CEVİZ (*Junglas regia* L.) YETİŞTİRİCİLİĞİNDE CBS TEKNİKLERİ KULLANILARAK MEKÂNSAL KARAR DESTEK SİSTEMİ (MKDS) GELİŞTİRİLMESİNDE ÇATAK-VAN (TÜRKİYE) ÖRNEĞİ

DEVELOPMENT OF SPATIAL DECISION SUPPORT SYSTEMS (SDSS) USING GIS TECHNIQUES IN WALNUT (*Junglas regia* L.) CULTIVATION: VAN-ÇATAK (TURKEY) CASE

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ÖZET

Bu çalışmada Dünyada ve Anadolu'da farklı ekolojik koşullarda yetiştiriciliği yapılan bölge ve ülke ekonomisine önemli katma değer sağlayan cevizin (*Junglas regia* L.)'in Çatak (Van) ilçesi sınırları dâhilinde yetiştirilebileceği alanların CBS ile belirlenmesi amacıyla yapılmıştır. Çalışma kapsamında Çatak ilçesinde cevizin yetişebileceği optimum alanların belirlenmesinde cevizin yetişmesinde etkili olan faktörler, daha önce yapılan çalışmalar ve uzman görüşleri dikkate alınarak belirlenmiş, CBS yazılımı kullanılarak muhtelif ölçekli raster tematik haritalardan (memleket, toprak), iklime ait veriler ile birlikte vektör haritalardan (eşyükselti eğrili E00 haritalar) model için gerekli unsurlar veri tabanına aktarılarak haritalandırılmış, elde edilen tüm veriler çakıştırılarak cevizin yetişebileceği alanlar tespit edilmiştir. Çatak ilçesinin topoğrafik yapısından dolayı cevizin rakımın ve eğimin nispeten düşük olduğu vadi, yamaç ve tabanlarında sorunsuz olarak yetiştirilebileceği fakat dağlık alanlarda ise yetiştiriciliğinin uygun olmadığı sonucuna ulaşılmıştır. Bu çalışma sayesinde, hem Çatak (Van-Türkiye) ilçesinde ceviz bahçelerinin tesis edilebileceği farklı alanların tarımsal potansiyelinin ortaya konulması hem de mekanlara bağlı, yer ve konuma dayalı bilgilerin yönetilmesinde kullanılabilecektir.

Anahtar Kelimeler: Uygunluk haritası, Ceviz (*Juglans regia* L.), Coğrafi Bilgi Sistemleri (CBS)

ABSTRACT

This study was carried out to determine the areas where walnut (*Junglas regia* L.), which is grown in different ecological conditions of the world and Anatolia and provides significant added value to the economy of the region and the country, can be grown within the borders of Çatak (Van) district by using GIS. Within the scope of the study, certain data sets were created by taking into account the factors affecting the cultivation of walnuts, previous studies and expert opinions in determining the optimum areas where walnuts can grow in Çatak district. These data sets were combined with the necessary elements in the raster thematic maps and climatic vector maps (E00 maps with the e-high curve) and then they transferred into the database. All the obtained data were compared with each other by using GIS software and the areas where walnut could grow were determined. Due to the topographic structure of Çatak district, it has been concluded that walnut can be grown in valleys, slopes and floors where the altitude and slope are relatively low, but it will not be suitable for cultivation in mountainous areas. Thanks to this study, it will be used both in revealing the agricultural potential of different areas where walnut orchards can be established in Çatak (Van-Turkey) district and it will be also used in managing information based on locations.

Keywords: Compliance map, Walnut (*Juglans Reia* L.), Geographical Information Systems (GIS)

1. INTRODUCTION

Walnut is an important fruit species widely grown all over the world due to the added value it brings to other products with its nutritional elements and high energy value. Walnut has a widespread area from China to the USA. According to FAO 2018 data, walnut is among the first four with 9.1% in terms of the area covered by hard-shelled fruits in the world, and in terms of production amount, it ranks second with 19.9% after cashew (32.2%). Turkey ranked fourth in walnut production in the world with 5.9%. 33.7% of walnut production areas belong to China, 12.6% belong to Iran and 12.2% belong to the USA. Turkey is in fourth place with a 9% share in the field of production as well as in production (Anonymous, 2020). In recent years, the number of walnut trees and the amount of walnut production in the Van Lake basin has been increasing day by day. Today, rapidly changing market conditions necessitate correct planning of walnut production and selection of varieties to reach the desired level in walnuts. Accurate, reliable and up-to-date information, namely "Spatial Decision Making" studies, is needed for sustainable planning of agricultural areas. With the development of GIS, such studies, which are difficult and require a long time with traditional methods, can be carried out in a short time with much higher performance with much higher reliability and research results can be revealed in a very short time.

Especially in the management of location-based information, Geographic Information Systems (GIS) play an important role in applications that require complex analysis such as the management and integration of many economic, political, social and cultural resources (Akbaş et al., 2008, Peşkircioğlu et al., 2013). Van Lake Basin, which is known as one of the gene centers of walnuts in the world, is one of the most important regions of our country in terms of both the number of walnut trees (279.853 trees) and the amount of production (5,666 tons) (Şen et al., 2006). Considering that the places where successful walnut cultivation is carried out in our country are a kind of microclimate area, the potential, place and importance of Çatak district in walnut cultivation will be more visible and will provide a local projection for walnut cultivation in the country.

This study aims to enable the areas where walnuts can be grown in Çatak district to be determined quickly and reliably without requiring great cost by using GIS techniques, to highlight the agricultural potential of different areas where walnut orchards can be established, to prevent wrong land use and to protect walnut gene resources. On the other hand, this study can be evaluated as a base for national and even international basin-based development models that take into account natural resources and fragile ecosystems with an ecological-geographical approach. Adding new information by constantly updating the created database will enable sustainable planning of agricultural areas, thus an ecological-based planning model.

2. MATERIAL and METHOD

2.1. Material

The research was carried out in Çatak (Van) district and its villages between 2019-2020. The province of Van is located in the Eastern Anatolia Region, where the continental climate is dominant. The location of the district is in the south of Van province, between 42° 54' and 43° 15' east longitudes and 38° 01' and 38° 45' north latitudes. The topographic structure of the district mostly consists of a mountainous area that starts from 1080 m and goes up to 3630 m (Anonymous-2018). Although walnut comes first in fruit growing, apples and apricots are also among the products grown. The location of Çatak (Van) district is given on the map of Turkey and the district borders evaluated within the scope of the research are seen (Figure 1).

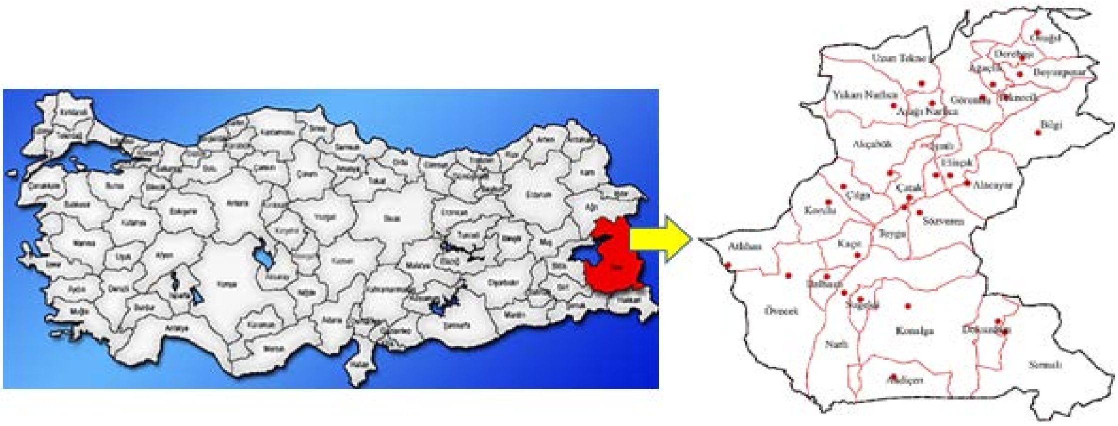

Figure 1. Working area.

In Çatak district, the annual average temperature is 10.96 °C, the highest annual average temperature is 16.5 °C and the lowest average temperature is -1.5 °C. On the other hand, the average rainfall for many years is 720 mm per m2. (Anonymous, 2019a). It is seen that the average temperature and precipitation of the settlements located in the north of Çatak district is low, while the average of temperature and precipitation of the settlements located in the south is high. (Table 2).

Table 1. Average values of Çatak District in 1985-2019.

Months	Temperature (°C)	Highest Temperature (°C)	Lowest Temperature (°C)	Sunbathing Time (hours)	Rainfall (mm)
January	-1.3	2.6	-18.1	2.6	85.2
February	-0.4	3.7	-17.5	4.3	92.5
March	3.7	8	-11.5	5.8	88.1
Engagement	9	13.8	-5.2	6	99.6
May	14.4	20	1.9	7.9	87
June	19.8	26.3	13.4	9.9	21.7
July	24.2	30.9	17.5	10.6	2.2
August	23.9	30.7	17.1	10.2	5.4
September	19.8	26.5	13.2	9.1	8.6
October	13.4	19.1	7.7	5.5	65.2
November	6.7	11.4	2.1	3.1	73.8
December	-1.6	5.3	-2.1	2.3	91.3
Annual Avg.	**10.96**	**16.5**	**1.5**	**6.4**	**60.05**

Table 2. Climatic data of the villages of Çatak District. (Climate-Data.org, 2019).

No.	Residential First Name	Average Temperature	Average Precipitatio	No.	Residential First Name	Average Temperature	Average Precipitation
1	Ağaçlık	6.25	49.50	15	Işınlı	8.00	52.33
2	Akçabük	8.17	53.75	16	Kaçıt	9.72	57.50
3	Alacayar	10.11	51.42	17	Konalga	10.81	58.08
4	Andiçen	9.23	55.25	18	Korulu	8.75	56.33
5	Aşağı Narlıca	7.41	51.00	19	Narlı Bucağı	10.23	49.83
6	Atlıhan	10.10	61.08	20	Onağıl	7.15	46.08
7	Bilgi	9.72	47.58	21	Övecek	11.55	60.75
8	Boyunpınar	6.73	48.17	22	Sırmalı	8.72	55.92
9	Çılga	7.26	55.75	23	Sözveren	9.49	54.08
10	Dalbastı	10.74	59.08	24	Sugeldi	10.53	59.00
11	Derebaşı	6.60	47.75	25	Teknecik	7.03	48.83
12	Dokuzdam	8.17	55.08	26	Toyga	9.98	54.25
13	Eliaçık	8.03	51.83	27	Uzuntekne	6.55	51.42
14	Görentaş	7.19	49.33	28	Yukarı Narlıca	6.88	52.58

The soils of the research area have developed under the influence of continental climate as a result of the effects of factors such as lithology, topography, vegetation and time. Chestnut colored soils cover the largest area in Çatak district. Limeless brown forest soils follow this. The soils covering the least area are Hydromorphic alluvial soils with 0.72 km2 (Figure 2-3; Table 3-5).

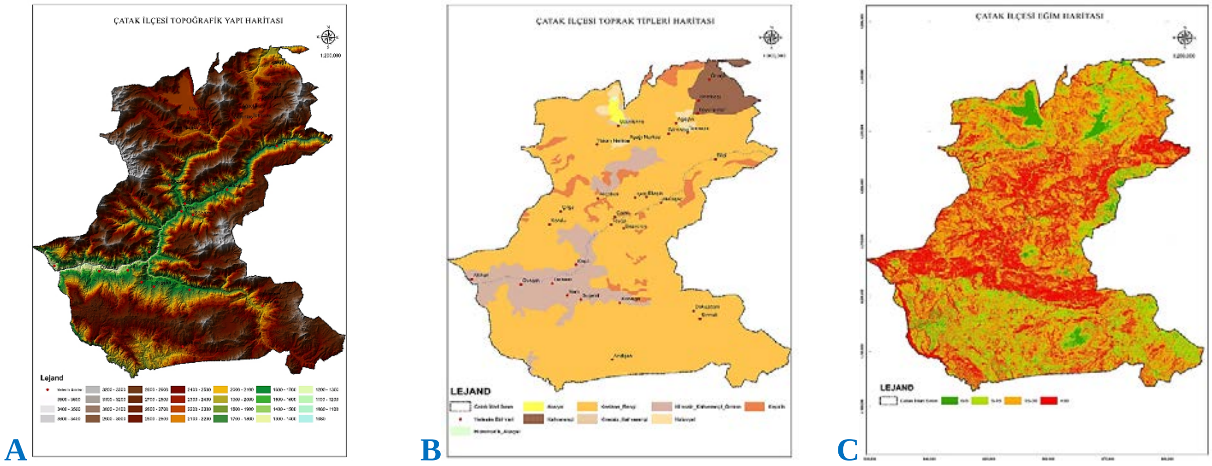

Figure 2. Çatak district topographic structure (A), slope (B) and distribution (C) maps of soil types.

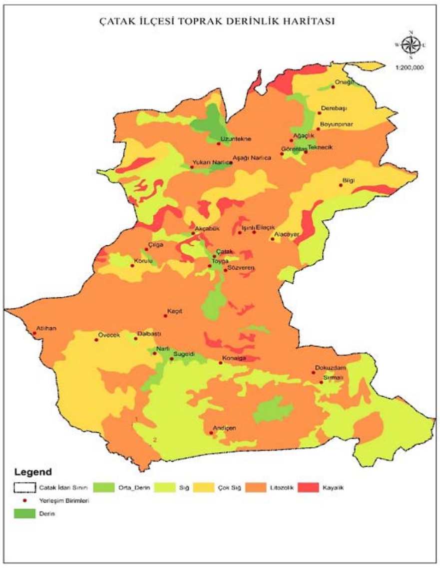

Figure 3. Soil depth map of Çatak District.

Table 3. Çatak District slope classes and areal distribution

Type	Slope Group	Area (km^2)
Straight	0-3	29
Little Sloping	3.01-10	139
Mid-level Sloping	10.01-25	645
Steeply-Sloping	25.01-90	1106.85

Table 4. Spatial distribution of soil depth in Çatak District

Depth	Area (km^2)	Depth	Area (km^2)
Deep	17.49	Çok sığ	354.45
Mid-level deep	74.90	Litozolik	1031.17
Shallow	363.33	Kayalık	78.50

Table 5. Spatial distribution of soil types in Çatak District

Soil Types	Area (km^2)	Soil Types	Area (km^2)
Limeless Brown	4.73	Brown	71.95
Limeless Brown Forest	224.90	Alluvial	8.41
Chestnut Colored Soils	1512.22	Cliff	78.50
Colluvial	18.51	Hydromorphic Alluvial	0.72

2.2. Method

In this study, determining the optimum areas where the walnut can be grown, taking into account the expert opinions, the factors affecting the cultivation of the walnut and the previous studies constituted the initial stage of the work. And then as the final stage, these data sets were combined with the necessary elements in the raster thematic maps and climatic vector maps (E00 maps with the e-high curve), and then they transferred into the database. All the obtained data were compared with each other by using GIS software and the areas where walnut could grow were determined. The following maps and data were used to be evaluated in the study;

- ✓ Vectorial E00 Maps obtained from 1/25000 scale HGK,
- ✓ Soil and Land Asset Maps of Van Province, prepared by the State Hydraulic Works and Provincial Directorate of Agriculture and Forestry on 1/25000 scale,
- ✓ Monthly and daily climate data of Çatak district, obtained from the Provincial Directorate of Meteorology and measured between 1985-2019,
- ✓ Village-based climate data from the Climate-data website.

In the first stage, a data set was created by determining the factors that are effective in determining the optimum areas where walnut can be grown. In the second stage, the database was created using ArcGIS software. Climate, edaphic and topographical layers were formed by determining the factors affecting walnut cultivation from the data obtained in the third stage. In the last stage, the areas where walnuts can grow were determined by overlaying all the data (Anonymous, 2012, 2018, 2019a, 2019b, 2019c, 2019d, Climate-Data, 2019).

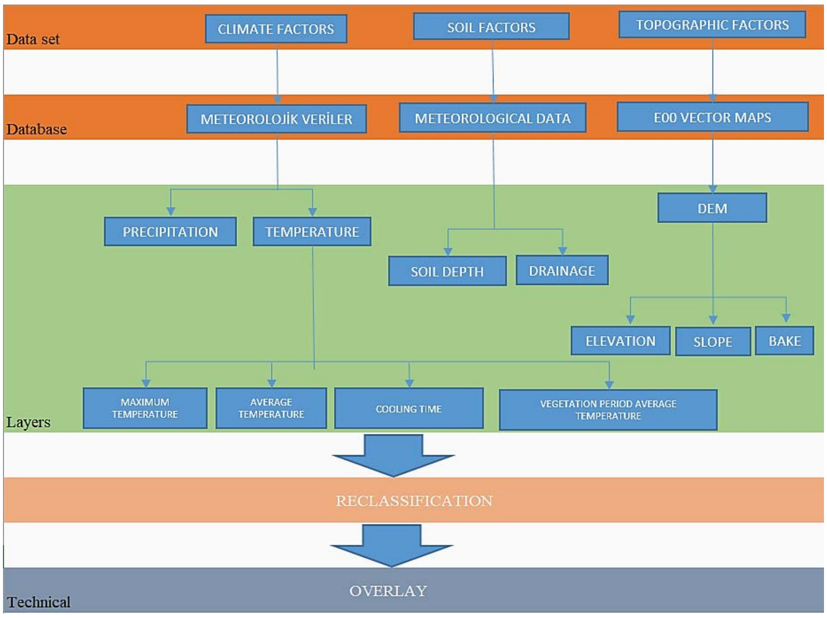

Figure 4. Flow Chart of the Method.

The modeling methods that form the basis of the study were designed according to Vahdati et al., 2019. The boundaries and parameters they used formed the main element of our modeling. The steps of the method to be followed in the study are given in the flow chart in Figure 4. "Extremely Suitable" condition for walnut planting is the most ideal conditions for planting pedoclimate conditions. "Pretty Suitable" and "Suitable" conditions are those under which walnut cultivation is possible with some restrictions.

2.2.1. Topographic Data Analysis

Aspect, elevation and slope maps were obtained with the ArcGIS-3D module by using the Digital Terrain Model obtained from the E00 vector maps belonging to the study area.

Table 6. Classification of pedoclimate status of walnuts for land suitability assessment

Pedoclimate Status	Extremely Suitable (The Best)	Pretty Suitable	Suitable	Not Suitable
Altitude (m)	0-1000	1000-2000	2000-3000	>3000
Land Slope (%)	0-5	5-15	15-30	30 <
Average in Vegetation Period Temperature (°C)	20-28	18-20	15-18	<15
Min. Temperature in Winter (°C)	-5<	-5 - -15	-15 - -20	>-20
Maximum Temperature (° C)	<30	30-35	35-38	>38
Cooling Requirement (0-7 °C)	1100-1800	900-1100	600-900	<600
Soil Depth (m)	2.5-3	1.5-2	1.5-1	<1
Drainage	Well Drainage	Not Enough Drainage	Bad Drainage	Rocky Terrain
Early Spring Frosts	April average temperature >0 °C			
Late Autumn Frosts	October temperature average > 0 °C			

2.2.2. Determination of Factors Affecting the Growth of Walnut

It is divided into four suitability classes according to the climate, edaphic and topography variables that are important for walnut production (Table 6). This classification is based on literature review and comments from expert walnut researchers around the world who advise on commercial walnut production (Germain 1999; Ramos 1997; Wilkinson 2005).

2.2.3. Edaphic Data Analysis

Soil Analysis was carried out by using the studies carried out by the State Hydraulic Works. These data were scanned and transferred into the ArcGIS environment and mapped according to the Drainage and Depth properties.

2.2.4. Evaluation of Climate Data

The changes in the meteorological parameters of the ground observation stations used in the study were analyzed statistically with the help of EXCEL software. All data were transferred to GIS environment with ArcGIS software and distribution maps were created by interpolation method.

2.2.5. Calculating the Sum of Effective Temperature

In the northern hemisphere, this value, expressed as "Degrees-Day (DD)" (Amerine and Winkler, 1944) used to predict the ability to grow and produce a high-quality product, is the average temperature at which fruit development begins, and is accepted as 7.2 °C. Based on the temperature, the date and day when the daily average temperature reached the threshold temperature for many years, the date and day when it fell below the threshold temperature, and the temperatures where the daily average temperature was above the threshold temperature for each day during this period were calculated as the total temperature.

$$EST = \sum (T - Te) \quad (1)$$

EST: Effective temperature sum (°C-day) **T:** Average daily temperature (°C)
Te: Threshold temperature (°C)

Precipitation; Since the annual precipitation averages of Çatak and its affiliated villages are above 500 mm per year, it was not considered necessary to take into account.

Cooling Request; The duration of the period (hours) below the threshold temperature of 7.2 °C, the number of days when the daily average temperature is 7.2 °C or lower (dT<7.2 °C) for each village, and the cooling times of the villages were calculated in terms of hours.

Highest Summer Temperature; Considering that the walnut tree, which is not affected much by the heat up to +38 °C, this factor has been ignored since the maximum temperature in Çatak and its villages are below this degree in the summer period.

Frost risk; The walnut tree is resistant to cold down to -25 °C during the rest period. Since the vegetation period is the beginning of April and the end of October in Çatak district and its villages, a Don map was created based on the minimum temperature averages in these months.

2.2.6. Database Creation and Compliance Analysis

A database was created with various scale raster thematic maps for Çatak district, climate data made available for GIS analyzes with Microsoft Excel software and data from vector maps. GIS-based ArcGIS 10.8 software was used to collect, store, query, transfer and display the data. All data were defined in the Zone 38 system with the WGS 84 projection, and the elements required for the model from raster hometown and soil maps, climate data were converted into vector data. Compliance analysis was carried out by formulating the weighted ratio result method according to the 9 parameters (Altitude, Slope, Average Temperature in My Vegetation Period (°C), Minimum Winter Temperature (°C), Maximum Temperature (°C), Chilling Period (0-7 °C), Drainage, Early Spring frosts and Autumn late frosts) obtained as follows.

$$\sum_{i=1}^{n} Ai \, x \, Vi$$

Ai : The weight of the i-th variable
Vi : The score of the class in variable i

The effects of all the parameters specific to the region on walnut cultivation were considered equal, and analyzes were made by assigning a score (Vi) between 1-10 in the ratio of their weights to the classes in the substratum layer of these parameters. The weight ratios of the classes in the substratum layer of each parameter were formed as follows (Table 7). Conformity analysis was performed by formulating the Pedoclimate Condition factors with the help of GIS analysis and the weighted ratio result method.

Table 7. Weight Ratios of substratum Layer Classes

Variables	V_i
Extremely Suitable (The Best)	10
Pretty Suitable	7
Suitable	4
Not Suitable	1

3. FINDINGS

3.1. Findings of Topography

Altitude: It both determines the growth limit of the walnut tree and is one of the important criteria in revealing the temperature. For example, as the altitude increases, the risk of frost also increases. In Çatak district, the altitude is between 1080 m and 3630 m, and the suitability map of the areas where walnuts can grow according to the altitude is shown in Figure 5.

When Figure 5 is examined, it is seen that the areas with suitable elevations where walnuts can grow are generally valley slopes where the altitude is relatively low. When Table 8 is examined, the altitude group between 0-1000 m, which is extremely suitable for walnut cultivation, is not included in the study area. The altitudes of 1000-2000 m, which are "pretty suitable" for walnut cultivation, and 2000-3000 m, which are "suitable", cover an area of 1.784.03 km^2 and correspond to 92.92% of the entire area.

Table 8. The areal distribution of the altitude of Çatak District

Altitude	Extremely Suitable (The Best) Area (0-1000 m)	Pretty Suitable (1000-2000 m)	Suitable (2000-3000 m)	Not Suitable (>3000 m.)
Area Covered (km^2)	0.00	307.08	1476.23	136.54

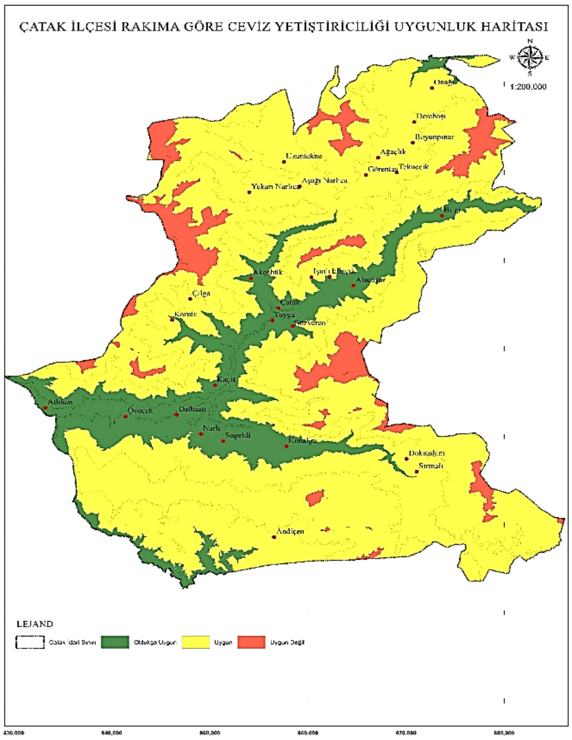

Figure 5. Çatak District altitude map.

Slope: In walnut cultivation, mild to medium slopes (3-10%) are preferred for the cold air to go away quickly, while slopes higher than these values are not preferred because they will cause erosion. Although steep slopes prevent effective gardening, some slopes can be corrected by leveling and used as a garden place (Şen et al., 2006). The slope suitability map for walnut cultivation in Çatak district is given in Figure 6 and its spatial distribution is given in Table 9.

Table 9. Spatial distribution of the slope conditions of Çatak district

Slope	Extremely Suitable (The Best) Area (0-5%)	Pretty Suitable (5-15%)	Suitable (15-30%)	Not Suitable (>30%)
Area Covered (km^2)	56.98	299.58	643.31	919.98

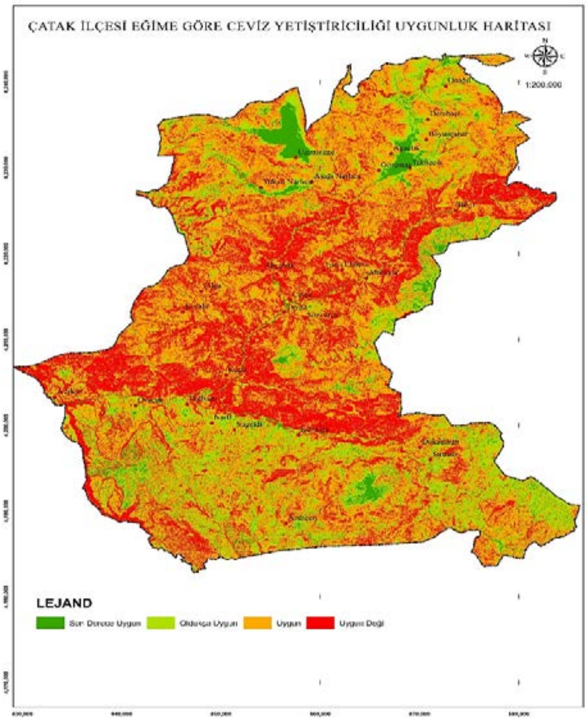

Figure 6. Çatak district slope map.

Slope exposure: For walnut trees, the delay in flowering on north-facing slopes may be valuable to prevent frost damage. Therefore, to protect from spring frosts, although the early ripening of the fruit in the northern aspects is economically important, the southern slopes should be considered (Sen et al., 2006). When Table 10 is examined, sunny slopes cover 48.74% of the study area, and shaded slopes cover 51.07% of the study area. Although sunny slopes are preferred due to the short vegetation period in the study area, shady views should be preferred where there is a risk of spring frost.

Table 10. Spatial distribution of Çatak district aspects

Direction	Area (km^2)	%
Düz	3.67	0.19
Kuzey	349.10	18.18
Kuzeydoğu	207.28	10.80
Kuzeybatı	243.19	12.67
Doğu	180.94	9.42
Güney	291.18	15.17
Güneydoğu	231.42	12.05
Güneybatı	225.26	11.73
Batı	187.81	9.78

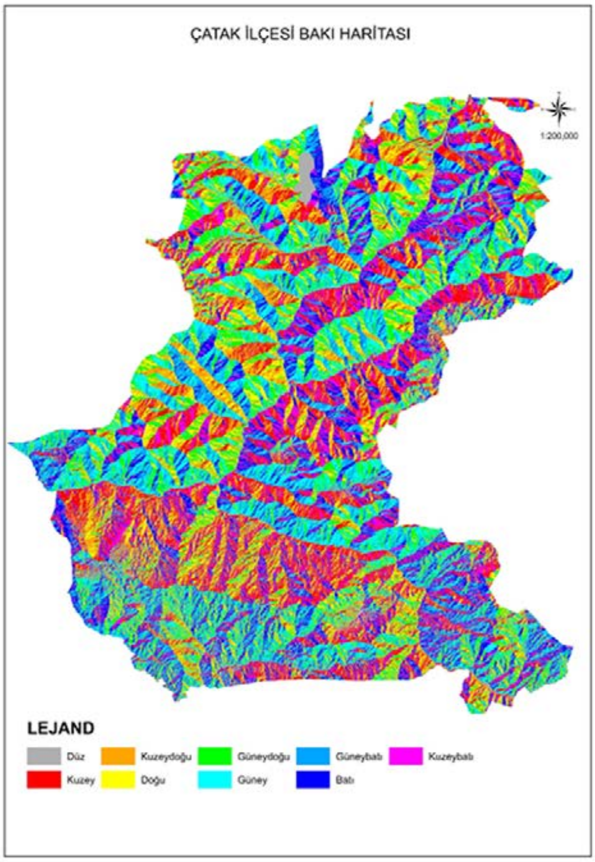

Figure 7. Çatak district slope exposure map.

3.2. Findings of Soil Properties

Soil Depth: Soil depth is an important factor in ensuring that the roots can easily hold and moderate water absorption, and a depth of 250-300 cm is ideal for walnut trees (Anonymous, 2012). The deep and medium deep soils where walnut can grow in Çatak district are given in Figure 8.

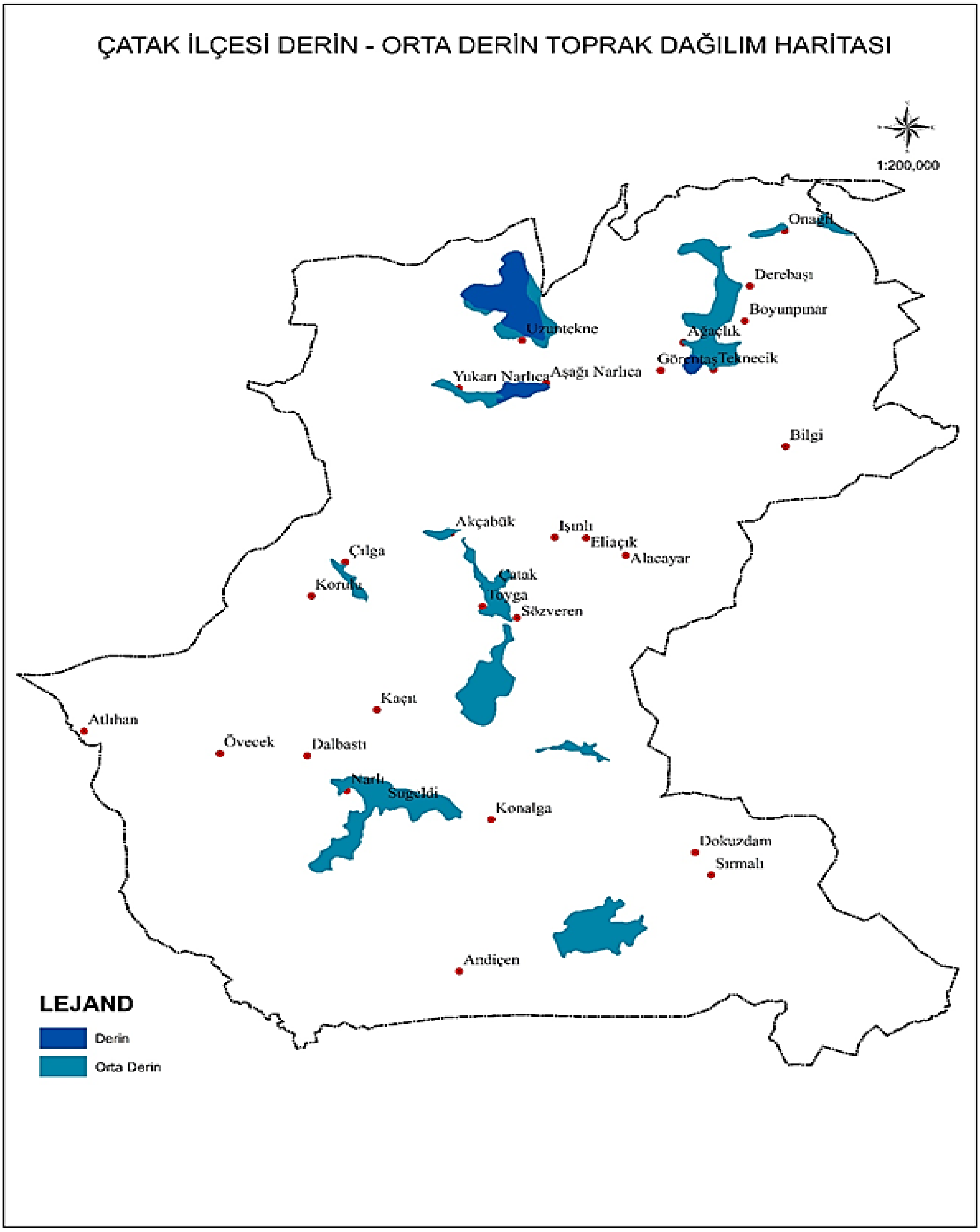

Figure 8. Soil depth map of Çatak district.

Soil Drainage: Although walnut trees are grown in many different soil types, poorly drained soils restrict cultivation (Andales, 2009). Soil drainage map in Çatak district is given in Figure 9, drainage classes and areal distribution are given in Table 11. When the figure is examined, it is seen that the soils with poor and insufficient drainage are around Uzuntekne District.

Çizelge 11. Çatak district drainage status values

Drainage Condition	Area (km^2)	%
Well Drained	1830.99	95.37
Poorly Drained	1.95	0.10
Insufficient Drainage	8.41	0.44
Cliff	78.50	4.09

When Table 11 is examined, it is observed that the soils without drainage problems are in the majority with 95.37%. Rocky areas come second with 4.09%. Soils with poor and insufficient drainage have an area of 4.53%.

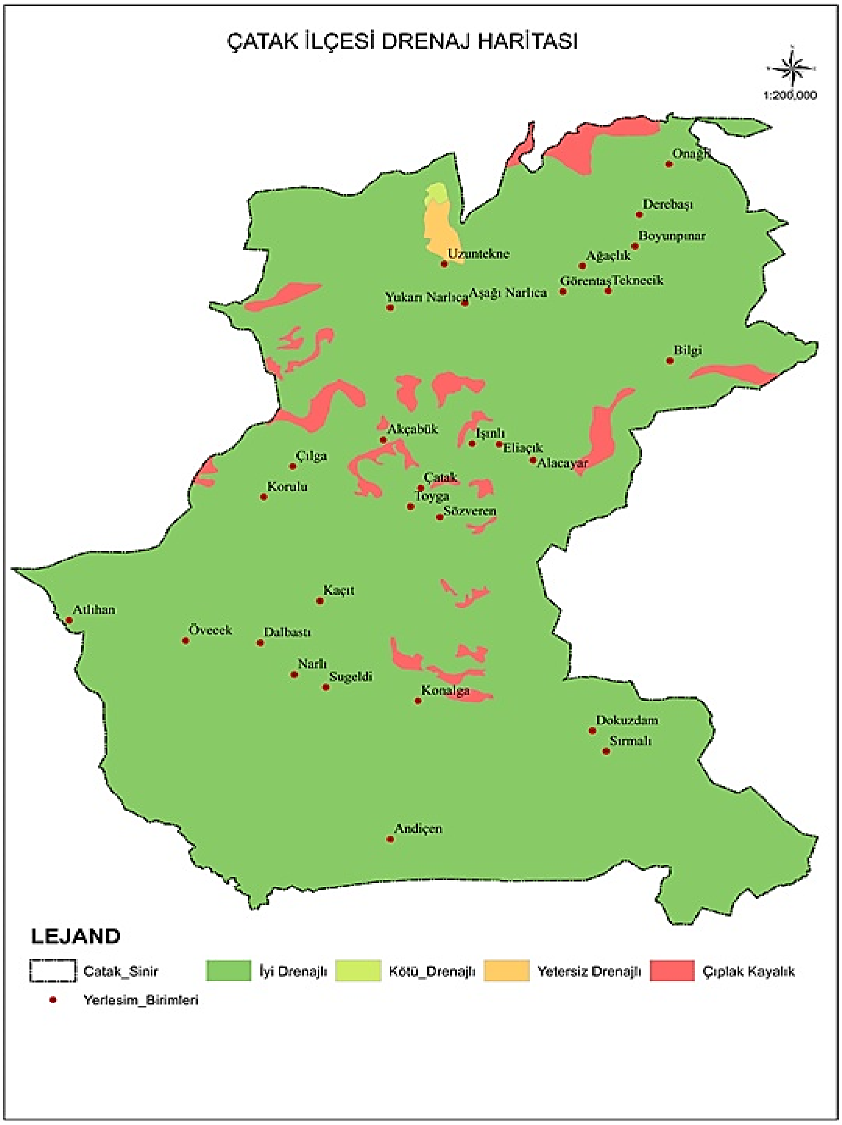

Figure 9. Çatak district soil drainage map.

3.3. Findings of Climate Characteristics

Effective Temperature Sum (ETS): Although there is no study on the effective total temperature at which walnuts can be grown successfully, it is believed that EST is sufficient in Çatak district. The distribution of the Effective Temperature Sum is presented in Table 12 and Figure 10.

Çizelge 12. Çatak'a bağlı yerleşimlerin etkili sıcaklık toplamı

No	Settlement Name	ETS	No	Settlement Name	ETS
1	**Ağaçlık**	1372.9	16	**Işınlı**	1612.0
2	**Akçabük**	1621.1	17	**Kaçıt**	2038.6
3	**Alacayar**	2016.2	18	**Konalga**	2184.4
4	**Andiçen**	1823.6	19	**Korulu**	1731.4
5	**Aşağı Narlıca**	1474.0	20	**Narlı Bucağı**	2043.9
6	**Atlıhan**	2007.1	21	**Onağıl**	1425.0
7	**Bilgi**	1933.6	22	**Övecek**	2337.3
8	**Boyunpınar**	1354.5	23	**Sırmalı**	1741.3
9	**Çatak**	2297.1	24	**Sözveren**	1881.7
10	**Çılga**	1452.5	25	**Sugeldi**	2129.5
11	**Dalbastı**	2159.9	26	**Teknecik**	1409.7
12	**Derebaşı**	1329.9	27	**Toyga**	1985.8
13	**Dokuzdam**	1661.0	28	**Uzuntekne**	1314.4
14	**Eliaçık**	1608.8	29	**Yukarı Narlıca**	1372.9
15	**Görentaş**	1443.3			

The total effective temperature is between 1314 gd (Uzuntekne) and 2337.3 gd (Övecek). As can be seen in Figure 10, the ETS is low in the settlements located in the north of Çatak district, and the ETS increases as you go south. ETS is highest in settlements located in the southwest.

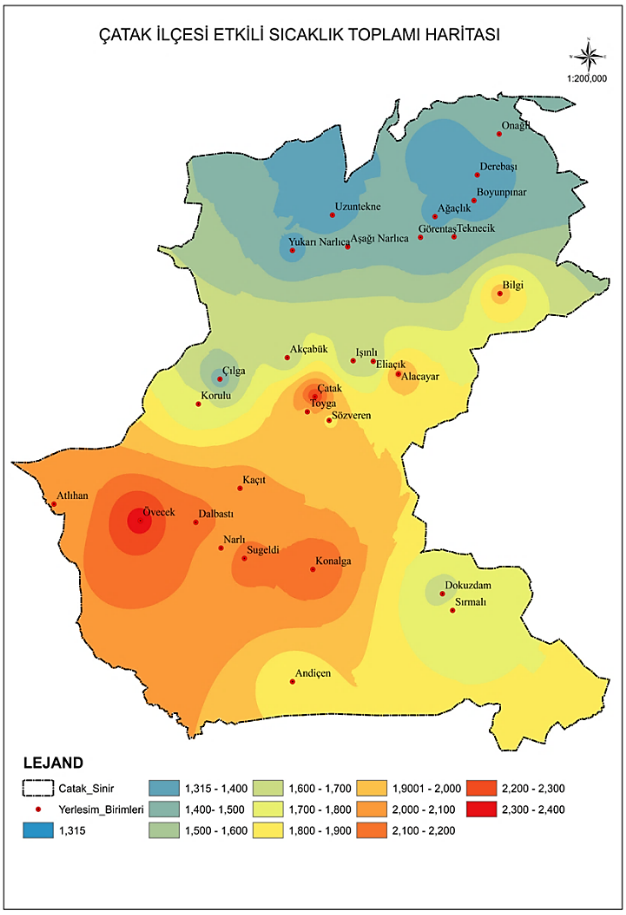

Figure 10. Çatak district effective temperature map.

Cooling Time: If the cold need of the plant is not fully met, low fruit quality such as bud shaking, leaf fall and fruit drop occurs (Chandler, et al., 1937, Şen, 1986, Orman, et al., 2017). The cooling times of the Çatak district and its affiliated settlements are given in Table 13 and Figure 11. When Table 13 is examined, the cooling time varies between the lowest 1058 hours (Toyga) and the highest 5574 hours (Çatak) in the town of Çatak and its settlements. When Figure 11 is examined, it is seen that the lowest cooling period is in the settlements located in the west and southwest. The chilling period in Toyga and Yukarı Narlıca settlements is "Quite Appropriate".

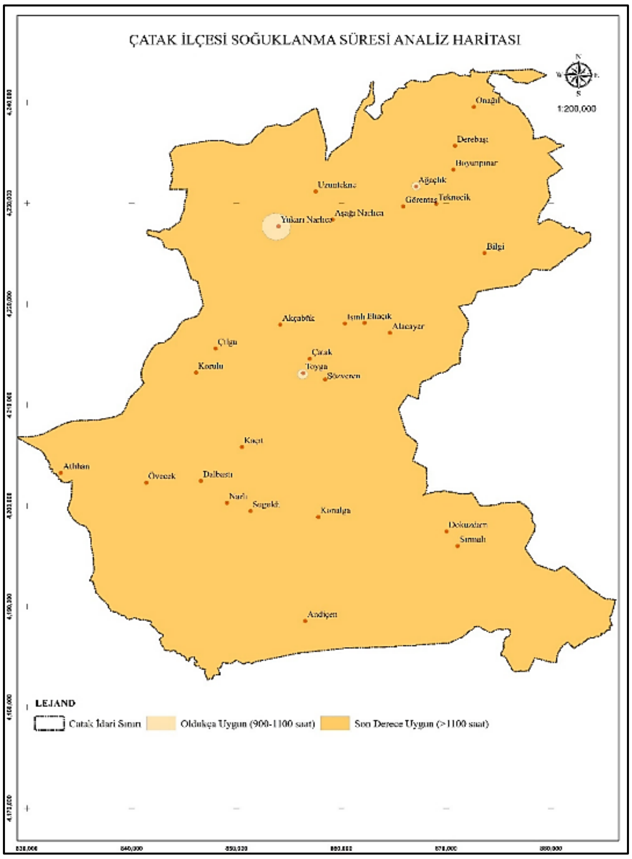

Figure 11. Çatak district cooling time analysis map.

Table 13. Spatial distribution of cooling periods in walnut cultivation in Çatak District

Cooling Time (hour)	Extremely Suitable (The Best) Area (1100-1800)	Pretty Suitable (900-1100)	Suitable (600-900)	Not Suitable (<600)
Area Covered (km^2)	1912.90	6.95	0.00	0.00

When Table 13 is examined, 99.6% of the area is "Extremely Suitable" and 0.4% is "quite suitable" in terms of "Cooling time" in walnut cultivation in Çatak district. However, in extremely suitable areas, measures should be taken against the risk of frost and burning of trees.

Average Temperature During Vegetation Period: The average temperature of the Çatak district and its settlements during the vegetation period is given in Table 14 and Figure 12.

Table 14. Average temperature values of the settlements of Çatak during the vegetation period.

No	Settlement Name	Average Temperature During Vegetation Period (°C)	No	Settlement Name	Average Temperature During Vegetation Period (°C)
1	**Ağaçlık**	12.63	16	**Işınlı**	14.41
2	**Akçabük**	14.56	17	**Kaçıt**	16.89
3	**Alacayar**	16.60	18	**Konalga**	17.39
4	**Andiçen**	15.66	19	**Korulu**	15.13
5	**Aşağı Narlıca**	13.76	20	**Narlı Bucağı**	16.73
6	**Atlıhan**	16.56	21	**Onağıl**	15.53
7	**Bilgi**	16.21	22	**Övecek**	18.10
8	**Boyunpınar**	13.13	23	**Sırmalı**	15.31
9	**Çatak**	17.46	24	**Sözveren**	15.97
10	**Çılga**	13.63	25	**Sugeldi**	17.13
11	**Dalbastı**	17.27	26	**Teknecik**	13.43
12	**Derebaşı**	13.00	27	**Toyga**	16.46
13	**Dokuzdam**	14.73	28	**Uzuntekne**	12.90
14	**Eliaçık**	14.47	29	**Yukarı Narlıca**	13.20
15	**Görentaş**	13.60			

The average temperature during the vegetation period is between 12.63 °C (Wood) and 18.1 °C (Övecek). When Figure 12 is examined, it is seen that the temperature decreases in the north and increases in the south and southwest.

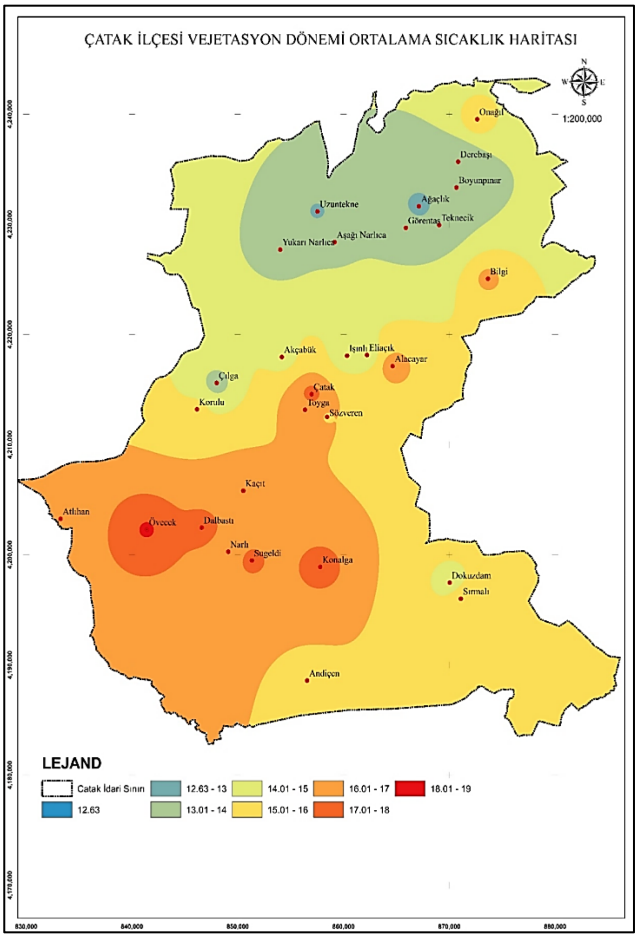

Figure 12. Çatak district effective temperature map.

The cooling times of the Çatak district and its subordinate settlements are given in Table 14 and Figure 12. When Table 14 is examined, the chilling time varies between the lowest 1058 hours (Toyga) and the highest 5574 hours (Çatak) in the town of Çatak and its affiliated settlements. When Figure 9 is examined, it is seen that the low cooling period is observed in the settlements located in the west and southwest. While the cooling period is "Pretty Suitable" in Toyga and

Table 15. Spatial distribution of Vegetation Period Average Temperature in walnut cultivation in Çatak district

Vegetation Period Average Temperature (°C)	Extremely Suitable (The Best) Area (20-28 °C)	Pretty Suitable (18-20 °C)	Suitable (15-18 °C)	Not Suitable (<15 °C)
Area Covered (km^2)	0.00	1.47	1237.22	681.18

When Table 15 is examined, 0.08% of the area is "Pretty Suitable", 64.44% is "Suitable" and 35.48% is "Not Suitable" in terms of "Vegetation Period Average Temperature" in walnut cultivation in Çatak district.

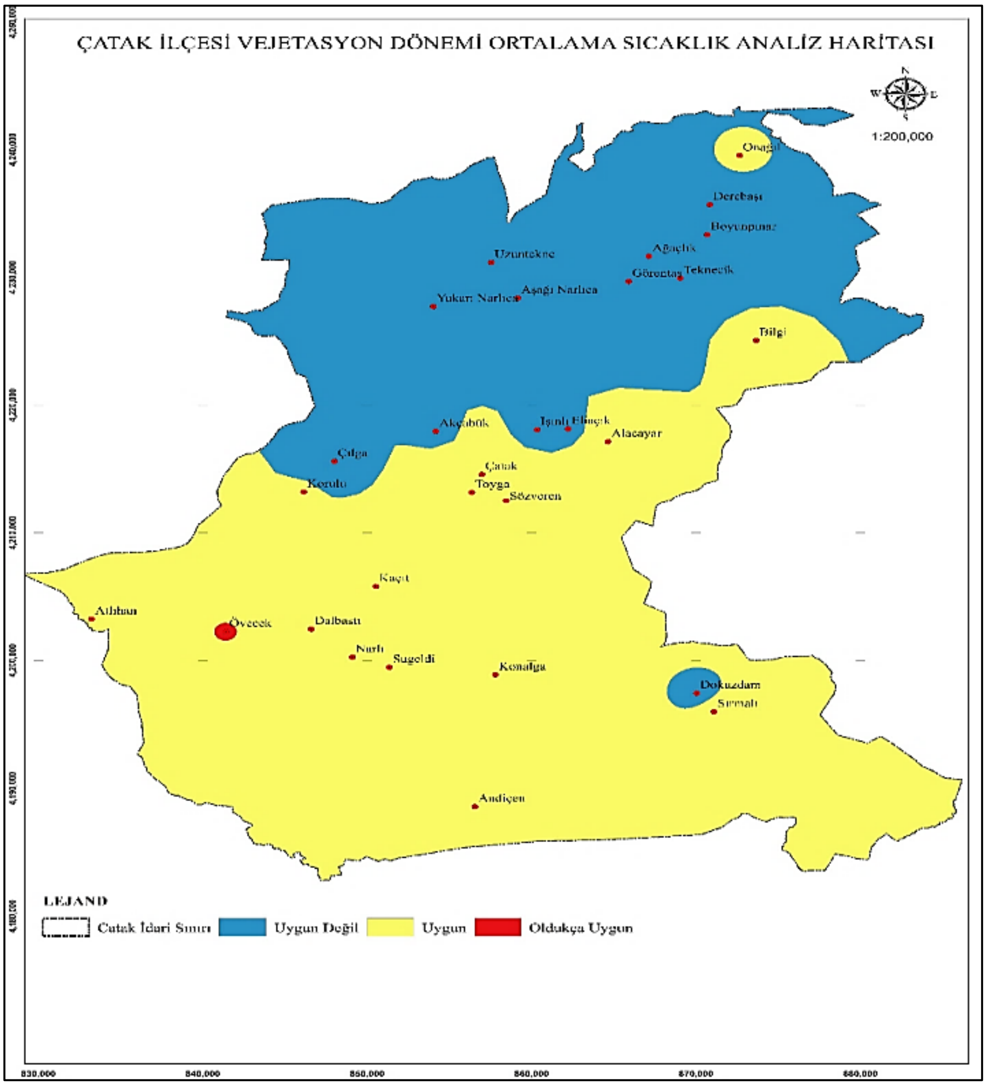

Figure 13. Çatak district vegetation period average temperature analysis map.

Yukarı Narlıca settlements, it is "Extremely Suitable" in other areas.

Minimum Winter Temperature: The minimum winter temperature of Çatak district and its settlements, which indicates the lowest point where the winter temperature drops during the year, according to the averages of many years, is given in Table 15 and Figure 12.

Table 16. Minimum winter temperature of Çatak District and its settlements

No	Settlement Name	Minimum Winter Temperature (°C)	No	Settlement Name	Minimum Winter Temperature (°C)
1	**Ağaçlık**	-8.73	16	**Işınlı**	-6.90
2	**Akçabük**	-6.67	17	**Kaçıt**	-4.60
3	**Alacayar**	-5.00	18	**Konalga**	-4.30
4	**Andiçen**	-5.63	19	**Korulu**	-6.00
5	**Aşağı Narlıca**	-7.47	20	**Narlı Bucağı**	-4.73
6	**Atlıhan**	-4.67	21	**Onağıl**	-7.93
7	**Bilgi**	-5.57	22	**Övecek**	-3.40
8	**Boyunpınar**	-8.33	23	**Sırmalı**	-6.53
9	**Çatak**	-12.57	24	**Sözveren**	-5.50
10	**Çılga**	-7.53	25	**Sugeldi**	-4.37
11	**Dalbastı**	-4.20	26	**Teknecik**	-5.97
12	**Derebaşı**	-8.50	27	**Toyga**	-1.10
13	**Dokuzdam**	-7.03	28	**Uzuntekne**	-8.30
14	**Eliaçık**	-6.90	29	**Yukarı Narlıca**	-3.83
15	**Görentaş**	-7.83			

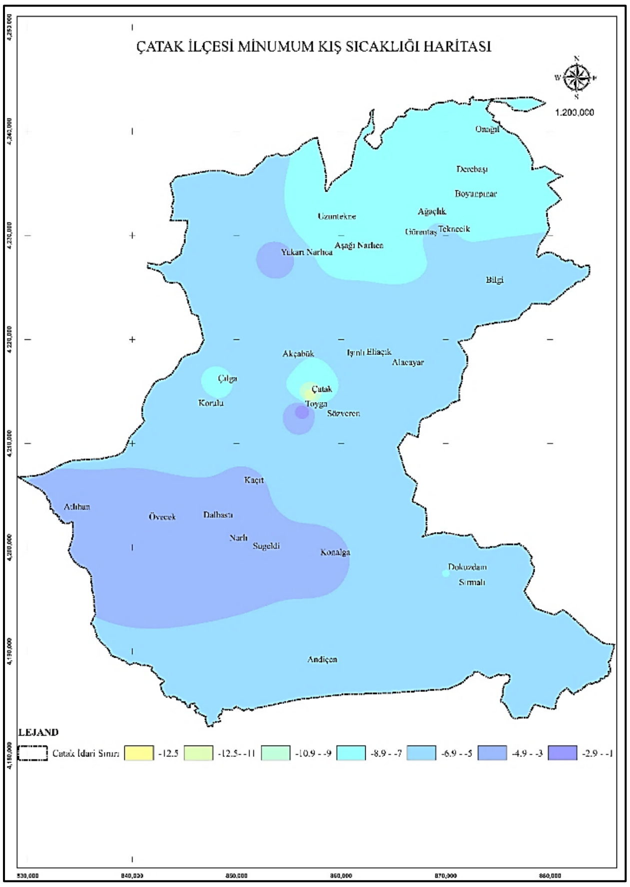

Figure 14. Çatak district minimum winter temperature map.

When Table 16 is examined, the minimum winter temperature varies between -12.57 °C (Çatak-Center) and -1.1 °C (Toyga).

While the southwestern areas of Çatak district are "extremely suitable" for walnut cultivation, the remaining areas seem to be "pretty suitable".

Table 17. Spatial distribution of minimum winter temperature in walnut cultivation in Çatak District.

Minimum Winter Temperature (°C)	Extremely Suitable (The Best) Area (< -5 °C)	Pretty Suitable (-5 -15 °C)	Suitable (-15 - -20 °C)	Not Suitable (> -20 °C)
Area Covered (km^2)	346.05	1573.80	0.00	0.00

When Table 17 is examined, in terms of "minimum winter temperature" in walnut cultivation in Çatak district, 18.03% of the area is "Extremely Suitable" and 81.97% is "Pretty Suitable".

Maximum Temperature: The maximum temperature of the Çatak district and the settlements connected to it is given in Table 18. The maximum temperature is 21.13 °C (Woodwood), the lowest, while the highest is 28.93 °C (Övacak). Since the maximum temperature (<30 °C) in Çatak district and its subsidiaries, 100% of the study area is "Extremely Suitable" for walnut cultivation, this factor has been ignored.

Çizelge 18. Maximum temperature of Çatak District and its settlements

No	Settlement Name	Maximum Temperature (°C)	No	Settlement Name	Maximum Temperature (°C)
1	Ağaçlık	23.13	16	Işınlı	24.85
2	Akçabük	25.03	17	Kaçıt	27.53
3	Alacayar	27.18	18	Konalga	28.10
4	Andiçen	26.13	19	Korulu	25.60
5	Aşağı Narlıca	24.23	20	Narlı Bucağı	27.38
6	Atlıhan	27.20	21	Onağıl	24.05
7	Bilgi	26.80	22	Övecek	28.93
8	Boyunpınar	23.63	23	Sırmalı	25.83
9	Çatak	28.60	24	Sözveren	26.48
10	Çılga	24.05	25	Sugeldi	21.33
11	Dalbastı	27.98	26	Teknecik	23.90
12	Derebaşı	23.50	27	Toyga	27.05
13	Dokuzdam	25.23	28	Uzuntekne	23.38
14	Eliaçık	24.95	29	Yukarı Narlıca	23.68
15	Görentaş	24.08			

Frost Risk: The most dangerous and damaging frost type for walnut cultivation is late spring frosts. In the spring, especially in walnut trees, the female flowers from which the fruits are taken can be damaged very easily, even at -0.2 or -0.4, while the male flowers can withstand up to -1 or -2 degrees. Although the average temperature does not fall below minus (-) degrees in April, which is the beginning of the vegetation period in Çatak district and its villages, instant temperature changes may pose a risk of frost. Since the average temperature in April of the settlement areas located in the north of Çatak district is greater than 0 °C, there is no risk of spring frost. It is also an important fact that immature shoots are damaged by early autumn frosts (Anonymous, 2020).

3.4. Suitability Analysis

The spatial distribution of walnut production suitability analysis in Çatak district with the overlay technique depending on 6 limiting factors is given in Figure 13 and Table 19. When Figure 15 is examined, it is seen that the areas suitable for walnut production are "Pretty Suitable" and "Suitable" areas, and these areas are concentrated in the southern parts of the district compared to the northern parts.

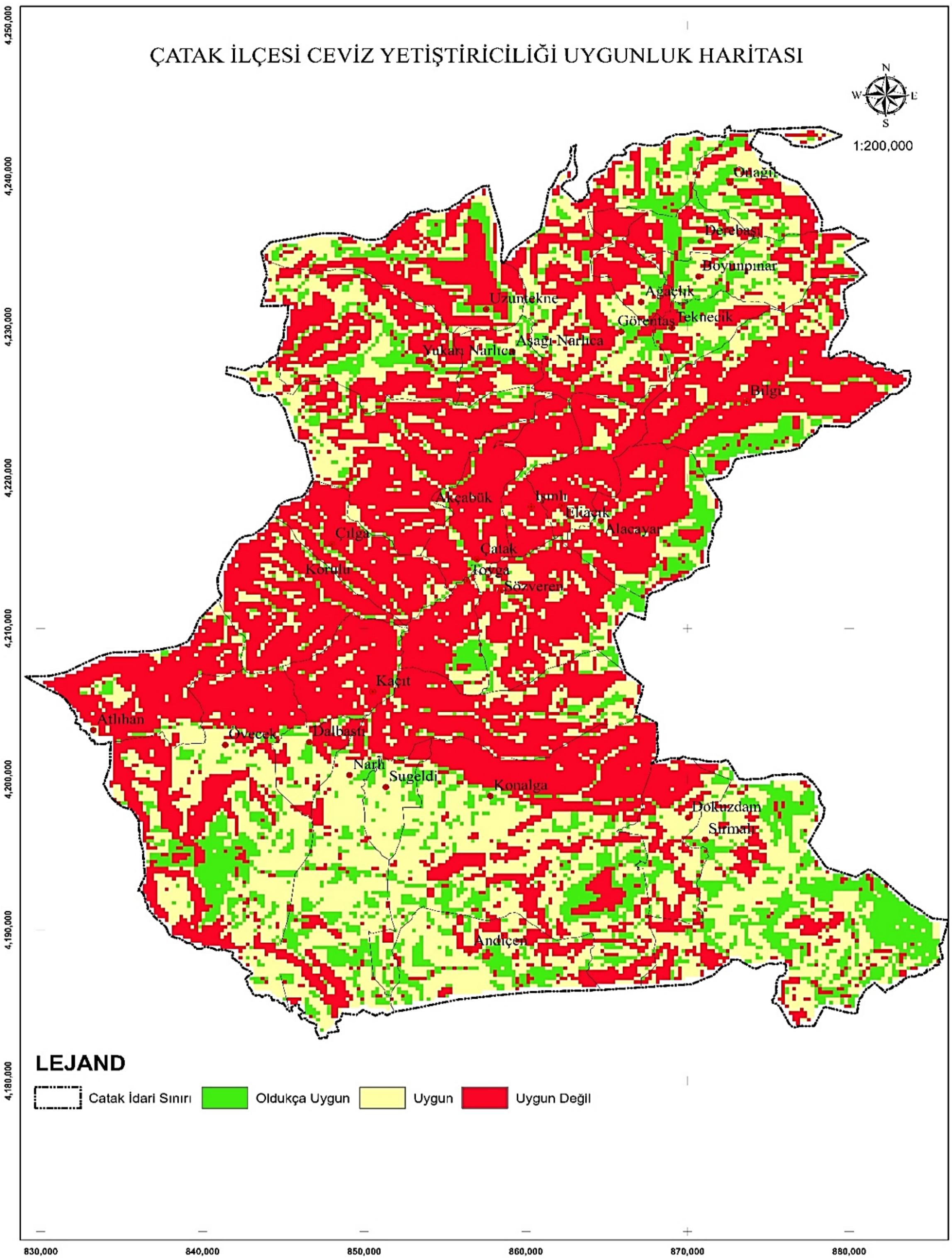

Figure 15. Çatak district walnut suitability map.

Table 19. Spatial distribution of walnut production suitability analysis.

Walnut Production	Extremely Suitable (The Best) Area	Pretty Suitable	Suitable	Not Suitable
Area Covered (km^2)	0.00	303.23	660.26	956.36

According to the ecological factors determined in Çatak district, 15.79% of the distribution of suitable areas for walnut cultivation was "Pretty Suitable", 34.39% "Suitable" and 49.82% "Not Suitable".

4. DISCUSSION AND CONCLUSION

In this study, suitable areas where targeted walnut varieties can be grown in Çatak district of Van province and the villages of the district were evaluated within the framework of 10 parameters (Altitude, Land Slope, Soil Depth, Soil Drainage, Average Temperature During Vegetation Period, Minimum Winter Temperature, Maximum Temperature, Chilling Requirement, Early Spring Frosts and Autumn Late Frosts) and modeled with GIS software. However, parameters such as Soil Depth, Maximum Temperature, Spring early frosts and Autumn late frosts have been ignored. It has been noted by many researchers that various results have been obtained by using different types of parameters in our country and different parts of the world. Rumayor-Rodriguez et al., (1998) stated that they determined suitable areas for peach cultivation by using GIS in Mexico. Gündüzoğlu (2004) used GIS to determine the most suitable areas to grow olives in Western Anatolia and stated that natural environmental conditions constitute their database. Yorgancı (2004) stated that suitable wheat cultivation areas for Northern Cyprus were determined using GIS and Dengiz (2006) also stated that the land of Field Crops Central Research Institute İkizce Research Farm located in the southern part of Ankara determined their suitability for surface and drip irrigation methods. Reis and Yomralıoğlu (2006), by using GIS technologies, determined the existing and potential hazelnut areas in Trabzon and Güler et al. (2005) also reported that they determined the production areas of canola, a plant with high commercial value, using GIS technique, and they carried out similar studies in GIS environment by using data such as temperature, precipitation, altitude and soil properties from plant demands in determining the production areas.

Tuğaç and Torunlar (2007) determined the agricultural suitability classes by creating the agricultural suitability index of the land using the cellular analysis method and GIS techniques according to ecological criteria. Wahba et al. (2007) stated that olive, peach, sunflower, melon and corn plants are the most suitable agricultural products for the soils in Farafra oasis in Egypt. Başayiğit and Şenol (2008) also stored the criteria that are important in the selection of fruit growing areas in the form of map layers in the GIS environment and databases containing the attribute information of these data were created. Considering the minimum conditions required for fruit growing, suitable areas were determined with the help of overlay, query and spatial analysis tools from GIS functions. Demir et al. (2011) determined the potential agricultural areas of the İspir district by using GIS. Erol (2012) created a frost risk map by using GIS for late spring frosts, which is one of the biggest problems of apricot growing in Malatya. Delibas et al. (2015) determined suitable areas for alternative crop cultivation (walnut) as a result of overlapping the slope, aspect and soil characteristics and soil maps in a total of 55 villages in the central district of Tekirdağ.

According to the 6 parameters that are used in the analyzes of the study, the areas suitable for walnut production within the boundaries of Çatak district were realized as "Pretty Suitable" and "Suitable" areas. Especially due to the effect of the topographic structure, “Extremely Suitable Areas” for walnut cultivation were not included. The fact that the "Pretty Suitable" and "Suitable" areas for walnut production are seen in the southern parts of the district compared to the northern parts of the district is because they show microclimate characteristics due to the relatively low altitude. The climate analyzes show that the southern part offers more favorable climatic conditions than the northern part of the area. It is important to determine the most suitable areas to increase production capacity, especially considering the environmental factors that form the basis of agroecological zoning due to the altitude of Çatak district over 1000 m and its mountainous terrain. In addition, it is of great importance to select the appropriate walnut variety in line with the topographical, edaphic and climatic characteristics of the area where walnuts will be grown. Therefore, it is necessary to determine the varieties suitable for the climate of the region. For example, considering the altitude, it would be appropriate to plant Chandler walnut saplings at an altitude of 0-1100 meters, and Fernor walnut saplings that bloom late in regions with an altitude of 1100-1800 meters. As in all fruit types, the most important factor limiting the cultivation of walnut is winter and spring frosts. Although there is no frost risk within the boundaries of Çatak district, it is a must to choose cold-resistant late-flowering varieties due to the continental climate. It is recommended for the regions where the altitude is generally higher than 1100 meters and the risk of late spring frost is high, as it is the latest flowering among Fernor walnut saplings at this altitude.

Since the Çatak district has a mountainous terrain, which limits flat and nearly flat areas, it is obligatory to use the terrace method in the cultivation of walnut trees in areas with high slopes. As a result of the aspect analysis, it has been determined that the existing walnut fields generally face southeast, south, southwest, west and northwest directions, and this situation does not cause economic problems for walnuts. In the newly established orchards, attention should be paid to the selection of the aspect according to the type of walnut and for protection against frost damage, the northern aspect should be preferred, and the southern aspect should be preferred for late harvest. In another study conducted by Çelik et al., (1998), it was stated that the type of product and cultivation vary according to the topographic slope, the slope of the land where the vineyards are established is of great importance in terms of climate, 5-10% of the slope of the land in temperate climates and south-facing in cold regions. reported that 10-15% of the slope on the ground may be suitable for viticulture. It is one of the criteria that cannot be preferred to grow walnuts in areas where the slope is high or near flat areas. Goudie (2004), in a study he conducted, stated that although the topographic features of the aspect state vary, especially plant development and snow-type precipitation play a major role in melting and flooding, snow melts are slow on north-facing slopes, and the factors that retain water are weak compared to other slopes in plant development. determined. Aspects should be taken into account in determining areas suitable for walnut cultivation and walnut cultivation should be carried out after the appropriate direction is determined. Within the walnut action plan, there are special afforestation areas throughout Turkey (Anonymous, 2012).

For walnut varieties to adapt to the region and provide optimum benefit, regional studies and product evaluations of the same variety in different regions in the same ecology should be taken into consideration. Taking into account the results of this study, which was carried out by determining the climatic characteristics of the Çatak district with the varieties that have economic importance and can be optimally productive, bringing the right product from the right place to the market at the most appropriate time can provide important contributions to our country's agriculture and producers. The obtained data is important in terms of contributing to both the researchers who want to work on the subject and the producers who want to establish a garden. The use of GIS techniques, which provide great advantages in terms of speed, accuracy, cost and time compared to terrestrial measurements and classical methods, plays an important role in determining and updating the changes in land use types (Özsoy, 2007). In such studies conducted with classical methods, it is very difficult to overlap different data and the margin of error will be quite high in the obtained results. For this reason, the active use of GIS in product pattern determination studies will contribute positively to the determination of agricultural sustainability and alternative crop cultivation (Delibaş et al., 2015).

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