: 0000-0002-7426-9358

[2]Department of Biology, Faculty of Arts and Science, Bolu Abant İzzet Baysal University, 14030, Bolu, TÜRKİYE, E-posta: muyaman@hotmail.com, ORCID No:0000-0001-5656-7266

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ABSTRACT

Beekeeping is one of the main livelihoods of our country, and our country's rich geography, different climate and topography are quite suitable for beekeeping. The increase in interest in beekeeping activities has led to more income with less maintenance and expense compared to other agricultural activities. The increasing interest has also revealed the necessity of determining suitable places for beekeeping to increase beekeeping activities' efficiency. For this purpose, weighted overlay analysis, which is one of the Geographical Information Systems (GIS) techniques, was carried out using ArcGIS 10.7.1 in this study for the province of Bolu. Slope, aspect, elevation, precipitation, vegetation and distance to roads, streams and settlements were used for analysis. As a result of the analyzes made, it was determined that 90.95% of Bolu province is suitable for beekeeping activities. In addition, it has been determined whether the existing beekeeping locations are suitable for beekeeping.

Keywords: GIS, Beekeeping, Weighted overlay Analysis, Suitable beekeeping sites

ÖZ

Arıcılık ülkemizin temel geçim kaynaklarından biri olup, ülkemizin zengin coğrafyası, farklı iklimi ve topoğrafyası arıcılık için oldukça uygundur. artması, Diğer tarımsal faaliyetlere göre daha az bakım ve masrafla daha fazla gelir elde edilen arıcılık faaliyetlerine olan ilgi artmıştır. Artan ilgi, arıcılık faaliyetlerinde verimliliğin artırılması için arıcılık için uygun yerlerin belirlenmesi gerekliliğini de ortaya çıkarmıştır. Bu amaçla Bolu ili için bu çalışmada ArcGIS 10.7.1 kullanılarak Coğrafi Bilgi Sistemleri (CBS) tekniklerinden biri olan weighted overlay analizi yapılmıştır. Analiz için eğim, bakı, yükseklik, yağış, bitki örtüsü ve yollara, akarsulara ve yerleşim yerlerine olan mesafe kullanılmıştır. Yapılan analizler sonucunda Bolu ilinin %90.95 oranında arıcılık faaliyetleri için uygun olduğu tespit edilmiştir. Ayrıca mevcut arıcılık konumlarının da uygun arıcılık yerlerinde olup olmadığı tespit edilmiştir.

Anahtar Kelimeler: CBS, Arıcılık, Ağırlıklı kaplama analizi, Uygun arıcılık yerleri

GENİŞLETİLMİŞ ÖZET

Amaç: Son zamanlarda mısır, buğday, fındık vb. gibi tarımsal faaliyetlere göre daha az bakım ve masrafla daha fazla gelir elde edilen arıcılık faaliyetlerine olan ilgi artmıştır. Artan ilgiyle beraber bilinçsiz arıcılıkta artmış ve elde edilen verim düşmüştür. Bu durum, arıcılık faaliyetlerinde verimliliğin artırılması için arıcılık için uygun yerlerin belirlenmesi gerekliliğini de ortaya çıkarmıştır. Bu nedenle, ülkemizin her köşesinde arıcılık için uygun lokasyonlar olsa da sahip olduğu zengin florası, iklimi, coğrafyasıyla Bolu ili için uygun arıcılık yerlerinin belirlenmesi ve mevcut arıcılık noktalarının uygun yerlerde olup olmadığının tespitinin yapılması amaçlanmıştır.

Gereç ve yöntem: Bolu ili uygun arıcılık yerlerinin belirlenmesinde, hızlı ve ekonomik bir yol olan CBS yöntemlerinden weighted overlay analizi kullanılmıştır. Weighted overlay analizi birden fazla tematik haritanın birbirine göre değerlendirilmesi ve çakıştırılmasıyla sonuç haritasının üretilmesini sağlayan bir çoklu kriter analizidir. Analiz için gerekli verilerden, il ve ilçe sınırı verisi, yerleşim, yol ve su kaynakları verileri, sayısal yükseklik modeli verisi, yağış verisi, flora verisi kriter olarak kullanılmıştır. Kriterlerin belirlenmesinde literatür ve uzman görüşleriyle beraber arıcılık yönetmeliğinden faydalanılmıştır. Her bir kriter için uygunluk haritası oluşturulmuş, kriterlerin ağırlık değerleri literatür yardımıyla belirlenmiş ve ArcGIS 10.7.1 programında weighted overlay analizi yapılarak Bolu ili için uygun arıcılık yerleri tespit edilmiştir. Üretilen sonuç harita üzerinde mevcut arıcılık lokasyonları işaretlenerek uygun yerlerde olup olmadığı analiz edilmiştir.

Bulgular ve Tartışma: Her bir kritere ait uygunluk haritası incelendiğinde yeşil renkli alanların arıcılık faaliyetleri için uygun lokasyonlar olduğu, kırmızı renkli alanların ise uygun lokasyonlar olmadığı görülmüştür. Bununla beraber bölgenin çok fazla bir eğime sahip olmadığı, ilin büyük çoğunluğunun güneye baktığı ve oldukça yağış aldığı tespit edilmiştir. Bunların yanı sıra yüksek bölgelerinin fazla olduğu, akarsulardan uzak olduğu ve yerleşim yerlerinin dağınık ve yakın olduğu görülmüştür. Tüm bu kriterler weighted overlay analiziyle çakıştırıldığında elde edilen sonuç haritada da yine yeşil alanlar uygun lokasyonları temsil ederken kırmızı alanlar uygun olmayan lokasyonları temsil etmektedir. Uygun arıcılık yerleri haritası incelendiği zaman yüksek uygunluk ve çok yüksek uygunluk sınıfları baz alındığında çalışma bölgesinin %90.95 oranında arıcılık faaliyetleri için uygun olduğu görülmüştür. Arazi çalışmalarıyla elde edilen 34 mevcut arıcının konumu uygunluk haritası üzerinde işaretlenmiş ise 3 tanesinin yüksek uygunluk, 9 tanesinin orta uygunluk, 2 tanesinin düşük uygunluk yerinde olduğu ve 20 tanesinin florasız konumlarda arıcılık yaptığı tespit edilmiştir. Gerçekleştirilen bu çalışma Bolu iline özgü olup, her ilin ekolojisi, florası, topoğrafyası ve iklimi birbiri ile aynı olmadığı için her uygunluk haritası kendi içerisinde oluşturulmalıdır. Bu nedenle yapılan çalışmaları birbiri ile kıyaslamak doğru bir yaklaşım olmayacaktır. Bolu ili gibi yaklaşık %90'ı arıcılık faaliyetlerini gerçekleştirmek için uygun olan bir şehirde mevcut arıcıların sadece %8'inin yüksek uygunluk yerinde arıcılık yapması çok düşük bir oran olup bu oran artırılmalıdır. Bunun içinde arıcılar gerekli kurumlarca, gerekli çalışmalarla bilgilendirilmelidir.

INTRODUCTION

Beekeeping, one of the important branches of modern agriculture, produces royal jelly, honey, pollen, beeswax, etc. It makes significant contributions to the country's economy with its products. In addition, these products contribute financially and to many fields such as health, cosmetics, paint, agriculture and food. At the same time, the place and importance of bees are great among the factors that play a role in pollination that ensures the continuity of nature. Bees need flower, plant and tree nectars to feed, and it is known that they travel around 100 flowers on average at their maximum speed during one flight to find these nectars. While this number is possible for a bee, the importance of bees in pollination can be seen when one considers the bees in a hive with even thousands of bees. Considering our country's favorable soils, suitable climate types and rich land cover, it is possible to practice beekeeping in almost every part of our geography. However, when the "2021 Product Report-Beekeeping" published by the General Directorate of Agriculture and Forestry is examined, it is seen that there is a decrease in annual honey production in Turkey despite the increase in the number of hives each. This is an indication that beekeeping activities are not sufficiently utilized.For this reason, determining suitable places to activate beekeeping activities, increasing honey production in parallel with the increasing number of hives, increasing the product yield obtained by these activities, and ensuring the

sustainability of the natural balance will offer practical solutions to these requirements. Knowing the environment and bees before determining suitable places for beekeeping is very important. In the experiments, it was seen that bees are very active at temperatures between 29-33˚C; their activities stop at temperatures below 10˚C, and above 36˚C, they begin to lose their ability to fly around 10˚C, and they become entirely inactive at 7˚C (Öder, 1989; Yalçın et al., 2019).

The diversity and continuity of the flora and the primary food source for bees are also important for beekeeping. For this reason, flora is one of the critical criteria in choosing a suitable place for beekeeping activities. When looking for a suitable place to position the beehives, places that do not receive much wind, are closed to the wind if possible and are not exposed to direct sunlight, rain, etc., and places, where there is no precipitation should be preferred (Yalçın et al., 2019), in other words, the land's surface, slope, aspect, height, etc., where beekeeping will be done. It is also effective in beekeeping because it is suitable for topographic conditions. When determining suitable places for beekeeping, the proximity of the beehives to the stream, the distance of the beekeeping region to the settlement and roads, factories etc., nearby, meaning the presence of industrial areas is another important criterion. Considering these criteria, the use of Geographic Information Systems (GIS), which has spatial analysis capability, provides a visual presentation of verbal/textual data and has an important and effective decision-making mechanism to determine suitable and unsuitable places for beekeeping activities, and it is the right tool. GIS is an information system that enables data collection, storage, analysis and presentation. The origin of GIS, which consists of many data types such as vector and raster data, is based on the science of geography. It is possible to see GIS in every area of our lives. GIS organizes layers of information obtained from data by performing spatial location analysis and creating maps, 3D scenes, etc., and allows visualization with presentations. Thanks to this capability, GIS helps users to make more accurate and effective decisions. The literature review found studies on using GIS in beekeeping activities in Turkey and worldwide.

Arslan et al. (2015) included the distribution of bee colonies, the relationship between land use and seasonal distribution of the colonies, and GIS techniques to determine the routes and accommodation places of the wandering beekeepers throughout the year while following the beekeeping activities and development in the Siverek district of Şanlıurfa. Ceylan and Sarı (2017) used GIS-based multi-criteria decision-making analysis to determine suitable beekeeping sites for Konya province. In another study to determine a suitable location for beekeeping activities in the Karaburun, Çeşme and Urla districts of İzmir province, Yalçın et al. (2019) used GIS's Weighted Overlay analysis. Sönmez and Gencal (2019) benefited from GIS in determining the potential honey forests that can be established within the Bursa General Directorate of Forestry borders. In their studies, after determining the criteria for potential honey forest areas, they created slope, elevation, wind, wetlands and settlement maps from the digitized map of the study area. They determined the potential honey forest areas that can be established by analyzing with Arc/Info program, a GIS interface.

Zoccali et al. (2017) used a GIS-based Analytical Hierarchy Method and Multi-Criteria Decision Making approaches while analyzing suitable sites for beekeeping in the Calabria region of Southern Italy. The data used in the study are temperature, water resources, road, land use and altitude data. GIS-based programs were also used to acquire, use and analyze these data. Abou-Shaara et al. (2013) utilized the Analytical Hierarchy Method, using criteria such as relative humidity, water resources, land cover, and temperature, to determine suitable places for bees in Saudi Arabia, where every region is not suitable for beekeeping. In this study, suitable places for beekeeping were determined by using Weighted Overlay Analysis, which is one of the GIS analyses, by using precipitation, flora, water resources, road, settlement, slope, aspect and elevation criteria for Bolu province and its districts and it was determined whether the existing beekeeping places are in suitable beekeeping areas. In addition, it is aimed that this study will lead future studies in this field.

MATERIALS AND METHODS

Study area

In order to determine suitable beekeeping areas, Bolu province, which is located between 30º 32' and 32º 36' east longitudes and 40º 06' and 41º 01' north latitudes and has a surface area of 8.323 km², was

chosen as the study area (Figure 1). Approximately 18% of the province's land comprises agricultural areas, 15% meadows and pastures, 64% forest areas and 8% non-agricultural areas (Url-1).

Material selection

In the study, analyses were performed using ArcGIS 10.7.1 Desktop software, and a suitability map was created. First of all, the necessary data were provided for the analysis. Information on the data obtained and the sources from which it was obtained are given in Table 1. Weighted Overlay analysis was conducted to create a "suitability map" and flora, distance to water resources, road and settlement, slope, aspect, elevation and precipitation criteria were used.

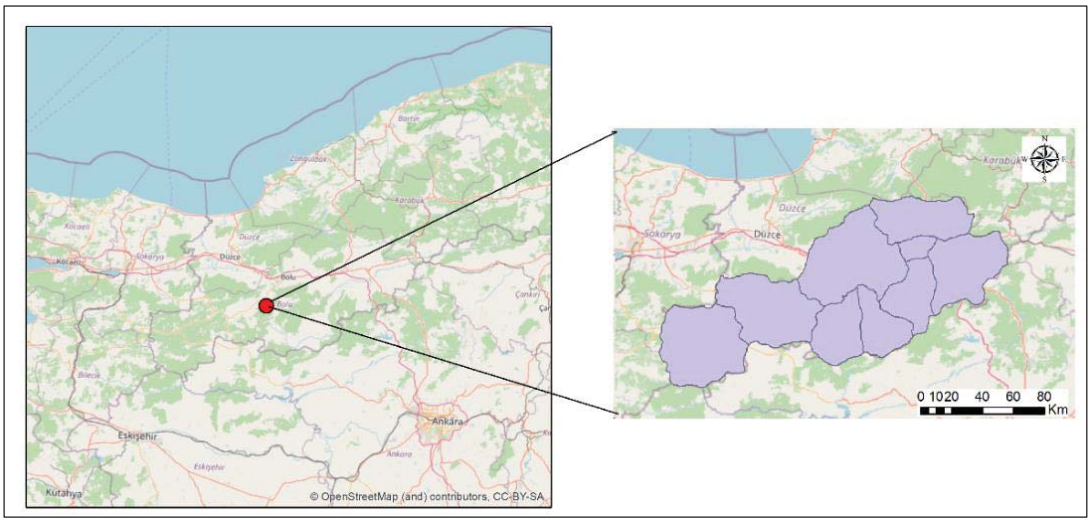


Figure 1. Study area

Table 1. Data and data sources used in the study

Data Name	Data Source
Provincial and District Boundary	General Directorate of Maps
Settlement, Road and Water Resources	Open Street Map
Digital Elevation Model	USGS Earth Explorer
Precipitation	General Directorate of Meteorology
Flora	CORINE 2018
Beekeeping Regulation	Official Newspaper

Criteria selection

Criteria selection was made by considering climatic, topographic and environmental conditions for suitable beekeeping activities. The selected criteria and their details are given below.

Slope: This criterion depends on topography and altitude and is very important for beekeeping activities. Less slope is more suitable for the beekeeping environment and yield.

Aspect: The north direction should be avoided while placing the beehives, and the south should be prioritized because the bees need light to be active.

Altitude: High places are not suitable for beekeeping as the air temperature drops at night in high places. Optimum hive positions should be determined.

Flora: Flora is one of the most important criteria for beekeeping activities as it affects honey yield and

quality. For this reason, flora selection should be made sensitively by paying attention to the plant species in the environment and the products in agricultural areas.

Precipitation: Since precipitation directly affects the flora, it is one of the criteria to be considered for appropriate beekeeping activities.

Distance to Roads and Settlement: The location of beehives is one of the most critical criteria for obtaining high efficiency from beekeeping activities. The hives should be away from roads, vehicles and the gases they produce, settlements, and air and noise pollution.

Distance to Water Resources: Another factor as important as roads and settlements in hive locations is the distance to water resources. The proximity of the hives to water sources increases the efficiency of beekeeping activities.

Methods

After the data were obtained from the necessary institutions and pages, analyses and maps were made using ArcGIS software. Water resources, road and settlement data were obtained from Open Street Map. Since the analysis was performed with raster data, criteria such as distance to water resources, distance to settlements and roads were converted to raster formats. Considering the suitable conditions for beekeeping activities, buffer zones of 500 meters for distance to the water resource and 1000 meters for distance from roads and settlements were created with the "multiple buffer" process. Digital Elevation Model (DEM) data was first downloaded from the USGS Earth Explorer page for slope, aspect and elevation data and made suitable for the study area. Slope, aspect and elevation maps were created from the DEM data. Flora data was obtained from CORINE 2018 data and prepared by the region. Precipitation data were obtained from the General Directorate of Meteorology, and areal precipitation data were obtained by the "Kriging interpolation" method. After making the data suitable for the study, Ceylan and Sarı (2017) and Yılmaz et al. (2021), class ranges were determined based on the studies. Then, since the singular value of the data is needed, not the interval value, the data were converted into singular values with the reclassification method. The criteria are given a value from 1 to 5 according to the degree of importance and the class ranges are assigned to the relevant class value. 5 represents the most suitable class for beekeeping and 1 represents the most unsuitable class. Intermediate values were classified according to the degree of importance depending on the studies and expert opinions. After this classification, the model was established for weighted overlay analysis. The weight value information of the criteria was entered into the established model, and the analysis was carried out. The mathematical algorithm behind the analysis is given below.

Suitability Assessment = (Flora * 0.440) + (Water Resources * 0.146) + (Aspect * 0.120) + (Elevation * 0.100) + (Precipitation * 0.076) + (Slope * 0.044) + (Roads * 0.039) + (Settlement* 0.033)

Weighted Overlay Analysis determined suitable places for beekeeping and whether the existing beekeeping places were in suitable beekeeping areas.

Determination of Criterion Weights

The importance and weight values of the criteria used were prepared concerning the study of Ceylan and Sarı (2017). The weights of the criteria used in the study are given in Table 2, and the class ranges and importance levels of the criteria are given in Table 3.

Table 2. Criteria and weight values

Criteria	Weight Value
Flora	0.44
Distance to Water Resources	0.15
Aspect	0.12
Height	0.10
Precipitation	0.08
Slope	0.04
Distance to Roads	0.04
Distance to settlement	0.03

Weighted Overlay Analysis

Weighted overlay analysis is a multi-layered and multi-criteria evaluation and decision-making tool. A new layer is obtained by weighting more than one raster layer relative to each other and within themselves and then overlapping, and the obtained

layer is evaluated by performing a conformity analysis according to the determined criteria.

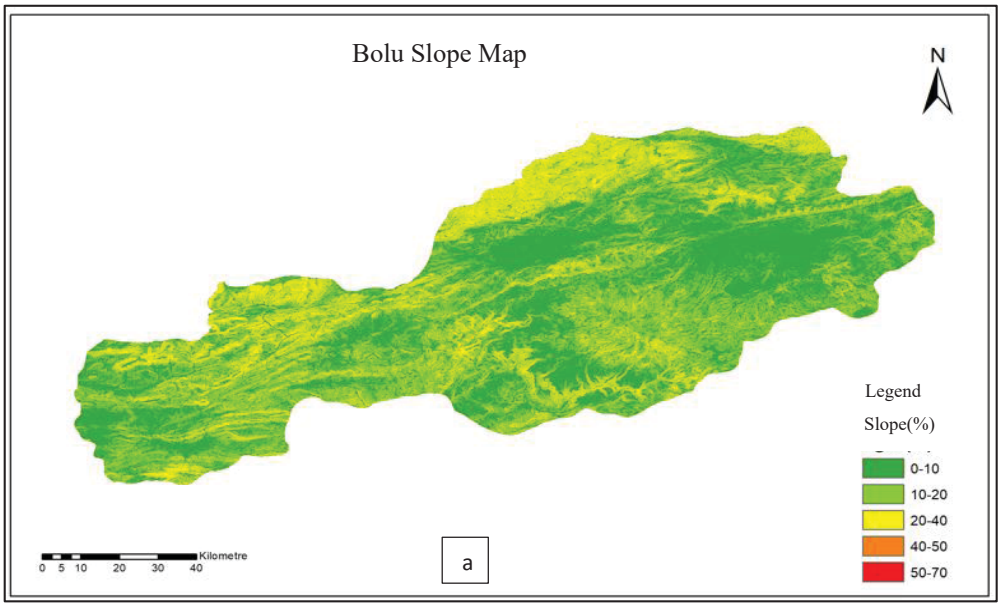
Weighted overlay analysis is a multi-layered and multi-criteria evaluation and decision-making tool. A new layer is obtained by weighting more than one raster layer relative to each other and in within themselves and then overlapping, and the obtained layer is evaluated by performing a conformity analysis according to the determined criteria. Each of these criteria may have a different impact rate. Therefore, weighted overlay analysis helps beekeepers to determine their land selection and management strategy. For example, in their study, Yılmaz et al., (2021) used weighted overlay analysis to determine the most suitable places for beekeeping in Şavşat district of Artvin province. Similarly, Yalçın et al., (2019) determined suitable places for beekeeping for the Karaburun, Çeşme and Urla districts of İzmir with multi-criteria decision analysis and weighted overlay analysis. Maris et al., (2008) discussed the applications of Geographic Information System (GIS) and Multi-Criteria Decision Analysis to locate beekeeping regions in the state of Selangor. Appropriate beekeeping locations determined by weighted overlay analysis were verified with actual data from existing beehives. A reasonable consistency was determined as a result of the study. Studies show that weighted overlay analysis can facilitate the selection of suitable beekeeping and contribute to the health and productivity of bees.

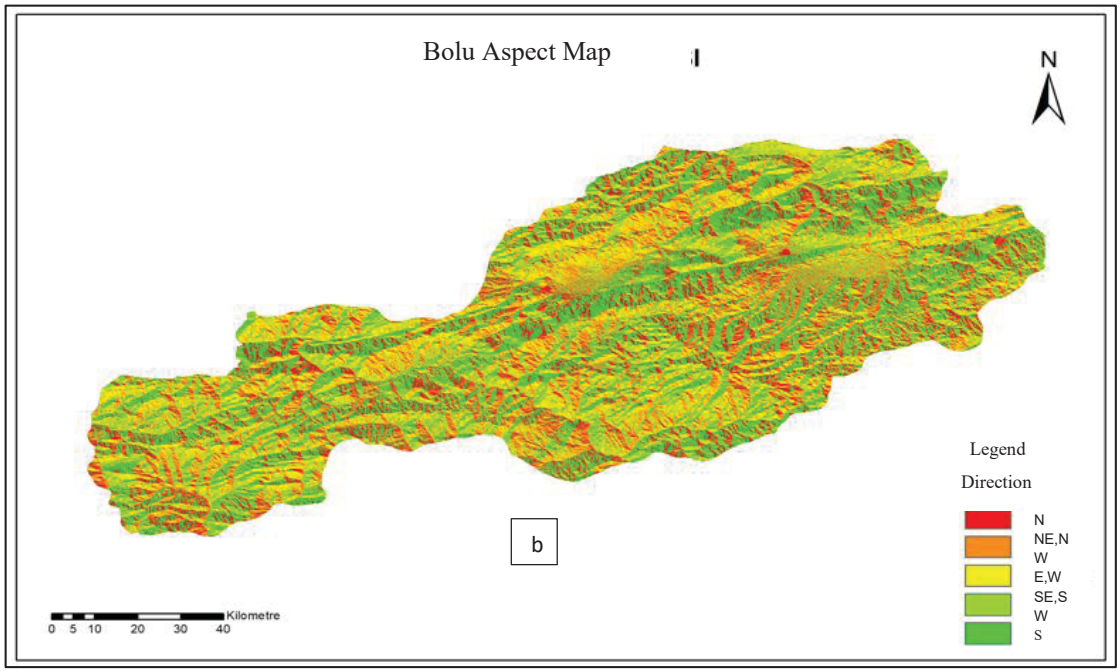
Table 3. Assignment of criteria class ranges and severity levels

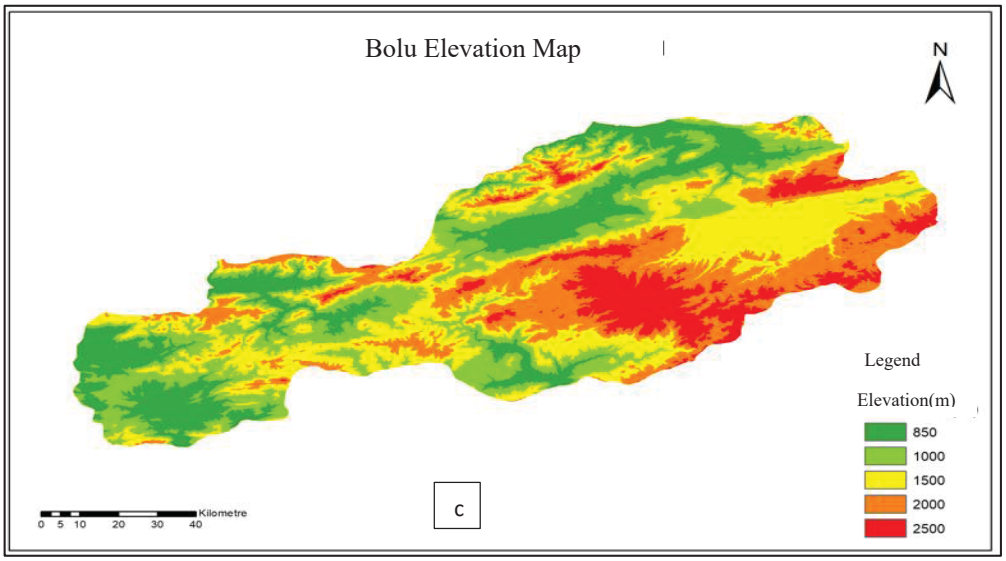
Criterias	1	2	3	4	5
Height	2500	2000	1500	1000	850
Slope	50-70	40-50	20-40	10-20	0-10
Aspect	North	NE, NW	West-East	SE, SW	South
Flora	Sparse Plant Areas	City Areas	Farming Areas	Meadows	Forests
Distance to Water Resources	2000	1500	1000	500	0
Distance to settlement	1000	2000	3000	4000	5000<
Distance to Roads	0	500	1000	1500	2000
Precipitation	400	600	8000	1000	1200

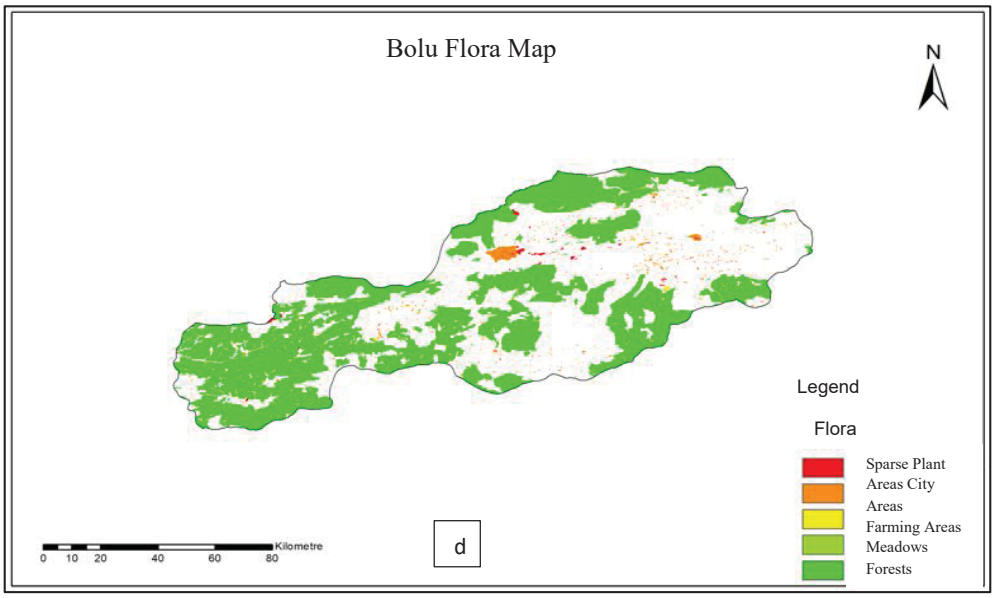
RESULTS

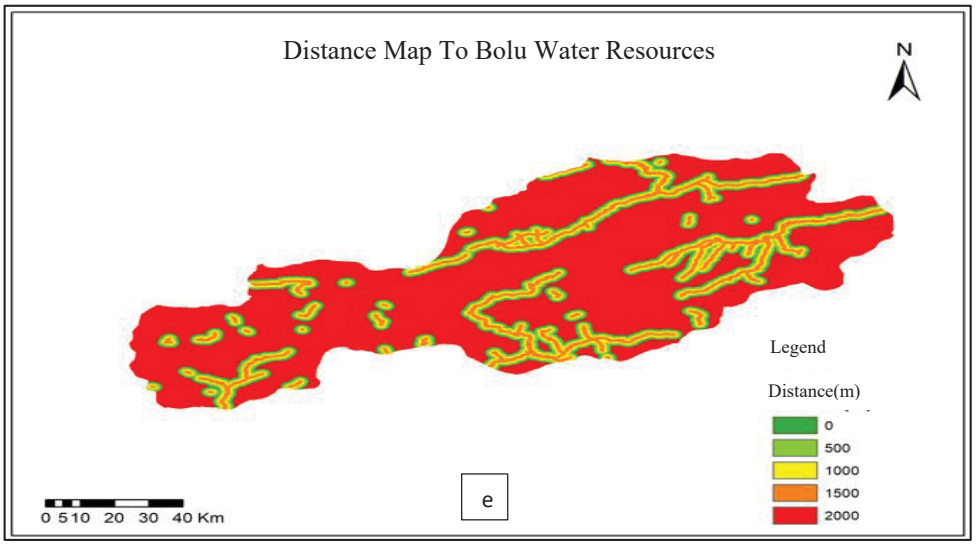
The resulting map obtained for each criterion for the weighted overlay analysis carried out to determine suitable beekeeping sites in Bolu province is shown in Figure 2. The red areas on the maps show suitable beekeeping areas, while the green areas show unsuitable areas. When the maps of each criterion were examined, it was seen that the majority of the city was covered with mountains and forests. In addition, the existence of many lakes has been determined due to heavy rainfall, elevation differences and high slope.

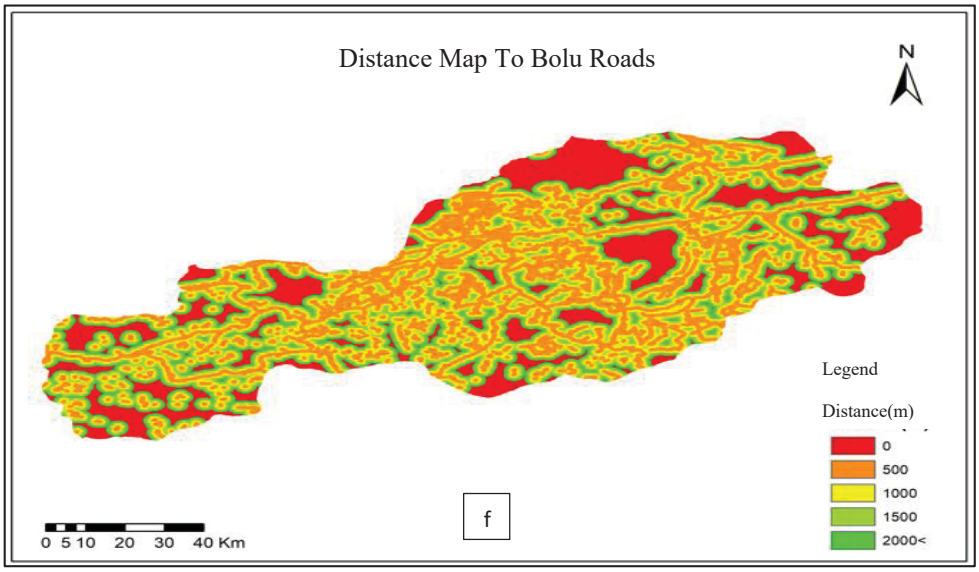

Bolu Slope Map
N
Legend
Slope(%)
0-10
10-20
20-40
40-50
50-70
Kilometre
0 5 10 20 30 40
a

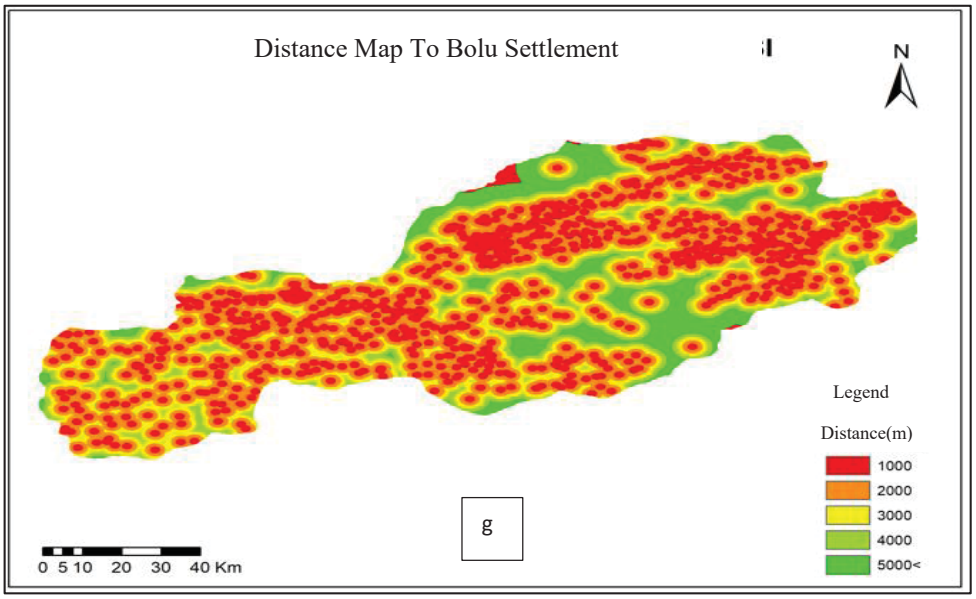

Bolu Aspect Map
N
Legend
Direction
N
NE,N
W
E,W
SE,S
W
S
Kilometre
0 5 10 20 30 40
b


Bolu Elevation Map
N
Legend
Elevation(m)
850
1000
1500
2000
2500
Kilometre
0 5 10 20 30 40
c


Bolu Flora Map
N
Legend
Flora
Sparse Plant
Areas City
Areas
Farming Areas
Meadows
Forests
Kilometre
0 10 20 40 60 80
d


Distance Map To Bolu Water Resources
N
Legend
Distance(m)
0
500
1000
1500
2000
0 5 10 20 30 40 Km
e


Distance Map To Bolu Roads
N
Legend
Distance(m)
0
500
1000
1500
2000<
0 5 10 20 30 40 Km
f



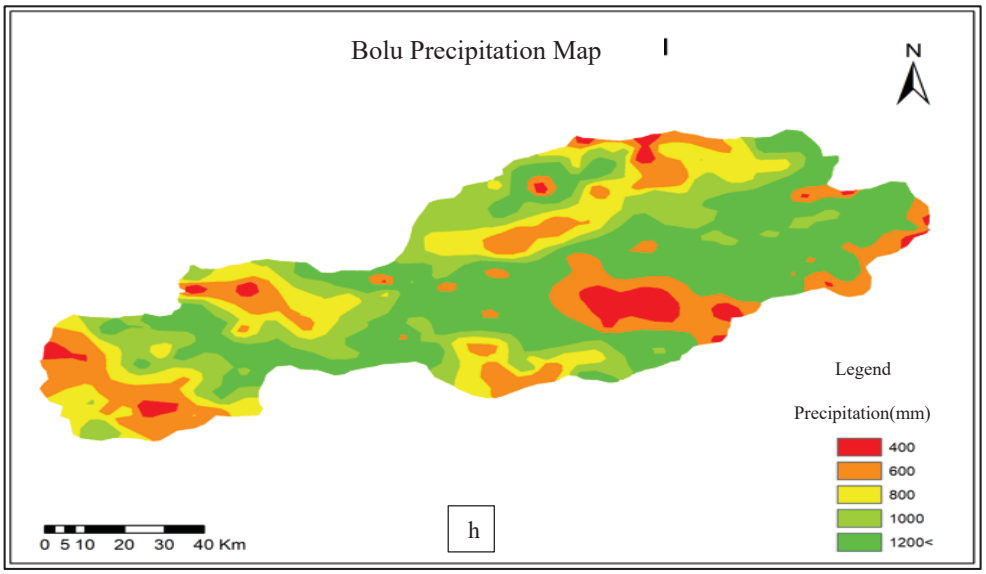


Figure 2. The class ranges and suitability map of the criteria (a: slope map, b: aspect map, c: elevation map, d: flora map, e: distance to water resources, f: distance to roads, g: distance to settlements map, h: precipitation map)

The map is divided into five classes according to the degree of suitability "very low, low, medium, high, and very high suitability". Red areas represent low-suitability areas, and green areas represent high-suitability areas. The suitability map formed as a result of the analysis is given in Figure 3.

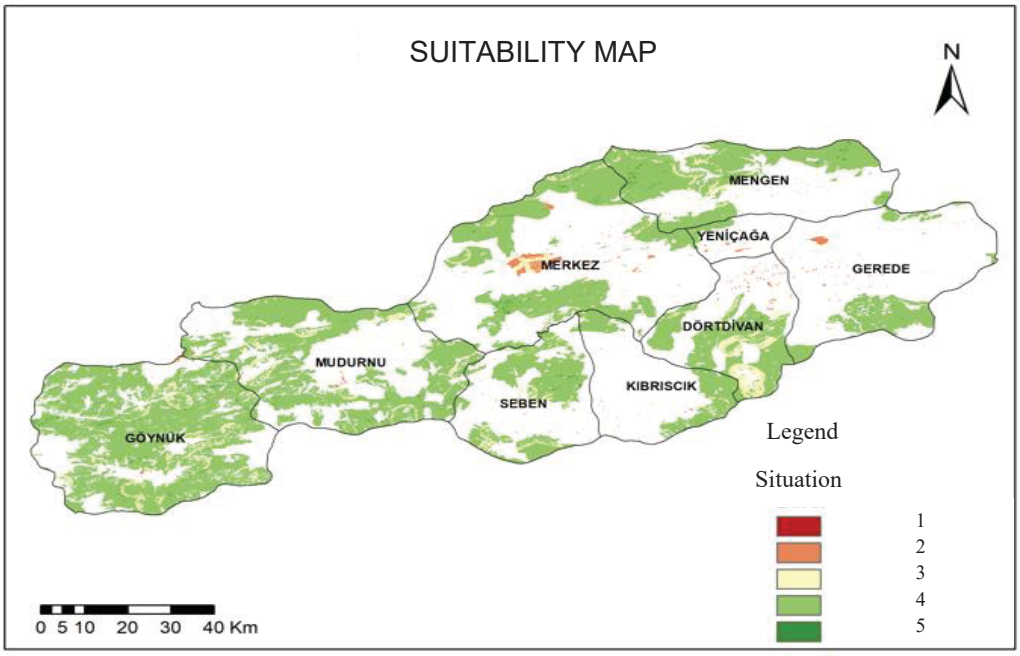


Figure 3. Map of suitable beekeeping places in Bolu province

After determining the suitable areas for the study, 34 beekeepers engaged in beekeeping in Bolu province were reached, and it was determined whether these beekeepers were in suitable beekeeping activities. Coordinates were obtained from the locations of 34 beekeepers through field studies. The coordinates are overlapped with the conformity map, which is given in Figure 4.

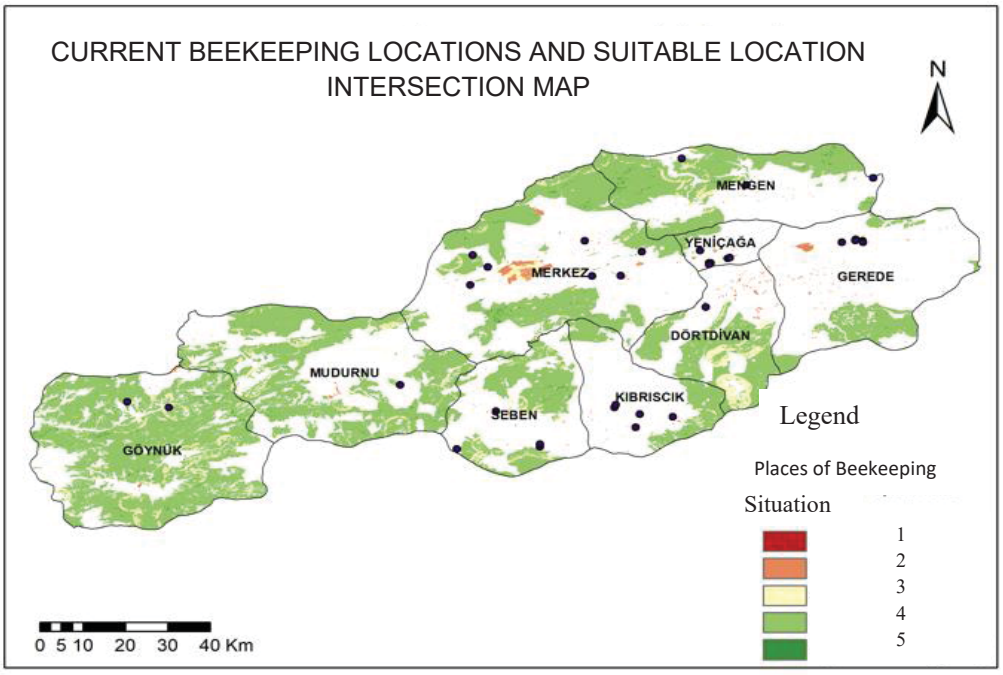


Figure 4. Existing beekeeping locations and intersection map of available locations

DISCUSSION

In order to continue beekeeping activities and increase the yield obtained from these activities, it is important to choose a suitable place and the success of the bee colony. Many factors affect success, such as the distance of the beehives to clean water sources, settlements and roads, the height of the hives location, precipitation, and flora. Each of these factors may have a different impact rate. Therefore, the use of Weighted Overlay Analysis in determining suitable beekeeping sites helps to determine the land selection and management strategies of the producers. In the studies, it is seen that weighted overlay analysis is widely used to determine suitable beekeeping sites (Maris et al., (2008); Yalçın et al., (2019); Yılmaz et al., (2021)). For example, Ceylan and Sarı (2017) used multi-criteria decision analysis to determine suitable beekeeping locations for Konya province. As a result of the study, it was determined that 82% of the existing bee areas intersect with the suitability map. In their study for the Montesinho Nature Park in Portugal, Fernandez et al., (2016) used multi-criteria decision-making analysis to determine potential beekeeping locations, and it was revealed that 60% of the existing bee sites in the study area were in suitable locations. In addition, it was emphasized that other bee sites that are not in suitable locations should be moved to suitable locations. Similar to these studies, weighted overlay analysis, one of the multi-criteria decision-making analysis methods, was used to determine suitable beekeeping areas in Bolu province and a suitability map of each criterion was created. Weighted overlay analysis was carried out by weighting the criteria and suitable beekeeping sites were determined. When the suitability map was examined, it was seen that 90.95% of the study area was suitable for beekeeping activities based on high suitability and very high suitability classes. Since the weight value of the flora criterion is high in forming the suitability map, it is one of the critical criteria affecting the map. When the unsuitable places are examined, it is seen that these areas are cemeteries, bushes, settlements, locations far from water sources, close to roads and on the north facade. When looking at suitable places, it has been determined that there are primarily forested and grassy areas, areas far from settlements, industrial areas and roads, areas close to water sources and in the southern regions. When the intersection of the 34 existing beekeepers' locations with the suitability map was examined, it was determined that 3 were in high suitability, 9 were in medium suitability, 2 were in low suitability, and 20 were beekeeping in non-flora locations. Considering that flora is an important criterion, the fact that beekeeping activities are carried out away from flora explains why the yield is low and shows that beekeeping activities are not sufficiently utilized.

Conclusion

This study is specific to the province of Bolu, and the suitability map of each province should be created within itself since each province's ecology, flora, topography, and climate are different. For this reason, it is not the right approach to compare the studies. To increase the efficiency obtained from the study, the number of criteria can be increased by adding criteria such as temperature, wind and humidity. Keeping more detailed records on these criteria, suitable beekeeping sites, and their determination will provide great convenience and important information for this and similar studies. Data on critical criteria such as flora, such as biodiversity, bloom duration and density of flora, etc. and adding such details will increase the efficiency obtained from the study and shed light on many studies.

In a city like Bolu, 90% of which are suitable for beekeeping activities, only 8% of the existing beekeepers do beekeeping at a high availability place, which is a very low rate, and this rate should be increased.

Spatial analysis results show how critical the geographical conditions of the region are for the sustainability of beekeeping activities in Bolu province. At the same time, it should not be forgotten that spatial analyzes can be used for other sustainable activities besides beekeeping, and such studies can be an important tool to strengthen the local economy. This study may also help local beekeepers improve their businesses by focusing on sustainable beekeeping practices. Identifying suitable beekeeping areas in the region can contribute to the local economy by allowing beekeepers to work more efficiently and effectively. For this, beekeepers should be informed by the related institutions and studies.

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