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Application of GIS and AHP for land use suitability analysis: case of Demirci district (Turkey)

Mustafa Topuz [1]✉ & Mehmet Deniz[2]

The current study aims to create a land use suitability map for the Demirci district of Manisa province in which the Analytical Hierarchy Process, one of the multi-criteria decision-making techniques, and Weighted Overlay methods are used. Eleven factors (soil, LCC, OSC, erosion, soil depth, elevation, slope, aspect, geomorphology, temperature, and precipitation) affecting land use were determined according to previous similar studies and expert consultation. Priorities of basic land use types were also designated based on expert consultation. After this process, layer maps were created using GIS software. With these layer maps, a land use suitability map of the district was drawn through an analytic hierarchy process and weighted overlay analysis. The suitability of the land in terms of three different forms of use, namely forest, meadow-pasture, and agricultural areas was revealed. As a result of the study, it has been revealed that the most incompatibility between the current land use and land use suitability is in agricultural land. The results also indicate that most of the areas which should be pasture are used as agriculture and forest areas. The southern slopes of the Simav-Demirci Mountains, Asi Tepe, and its surroundings are suitable for forest areas. The study not only contributes to the local and national economy by revealing unsuitable land uses in the research area suggesting different ways of use but also helps the continuity of the ecosystem by ensuring the protection of natural areas.

[1] Graduate Education Institute, Uşak University, Uşak, Türkiye. [2] Faculty of Arts and Sciences, Uşak University, Uşak, Türkiye. ✉email: mustafa.topuz45@gmail.com

Introduction

The concepts of sustainability and sustainable development are among the important issues that are studied scientifically in almost every field. However, the fact that sustainability can be a solution to problems depends on the development of sustainable practices in everyday life (Arslan, 2018a). Although anthropogenic effects had not been felt much on natural resources until the end of the 17th century, they began to be more effective, especially with industrialization and increasing population (Efe et al., 2008). This case has negatively affected the protection and sustainable use of natural resources. Particularly, the unconscious and excessive use of natural resources that cannot be renewable such as land deteriorates the sustainable use of resources. (Akıncı et al., 2012). Accordingly, in 1992, "United Nations Conference on Environment and Development-Agenda 21" meeting was held in Rio, Brazil, with the participation of 178 countries, and decisions were made at the meeting in accordance with the sustainable use of available resources (Yomralıoğlu, 2011). Agenda 21 consists of four important sections: (a) Social and Economic Dimensions; (b) Conservation and Management of Resources for Development; (c) Strengthening the Role of Major Groups; and (d) Means of Implementation. Notably, the first two of these sections cover topics, such as combating deforestation, protecting the environment, and sustainable settlement (United Nations, 1992). Considering the content of these dimensions, it is outstanding that they are related to land and land use.

The difficulties experienced in land use were generally caused by unplanned activities carried out on behalf of the economy (Arslan, 2018b). Unplanned use of existing lands has brought many social and ecological problems, such as poor transportation, the inefficiency of lands over time, increasing erosion severity, rural-to-urban migration, and rural poverty. Potential analysis and determination of appropriate ways to use the area can be made with land use studies to reach sustainable land use and to prevent unfavorable cases stated above (Yılmaz, 2009). Land use studies can be divided into three stages; determining the current land use of the area, classifying the land-capability, and land use planning (Gözenç, 1978). For sustainable land use, it is remarkable to use existing lands in a planned way based on particular elements. At the stage of land planning, land should be analyzed and the suitable land use should be determined by considering the natural conditions.

Generally, land suitability analyses are carried out by considering the social, economic, and physical elements of the land (Brinkman and Young, 1976; Yang et al., 2007, 2021; Akbulak, 2010; Abbaspour et al., 2011) and show opportunities and constraints of prescribed land use (Liu et al., 2014). The analysis of this study focused on only physical elements, which have been stated clearly in the methodology. These elements could involve elevation, slope, soil, geomorphology, etc. One of the methods used in land suitability analyses, in which many elements are included, is the multi-criteria decision-making (MCDM) process (Carver, 1991; Malczewski, 1999; Cengiz and Akbulak, 2009; Karaatlı et al., 2015; Abudeif et al., 2015; Dağlı and Çağlayan, 2016). The GIS and MCDM processes provide significant benefits. The analytical power provided by the MCDM process and the spatial advantages of GIS are more effective when they are used together in analyses made for different purposes (Banai, 1993; Mendoza, 1999; Feizizadeh and Blaschke, 2013a; Abedi Gheshlaghi et al., 2020).

This study is aimed to determine the suitability of the Demirci district for land use and to identify non-suitable situations in the current land use. The analytical hierarchy process, which is one of the MCDM methods, was used by integrating it with GIS. The priorities of the criteria were determined by the pairwise comparison method developed by Saaty (1980). The layer maps prepared using the GIS were introduced into the weighted overlay analysis by taking into account the priorities determined by the analytical hierarchy process (AHP) and suitable areas were determined for agriculture, forest, and pasture areas. Suggestions were offered to obtain the highest efficiency from existing lands and ensure sustainable land use through the data obtained by comparing the results with the existing land structure. This study contributes to the protection of the natural environment and suggests using the area for different purposes by revealing the situation of unsuitable land use in a rural area in terms of economic, social, and cultural features compared to settlements around developed regions of Turkey.

The research area is in the Manisa Province, one of the most industrialized and urbanized regions of Turkey. Although Manisa is a highly populated and industrialized center, we cannot say that the entire province is socioeconomically developed. Manisa ranks first among the most developed provinces of Turkey in terms of socio-economic development. If one looks at the situation of the Demirci in this regard, it is among the undeveloped centers of 427th rank in the development ranking, which covers about 900 districts in Turkey. In addition, it is located at the lower ranks as a 4th-level district in Turkey's settlement hierarchy (Acar et al., 2022). Demirci is a district in the province of Manisa where urbanization is at the lowest level and mainly rural economic activities are carried out. For this reason, the district of Demirci was chosen as the research area. The study has a remarkable subject since it tries to reveal how land, the most valuable resource in the fields, where rural activities are carried out, is used. Moreover, trying to find out the land use suitability has increased the significance of the study.

The statistical data in Turkey are gathered based on the district boundaries, which are the smaller unit that accounts for the provinces, according to the Nomenclature of Territorial Units for Statistics (NUTS). Besides, the plans are prepared considering these data. For this reason, the research area has covered the borders of the district to be the basis for the management and regional plans made for the Demirci district. The boundaries of the research field are restricted to this district to obtain more useful and practical results for this analysis.

After this part, some geographical features and the location of the study area have been explained. The second section (Methods) shows how AHP and GIS were applied. The methodology also includes how the criteria used in the analysis are selected and weighted in the study. The results section consists of analysis findings and maps created according to these findings. In the last part of the study, the findings were interpreted.

Location and geographical features of the area

The study area is located in the Inner Western Anatolia part of the Aegean Region. Demirci district, administratively a part of Manisa Province, borders Balıkesir and Kütahya in the northeast of the province (Fig. 1).

The Menderes massif, consisting of gneisses, micaschists, and marbles, formed in the Paleozoic and metamorphosed in the Caledonian and Hercynian orogeny, forms the basis of the Demirci district's terrain. The study area is located in the northern part of the Menderes Massif. There are sediments of Precambrian-aged gneiss, granite, and andesite of Middle Miocene age, dacite, rhyolite, as well as Mesozoic-aged limestone, sandstone, a conglomerate in the area (Atalay and Mortan, 2011; Ceylan, 2011; Topuz, 2020).

Demirci, which has a very rough field, has the appearance of a plateau in general terms (Taşlı, 1992). There are three different mountainous areas in the field, which consist of plateaus that are deeply split by rivers. The first of these is the Simav-Demirci

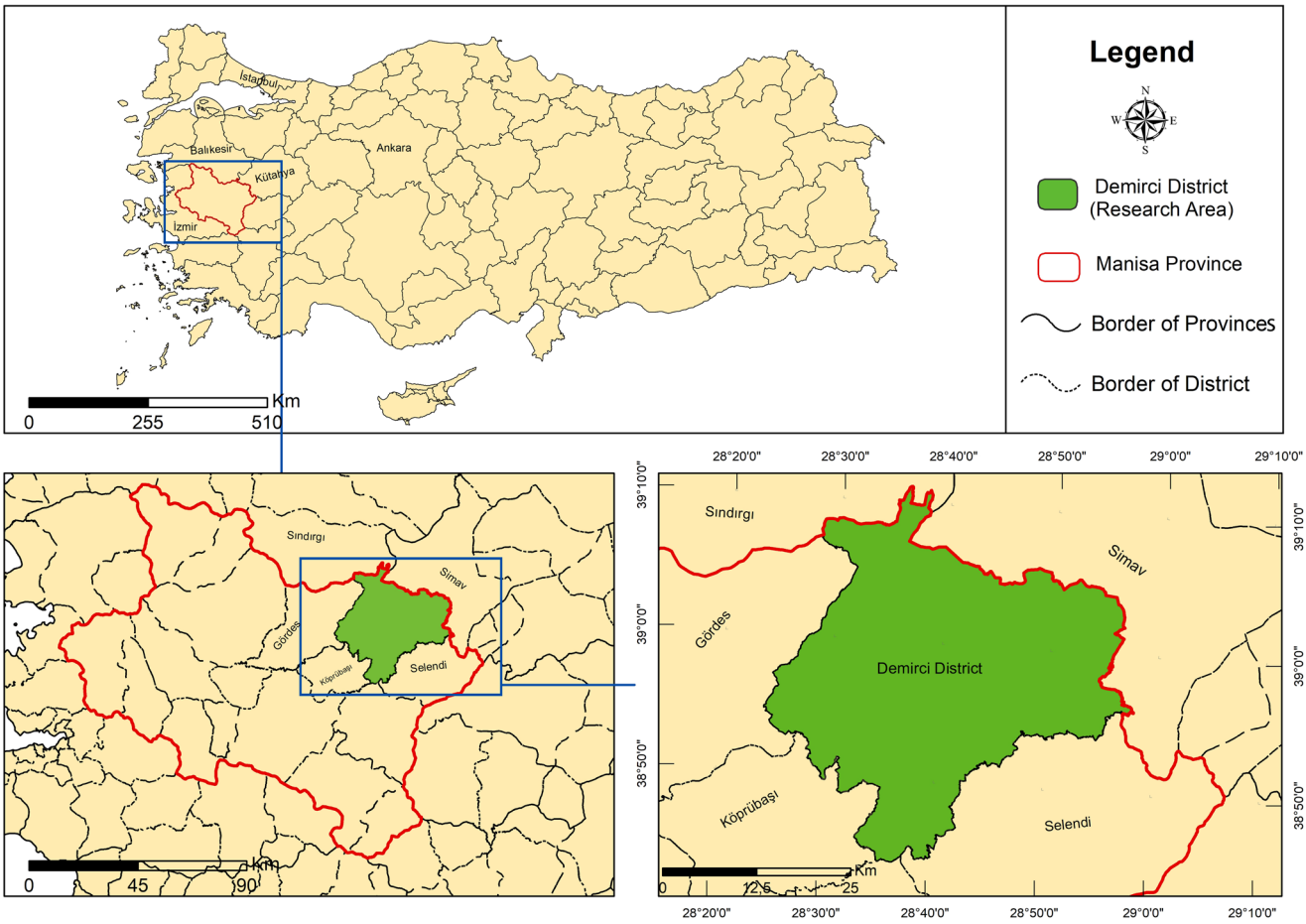

Fig. 1 The location of the study area in Manisa province, Turkey. This figure is covered by the Creative Commons Attribution 4.0 International License. Copyright © the authors, all rights reserved.

Mountains stretching along the northern border of the county. Türkmen Hill (1487 m), located at the westernmost end of this mountain range, is one of the highest parts of the field, and Bardakçı Mahallesi, the highest settlement in the study area, is on this mass. Another mountainous area is Çomaklı Mountain, which extends from Türkmen Hill to the southwest. Asi Hill (1535 m), fully located within the boundaries of the district, constitutes the third mountainous area in the field (Topuz, 2020). The field, which is based on andesite, is a horst due to faults in its east and west (Taşlı, 1992).

In the district where the roughness is high, there is a large alluvial deposit suitable for agriculture in the area where the confluence of tributaries of Demirci Stream, Çad Stream, and Çiftlik Stream meet. The largest settlement in this area is Aşağı Kılavuzlar village. The Aşağı Kılavuzlar Plain, which has the same name as the village, is 10–12 km long and 1–2 km wide in the north-south direction (Ünlü, 1998).

Climate is also a significant factor that determines land use. Furthermore, it is more important than soil and relief conditions in deciding the potential of an area (Koçman, 1993). Considering the climatic characteristics of the study area, the average annual temperature is 13.7 °C. In July, the hottest month in the field, the average temperature is 24.4 °C, and in January, the coldest month, it is 3.4 °C. It is seen that the monthly average temperatures in the field do not fall below zero. The situation of precipitation in the field, which has a very important place in the shaping of agricultural activities, is seen that an annual average of 624 mm of precipitation falls on the field. Most of these precipitations occur in the winter and spring seasons (Topuz, 2020).

The district has a very old history in terms of settlement history. Saittai (Ramsay, 1962), an ancient Lydian city in the research area, shows how old the settlement date is. In the first census of the Republic of Turkey (1927), the population of the district consisted of 26,162 people. Except for a few periods in which administrative changes had taken place until 1997, the population increased continuously during the Republican period. In the period from 2000 to the present, the population has been in a decreasing trend with immigration given to abroad (Aydın, 2004). Today, the population of the research area, which is a district of Manisa province, is 39,258 (TÜİK, 2021).

Methods

Many factors must be taken into account to determine the appropriate use of land. In this regard, the appropriate land use analyses applied during the land planning have a multi-criteria structure (Mendoza, 1999). In the study, MCDM analysis and analytical hierarchy process (AHP) supported by GIS were applied. Analyses were made with Arcgis 10.2 software. A field study was also conducted in order to prepare the data and to see the accuracy of the results of the analysis.

AHP is a general measurement theory developed by Thomas L. Saaty in the 1970s. AHP, which is used to create ratio scales from both continuous and discrete pairwise comparisons in multi-criteria complex structures, enables the determination of numerical weight values by considering the relationships between more than one factor at the same time (Saaty and Vargas, 2012). In another study, AHP can be defined as an MCDM process designed to eliminate the difficulties that arise in the multi-center

Table 1 Sub-criteria values for land use types.

	Agriculture	Meadow and pasture	Forest		Agriculture	Meadow and pasture	Forest
Soil type				**Elevation (m)**			
Noncalcic brown forest soils	5	8	10	224–750	10	1	1
Noncalcic brown soils	5	8	5	750–1000	7	4	2
Alluvial soils	10	1	1	1000–1250	5	8	5
Rendzina soils	8	3	3	1250–1750	1	7	10
Chestnut soils	3	4	5	1250+	1	9	10
Brown forest soils	8	8	10	**Slope (%)**			
Reddish chestnut soils	3	4	5	0–2	10	1	1
Rock debris	0	1	1	2–6	8	10	1
LCC				6–12	6	10	5
I	10	1	1	12–20	4	7	7
II	10	1	1	20–30	2	3	10
III	10	2	1	30+	0	1	10
IV	6	7	5	**Aspect**			
VI	2	10	10	N	2	3	4
VII	1	10	10	NE	5	5	6
VIII	0	2	1	E	8	8	8
OSC				SE	8	9	10
No limitations	10	10	10	S	8	10	10
Stony	5	8	4	SW	8	9	10
Rocky	1	4	5	W	5	8	7
Soilless	0	2	1	NW	2	5	6
Erosion				**Geomorphology**			
1	10	10	1	Plain	10	1	0
2	8	8	5	Plateau	8	4	4
3	4	3	10	Mountains	0	5	10
4	2	1	10	Valleys	3	1	1
Soil depth				Rough fields	3	7	5
Very shallow (<15 cm)	2	2	2	Rough field on the plateau slopes	4	7	5
Shallow (15–30 cm)	6	6	6	Fans	0	1	0
Moderately deep (30–60 cm)	8	8	8	**Temperature**			
Deep (>60 cm)	10	10	10	7.9–16.4	10	10	10
Precipitation (mm)							
387–550	6	3	1				
550–680	7	4	5				
680–820	10	6	8				
820–988	9	10	10				
988–1274	3	10	10				

and multi-factor decision phase in intuitive, rational, and irrational situations where there is more than one alternative (Harker and Vargas, 1987).

Land use studies can be classified into two main issues. These are the general land division in which the land use forms in an area are divided into three basic land uses agricultural areas, grassland areas (pasture and meadow), and natural vegetation without detail, and private land divisions in which these land use forms are also classified within themselves (Taş, 2006). In the study, the field was divided into three agricultural, pasture, and forest areas, taking into account the land use. It was seen that a similar approach was used in many studies on land use in the past (Hossain et al. 2007; Cengiz and Akbulak, 2009; Akbulak, 2010; Şahin, 2016; Dağlı and Çağlayan, 2016; Everest et al., 2021). According to expert opinion and residents' knowledge, it was determined to use these three land use classes in this study as well. Since the Demirci district is constantly losing population, the settlement areas are no longer expanding to a large extent. It has been taken into account that the low growth will be at the periphery of the current settlements. For this reason, settlement areas were not included in the analysis.

In this study, which was carried out to determine the land use suitability of the Demirci district, similar studies' analyses on land use suitability (Feizizadeh and Blaschke, 2013b; Luan et al., 2021; Al-Taani et al., 2021) were examined and many criteria that can be used in present research have been chosen. Based on researchers' experiences, expert opinions, and field observations, numerous criteria compiled from the literature were reduced to 11 main criteria, namely: land capability classification (LCC), soil type, other soil characteristics (OSC), erosion severity, soil depth, elevation, slope, aspect, geomorphological units, temperature, and precipitation (Table 1 and Fig. 2). After the criteria were selected, weight values were determined for the priorities of the criteria. Later, these criteria were divided into sub-criteria within themselves, and they were graded between 1 and 10 as the lowest 1 and the highest 10, based on previous studies and expert knowledge (Zengin and Yılmaz, 2008; Yılmaz, 2009; Akbulak, 2010; Demir et al., 2011; Akıncı et al., 2012, 2013; Cengiz et al., 2013; Burian et al., 2015; Şahin, 2016; Dağlı and Çağlayan, 2016; Saxena and Jat, 2020). The workflow of the research could be seen in Fig. 3.

The data required for the criteria in the research were collected from field studies and various institutions. Topographic maps of Turkey (from the General Directorate of Mapping)

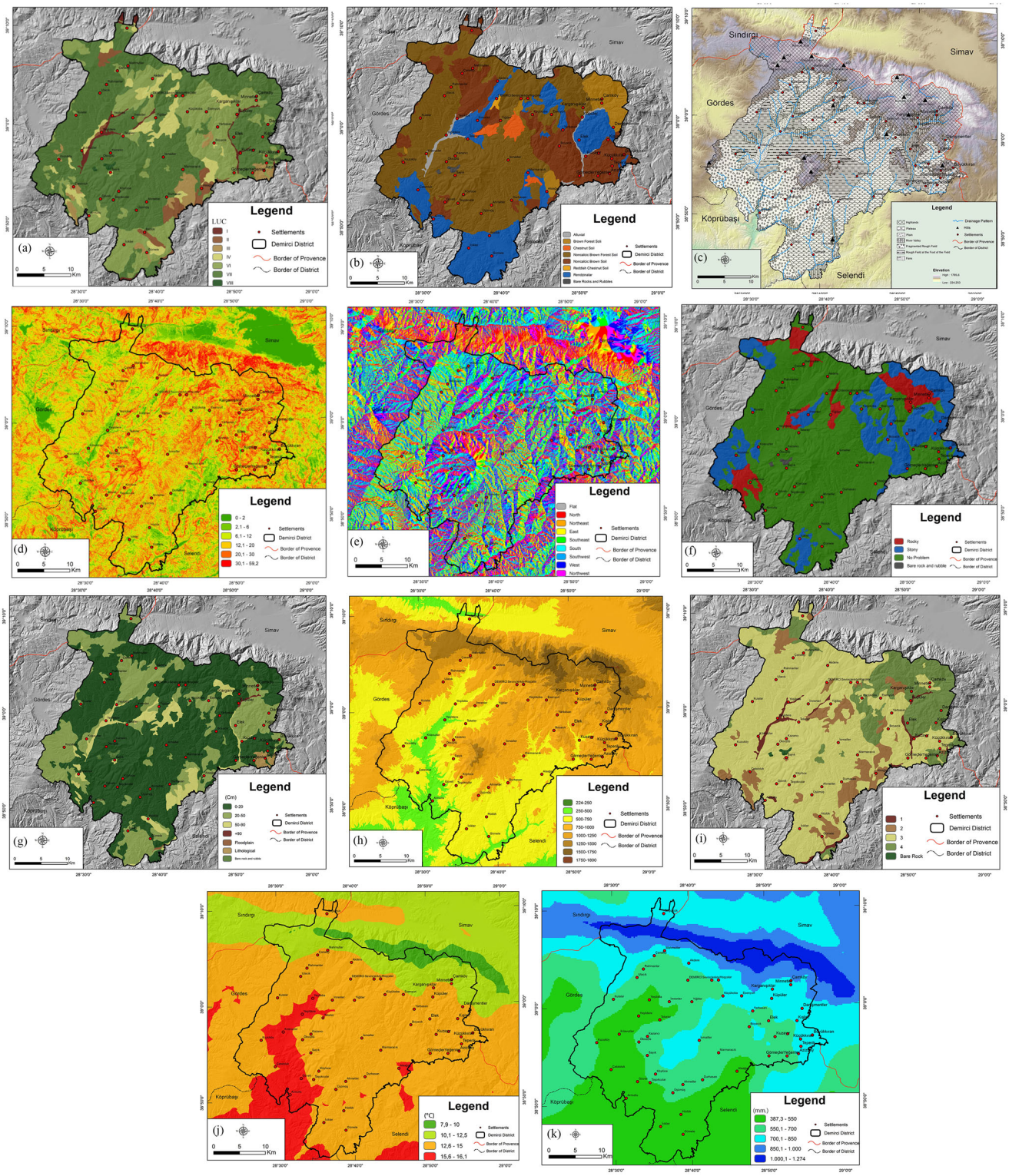

Fig. 2 The criteria used in the analysis. The criteria used in the analysis: land capability (**a**), soil type (**b**), geomorphology (**c**), slope (**d**), aspect (**e**), other soil characteristics (**f**), soil depth (**g**), elevation (**h**), erosion (**i**), temperature (**j**), and precipitation (**k**). This figure is covered by the Creative Commons Attribution 4.0 International License. Copyright © the authors, all rights reserved.

were applied to elevation, slope, aspect, and geomorphology maps. Meteorological data provided by the Turkish State Meteorological Service were used to create rainfall and temperature maps. Soil maps (T.C. Başbakanlık Köy Hizmetleri Genel Müdürlüğü, 1998) prepared by the General Directorate of Soil & Water of the Ministry of Rural Affairs and Cooperatives were utilized to derive the soil characteristics (class, land capability, depth, and erosion).

The main purpose of the application of the analytical hierarchy process is to determine the weight values of the criteria discussed in order to solve the problem and their place in the hierarchical structure at the solution stage. While doing this, the scale in

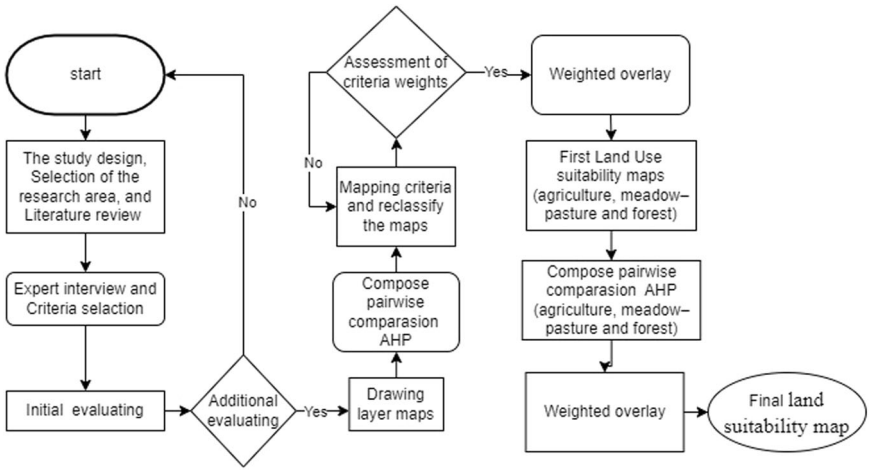

Fig. 3 Workflow of research methodology. This figure is covered by the Creative Commons Attribution 4.0 International License. Copyright © the authors, all rights reserved.

Table 2 The fundamental scale (Saaty, 1990, p. 15).

Intensity of importance on an absolute scale	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Moderate importance of one over another	Experience and judgment strongly favor one activity over another
5	Essential or strong importance	Experience and judgment strongly favor one activity over another
7	Very strong importance	An activity is strongly favored and its dominance demonstrated in practice
9	Extreme importance	The evidence favoring one activity over another is of tile highest possible order of affirmation
2, 4, 6, 8	Intermediate values between the two adjacent judgments	When compromise is needed

Table 2 developed by Saaty was used. While the value of 1 on the scale indicates that there is no superiority between the two criteria, the superiority between the criteria increases as the value heightens. In this structure, the value 9 corresponds to extreme importance (Table 2).

AHP is based on pairwise comparisons between criteria. The pairwise matrix is generally composed of experts' opinions (Ghorbanzadeh et al., 2018). After the pairwise comparison matrices, the first step of AHP was created, and the relative weight vectors of the criteria were calculated. While doing this calculation, first, all the columns were summed and all values in the columns were normalized by dividing by the sum of the columns. Normalizing the values means that the sum of the values in each column is equal to 1 and allows these criteria to be compared. The priority vectors for the criteria are determined by dividing the normalized pairwise matrices by the sum of the column they are in (Topel, 2006; Saaty, 2008; Timor, 2011; Şahin, 2016). At the end of this whole process, it was necessary to determine whether the hierarchical structure created was usable or not. The consistency ratio (CR) was determined according to Eq. (1) to identify whether the structure was consistent. The consistency ratio was calculated by dividing the consistency index (CI) by the random index (RI) corresponding to the number of criteria (Saaty and Kearns, 1985). The index value (Table 3) that coincides with the number of criteria in the random index was processed. Consistency index calculation method is given in Eq. (2). In order to determine the consistency index used at this stage, the principal eigenvalue (λ_{max}) was calculated in two steps. First, the weighted total vector was found by multiplying the comparison matrices and the priority vectors. In the second step, after each element of the weighted total vectors had been divided by its priority value, the maximum eigenvalue was found by taking the arithmetic average of the values (Yılmaz, 1999; Saaty, 2004; Yalçın, 2005; Eleren, 2007; Öztürk and Batuk, 2007; Aydın et al., 2009). The application developed by Goepel (Goepel, 2018 was used to determine the priorities in the analytical hierarchy process.

$$\mathrm{CI} = \left(\lambda_{\max} - n\right)/(n-1) \quad (1)$$

$$\mathrm{CR} = CI/RI \quad (2)$$

The suitability of the hierarchical structure created as a result of AHP for analysis depends on the consistency ratio. When the studies on the subject were examined, although it was accepted that different consistency rates were suitable for the analysis, Saaty stated that the acceptable consistency rate in his studies was 10% (0.1) (Saaty, 1990). Hierarchical structures below this ratio were considered consistent, while hierarchical structures above this ratio were considered inconsistent and not suitable for analysis (Öztürk and Batuk, 2007). As a result of the pairwise matrices created for three different forms of land use, the consistency ratio was calculated as 0.085 for agricultural areas, 0.062 for pasture areas, and 0.075 for forest areas (Tables 4–6).

In the second stage of the land suitability analysis, the human characteristics of the field were taken into account, the land use forms were included in the AHP, and priority vectors were

Table 3 Average random index (RI) (Saaty, 1980).

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1,49	1.51	1.48	1.56	1.57	1.59

Table 4 Pairwise comparison matrix for agriculture.

	Soil	LCC	OSC	Erosion	Soil depth	Elevation	Slope	Aspect	Geom.	Temperature	Precipitation
Soil	1.0	0.2	5.0	6.0	3.0	5.0	0.3	5.0	5.0	0.3	0.3
LCC	5.0	1.0	7.0	7.0	4.0	7.0	3.0	5.0	5.0	3.0	3.0
OSC	0.2	0.1	1.0	2.0	0.3	0.5	0.2	2.0	0.3	0.3	0.3
Erosion	0.2	0.1	0.5	1.0	0.3	2.0	0.2	0.3	0.3	0.2	0.2
Soil depth	0.3	0.3	3.0	4.0	1.0	4.0	0.3	3.0	2.0	0.3	0.3
Elevation	0.2	0.1	2.0	0.5	0.3	1.0	0.3	0.5	0.3	0.3	0.3
Slope	4.0	0.3	5.0	5.0	4.0	4.0	1.0	5.0	3.0	0.5	0.5
Aspect	0.2	0.2	0.5	3.0	0.3	2.0	0.2	1.0	0.5	0.2	0.2
Geom.	0.2	0.2	4.0	4.0	0.5	3.0	0.3	2.0	1.0	0.3	0.3
Temperature	3.0	0.3	4.0	5.0	3.0	3.0	2.0	5.0	4.0	1.0	1.0
Precipitation	3.0	0.3	4.0	5.0	3.0	3.0	2.0	5.0	4.0	1.0	1.0

Table 5 Pairwise comparison matrix for meadow and pasture.

	Soil	LCC	OSC	Erosion	Soil Depth	Elevation	Slope	Aspect	Geomorphology	Temperature	Precipitation
Soil	1.0	0.2	0.5	0.3	3.0	0.3	0.3	4.0	0.5	0.5	0.3
LCC	5.0	1.0	5.0	4.0	6.0	2.0	3.0	6.0	4.0	4.0	3.0
OSC	2.0	0.2	1.0	0.3	3.0	0.2	0.3	3.0	0.3	0.5	0.3
Erosion	4.0	0.3	3.0	1.0	4.0	0.3	2.0	4.0	2.0	2.0	2.0
Soil depth	0.3	0.2	0.3	0.3	1.0	0.3	0.3	2.0	0.2	0.5	0.3
Elevation	4.0	0.5	6.0	3.0	4.0	1.0	2.0	6.0	2.0	2.0	3.0
Slope	3.0	0.3	3.0	0.5	4.0	0.5	1.0	4.0	2.0	2.0	2.0
Aspect	0.2	0.2	0.3	0.3	0.5	0.2	0.3	1.0	0.2	0.3	0.3
Geomorphology	2.0	0.3	3.0	0.5	4.0	0.5	0.5	6.0	1.0	2.0	2.0
Temperature	2.0	0.3	2.0	0.5	2.0	0.5	0.5	3.0	0.5	1.0	0.5
Precipitation	3.0	0.3	3.0	0.5	3.0	0.3	0.5	4.0	0.5	2.0	1.0

Table 6 Pairwise comparison matrix for forest.

	Soil	LCC	OSC	Erosion	Soil Depth	Elevation	Slope	Aspect	Geomorphology	Temperature	Precipitation
Soil	1.0	0.1	2.0	0.17	2.0	0.20	0.17	0.50	0.33	0.25	0.20
LCC	7.0	1.0	6.0	4.0	6.0	3.0	4.0	6.0	6.0	22.0	3.0
OSC	0.5	0.2	1.0	0.20	0.3	0.20	0.20	0.33	0.20	0.20	0.17
Erosion	6.0	0.2	5.0	1.0	5.0	0.25	1.0	5.0	3.0	0.50	0.50
Soil depth	0.50	0.2	3.0	0.20	1.0	0.25	0.25	0.30	0.33	0.25	0.20
Elevation	5.0	0.3	5.0	4.0	4.0	1.0	4.0	6.0	6.0	2.0	3.0
Slope	6.0	0.3	5.0	1.0	4.0	0.25	1.0	6.0	2.0	0.33	0.33
Aspect	2.0	0.2	3.0	0.20	3.0	0.17	0.17	1.0	0.50	0.25	0.20
Geomorphology	3.0	0.2	5.0	0.33	3.0	0.17	0.50	2.0	1.0	0.50	0.50
Temperature	4.0	0.5	5.0	2.0	4.0	0.50	3.0	4.0	2.0	1.0	0.50
Precipitation	5.0	0.3	6.0	2.0	5.0	0.33	3.0	5.0	2.0	2.0	1.0

determined. Considering the geomorphological characteristics of the area, although it was not suitable for agricultural activities, agriculture was still the most important source of income due to the lack of development of alternative economic activities (Aydın, 2004). As in the previous stages, fieldwork and expert opinion were also taken into account in this part. In the analysis, agriculture, which was the most important economic activity of the district, was prioritized over pasture and forest areas. In the 2019 data of Demirci District Directorate of Agriculture and Forestry (Demirci District Directorate of Agriculture and Forestry, 2019), there was a total of 113,533 animals, including 96,642 ovine and 20,890 cattle, in the field. These data show that pastures in the field are very important in stock farming. For this reason, pasture areas were analyzed considering that they were as important as forest areas (Table 7). The order of importance of the hierarchical structure created by AHP was determined as agricultural areas, pasture, and forest areas. The consistency rate (CR) in the AHP created for land use forms was calculated as 0.019.

Land suitability scores of the analysis were calculated according to Eq. (3). In the equation SI: Land suitability index; W_i: Weight of the land suitability sub-criterion i; μ_i is the sub-criterion grade of the land suitability criterion for i; n is the number showing how

many land suitability criteria are used (Cengiz et al., 2013; Zhang et al., 2015). The criterion weights (priority vectors), varying between 0–1 and their sum as 1, of the factors in determining land use, were calculated according to this equation (Table 8).

$$SI = \sum_{i=1}^{n} (Wi.\mu i) \quad (3)$$

In the last part of the study, the weighted overlay method was used by applying ArcMap 10.2 software and a land use suitability map of the Demirci district was created. Input datasets and maps were georeferenced to research area WGS-1984 UTM Zone 35N.

The land suitability map created from weighted overlay analysis was reclassified as FAO's land suitability classification. In this classification, each class reflects degrees of suitability (Brinkman and Young, 1976). In this paper land suitability maps, as in similar studies (Feizizadeh and Blaschke, 2013b; Otgonbayar et al., 2017; Luan et al., 2021; Everest et al., 2021), shows four classes as follows: (a) unsuitable, (b) marginally suitable, (c) moderately suitable, and (d) highly suitable.

Results

The purpose of the study is to determine and map the land use suitability of the field by taking into account the characteristics of the land in the Demirci district. In the analysis phase of the study, both the main criterion and sub-criteria weights of the criteria included in the analysis should be calculated separately. Although the effective rate of a criterion in the analysis is low, sub-criteria can also play a limiting role in the field (Dağlı and Çağlayan, 2016).

Table 7 Pairwise comparison matrix for land use types.

	Agriculture	Meadow and pasture	Forest
Agriculture	1	3.00	6.00
Meadow and pasture	0.33	1	3.00
Forest	0.17	0.33	1

Table 8 Priority vectors used in the analysis.

	Agriculture	Meadow and pasture	Forest
Soil type	0.102	0.042	0.025
LCC	0.26	0.247	0.25
OSC	0.027	0.043	0.018
Erosion	0.021	0.117	0.088
Soil Depth	0.061	0.026	0.025
Elevation	0.026	0.173	0.195
Slope	0.135	0.104	0.082
Aspect	0.029	0.02	0.032
Geomorphology	0.049	0.092	0.051
Temperature	0.144	0.058	0.11
Precipitation	0.144	0.077	0.126

In the suitability analysis for the Demirci district, it is determined that the district lands are not very suitable for agriculture. The area of 837 km^2, which corresponds to 67.19% of the area, consists of marginally suitable areas for agriculture. Pasture areas are very substantial in the district where animal husbandry is very intense. Considering the lands that may be suitable for pasture, it is seen that most of the field consists of Moderately Suitable (42.52%) and Highly Suitable (43.91%) lands. Regarding the topographic conditions of the district, it is seen as a result of the analysis that the current land use is suitable for forestry (Table 9).

As a result of the analysis, four particular fields have been determined as moderately suitable or highly suitable for agricultural activities. Areas with a slope of 2–6% at an altitude of 1500 m in the northeast of Türkmen Mountain are suitable for agriculture. Another suitable field for agriculture is the area consisting of Class I lands formed by Minnetler Stream. İçikler Plateau (east part of the district, 500–750 m), which consists of Land Capability Class II and Class III, is another place suitable for agriculture. The fourth area, which is suitable for agriculture in the field, is the Kılavuzlar Plain, which stretches along the Yeşiloba, Yeşildere, and Kılavuzlar villages formed by the Demirci Stream (Fig. 4).

The field stretching along the northern border of the district in the east–west direction along the west of Türkmen Mountain, north and west of Çanakçı and Mahmutlar villages, and the Simav-Demirci Mountains is highly suitable for pasture areas. The area forming the western border of the district and extending from Çomaklı Mountain to the north to Türkmen Mountain and the northeast of Asi Hill are also very suitable for pastures. The lands in the south along with the Demirci Stream, the west of Yeşiloba, Yeşildere, and Kılavuzlar villages constitute moderately suitable areas for pasture (Fig. 5).

As a result of the weighted overlay analysis applied, the Simav-Demirci Mountains forming the northern border of the field, mostly class VII areas where with a slope of +20%, the soil depth is very shallow and the elevation is more than 1250 m have been determined as highly suitable areas for forestry. One of the most suitable areas for forestry in the district is Asi Hill and its surroundings where the slope has increased considerably (Fig. 6). Areas with an elevation of more than 1000 m and lands with a slope of more than 30% constitute highly suitable areas for forestry.

The suitability maps produced for the determined land use forms were re-analyzed in the ArcMap environment and the appropriate land use map of the area was created. The present land use map of the field was prepared using CORINE 2018 data and field observation. The CORINE project was first started in the European Union countries in 1985, especially in order to reveal the changes in land use today, and Turkey was included in the project in 1998. While generating CORINE land use data, the land is classified into three levels. At the first level, the land is divided into five basic uses. At the second stage, the five main land use types are divided into 15 subclasses. At the third and most detailed level, land use forms are classified into 49 groups in

Table 9 The land suitability of Demirci District.

	Agriculture		Pasture		Forest	
	Area (km^2)	Ratio (%)	Area (km^2)	Ratio (%)	Area (km^2)	Ratio (%)
Highly suitable	93.11	7.48	547.00	43.91	330.43	26.53
Moderately suitable	303.21	24.34	530.32	42.52	761.67	61.14
Marginally suitable	837.03	67.19	161.98	13.01	54.04	4.34
Not suitable	12.34	0.99	6.39	0.56	99.55	7.99
Total	1245.69	100.00	1245.69	100.00	1245.69	100.00

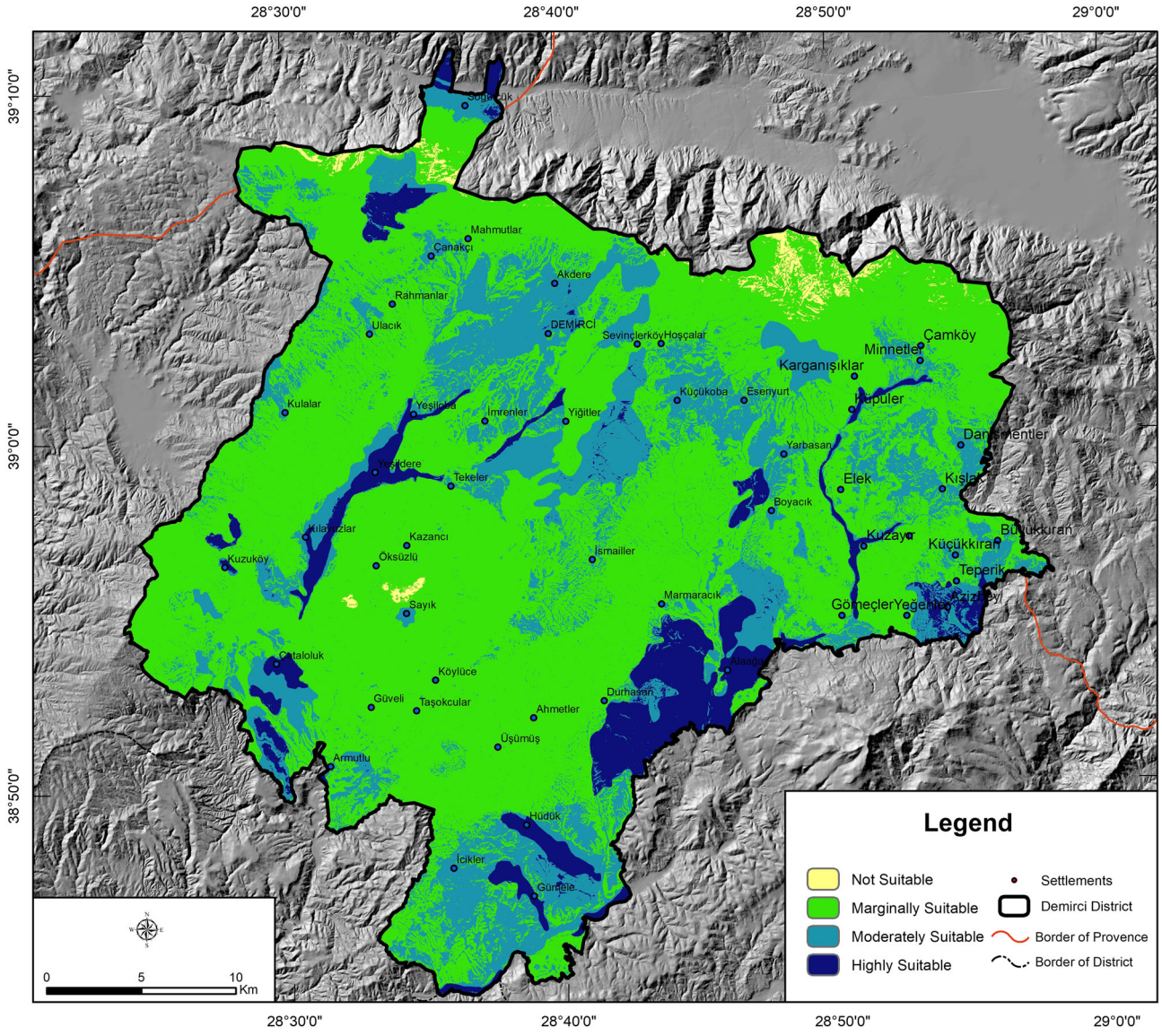

Fig. 4 Land-use suitability for agriculture. This figure is covered by the Creative Commons Attribution 4.0 International License. Copyright © the authors, all rights reserved.

which human and natural structures are completely separated from each other (Başayiğit, 2004; CORINE Copernicus Land Monitoring Service, 2018). Considering the topographical conditions of the field, suitable fields for agricultural lands are quite low. Regarding the current land use prepared using CORINE 2018 data, 44.4% of the study area consists of agricultural areas (Table 10). As a result of the analysis, 236.7 km^2, which corresponds to 19% of the field, constitutes suitable areas for agriculture. The fact that there is a big difference between these two data reveals that the lands that are not suitable for agriculture in the field have been destroyed over time and turned into agricultural areas (Fig. 7).

Evaluating the current land use, it was seen that 167.7 km^2 area was used as pasture. However, an area of 477.8 km^2 was determined as suitable for pasture fields. This situation shows that most of the fields that should be used as pasture are opened for agriculture. Considering the distribution of suitable grasslands in the district, it is seen that the lands are appropriate for pasture in general. Nevertheless, three different fields are seen as suitable for pasture when the fields with the suitable slope for agriculture, low erosion risk, and fertile soil properties are removed. The first of these areas is the foothills of Asi Hill. The surroundings of the Kılavuzlar Plain, which is also suitable for agriculture, is another suitable area for pasturelands. Besides, class VI and class VII lands are suitable areas for pastureland, which has a slope of 2–12% on the Simav-Demirci Mountains and has a high erosion risk.

It is observed that parts of the Simav-Demirci Mountains higher than 1250 m and with a slope of more than 20% are suitable for the forests. Sarıyar Hill, Mazı Hill, Kızılkıran Hill, and its surroundings located in the east of Simav-Demirci Mountains are suitable areas for forestry. Another suitable area for forest areas is the Asi Hill peaks. Within the scope of Corine 2018 data, it is seen that the area around 512.7 km^2 is used as a forest. However, an area of 531.2 km^2 in the district is determined as suitable for forest land (Fig. 8).

Discussion and conclusion

This research aims to reveal the present land use and land use suitability of the Demirci District. For this purpose, individual maps of the research area were drawn. In the next stage, the criteria for land use suitability were determined through previous

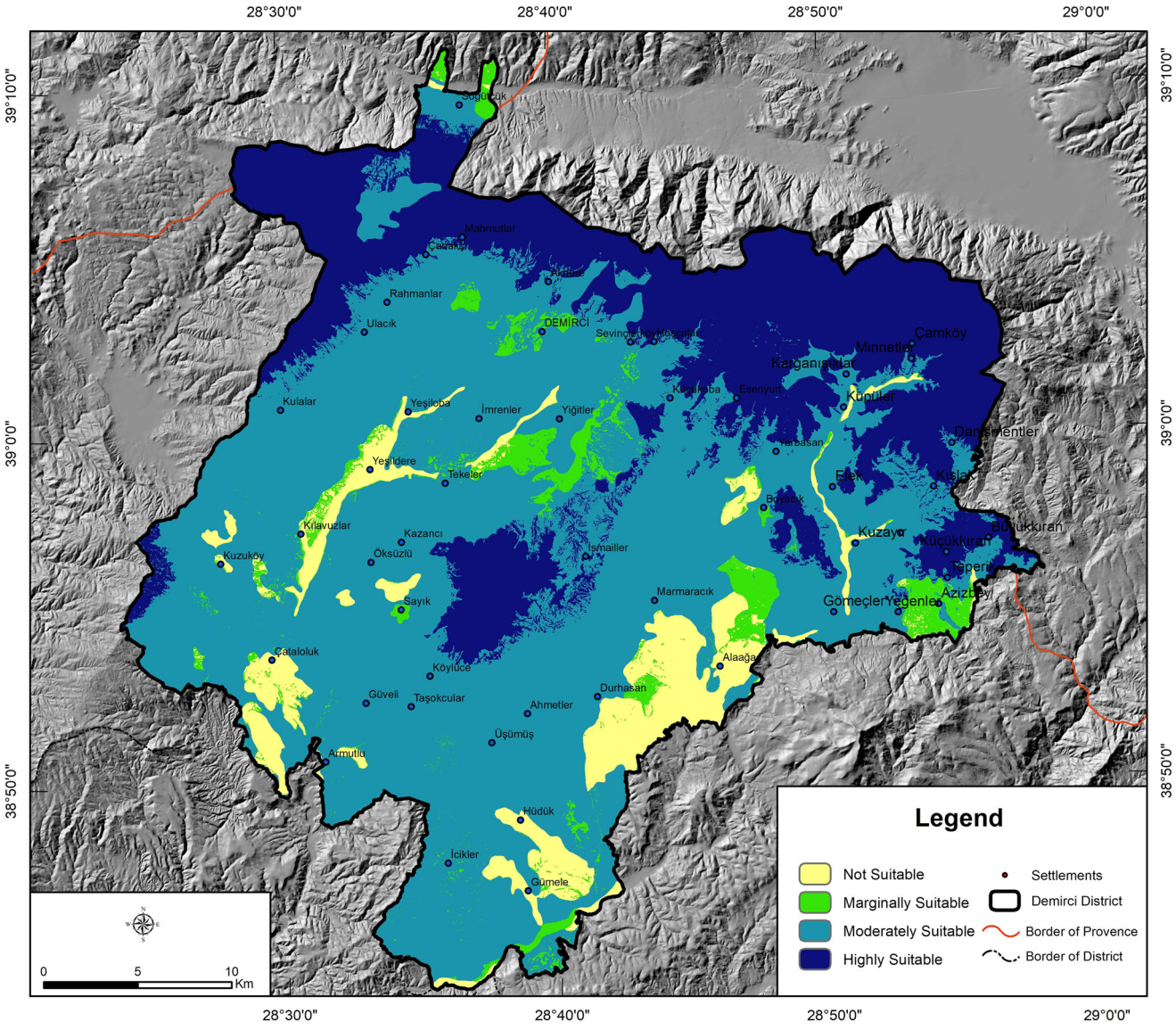

Fig. 5 Land-use suitability for meadow-pasture. This figure is covered by the Creative Commons Attribution 4.0 International License. Copyright © the authors, all rights reserved.

similar studies and experts' consultations. Then, the present land use in the field was revealed, and how the land use suitability within the selected criteria was determined. This study makes a practical contribution to society, the local economy, and the protection of the natural environment by revealing the unsuitable land use in the Demirci District and suggesting how the lands should be used.

The study provides information to regional and local planners and decision-makers about how the land should be used. In this way, local data with high accuracy that can be used in further studies and plans related to the region were produced. With its very rough terrain, the Demirci district does not have large areas suitable for agriculture. Considering the suitability rates obtained by the analysis, it was determined that only 19% of the district with 236.7 km^2 is suitable for agricultural lands. The plain land located on the foothills of the Kılavuzlar Plain, Minnetler Stream basin, İçikler Plateau, and Türkmen Mountain formed by the Demirci Stream Basin in the field is suitable for agricultural lands. Regarding the current land use situation, 553.5 km^2, which corresponds to 44.43% of the area, is used as agricultural land. When this ratio is compared with the results of the analysis, it shows that the forests and pasture, which are not suitable for agriculture in the field, have been opened to agriculture over time. Although the fields opened for agriculture, though not suitable, increase the agricultural production in the district, the yield decreases over time and the sustainable use of the lands becomes difficult. It is essential for sustainable land use to rearrange the fields suitable for pasture and agricultural land and to increase productivity by using modern farming techniques in the fields determined as suitable for agriculture according to the analysis results.

Considering the economic characteristics of the field, it is seen that the primary economic activity in the district is agriculture and animal husbandry (Aydın, 2004; Topuz, 2020). According to Corine's 2018 data, there was a total of 167.72 km^2 of pasture area in the field. However, as a result of the analysis, an area of 477.79 km^2 was determined as suitable for pasture lands. According to the data obtained from Demirci Agriculture and Forestry Directorate, there is a total of 92,643 ovines in the district, including 64,256 sheep and 29,387 goats. Some studies on pastures in Turkey have stated that 3–6 ha of pasture land per ovine animal (Soya, 2006), or 200 bovines and 1500 ovine animals per 100 ha of meadows, are ideal for healthy livestock (Doğanay, 1998). In the

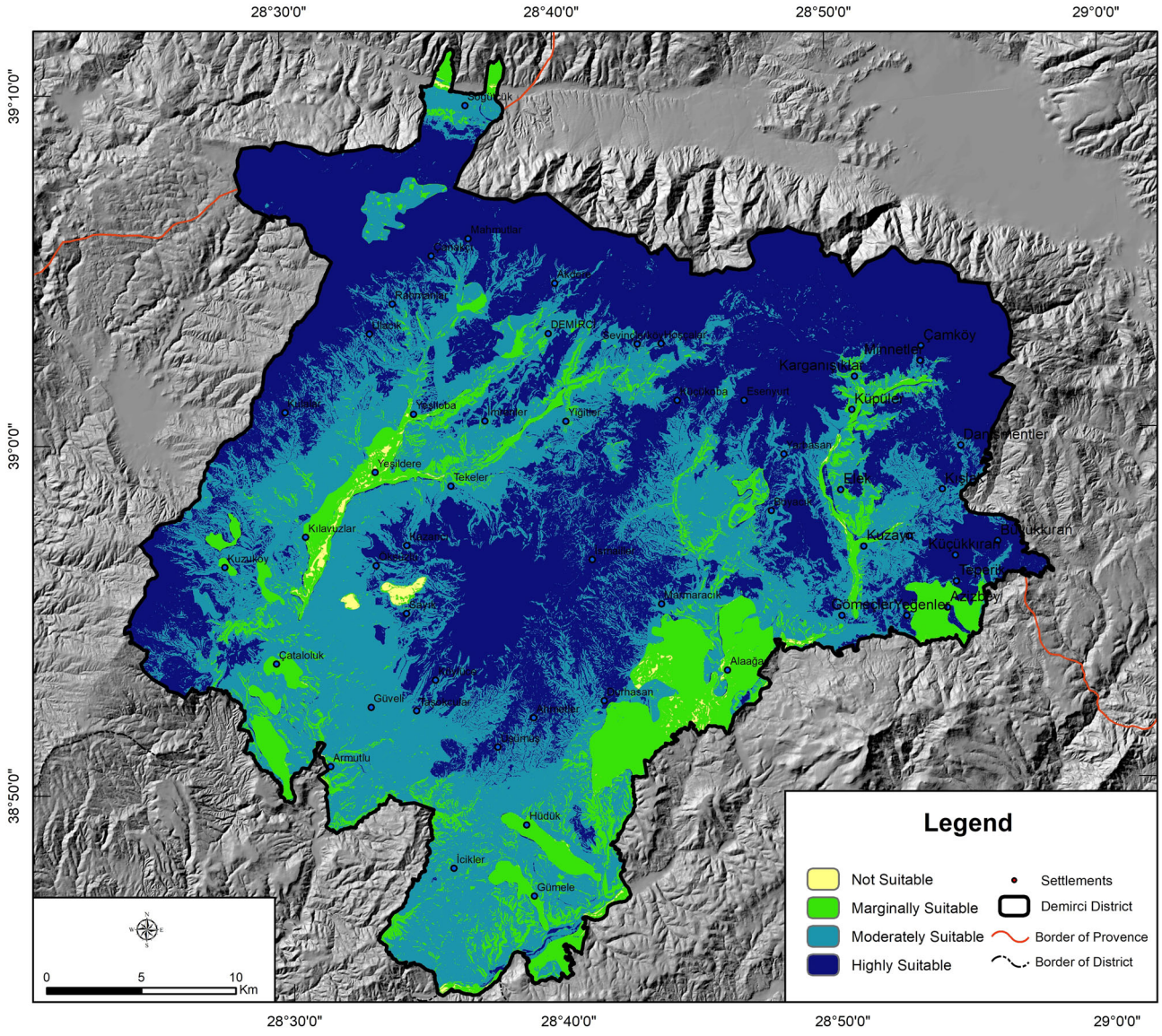

Fig. 6 Land-use suitability for the forest. This figure is covered by the Creative Commons Attribution 4.0 International License. Copyright © the authors, all rights reserved.

Table 10 Landuse types of Demirci district and suitable (Proposed) land use (km^2).

	Agri.	(%)	Forest	(%)	Pasture	(%)	Other	(%)	Total
In 2020	553.5	44.4	512.7	41.2	167.7	13.5	11.8	0.9	1245.7
Suitable	236.7	19.0	531.2	42.7	477.8	38.4	-	-	1245.7

Source: CORINE Copernicus Land Monitoring Service (2018).

county pastures, there is an area of 0.18 ha per ovine and 0.80 ha per bovine animal. It is obvious that the pastures in the field are insufficient for these animals. It has been determined that the data in the research area are far below the average values given in previous studies (Doğanay, 1998; Soya, 2006). This situation not only increases the cost of animal husbandry in the region but also causes the national wealth to be partially wasted since the land is not used rationally. In addition, changing the areas that should be left as pasture, especially for agricultural purposes, damages the habitats of other living things and the natural ecosystem.

Agricultural activities on very steep and sloping lands without taking the necessary precautions, starting grazing early in the pastures, and intensive grazing in this period cause the grasslands to become unproductive over time and decrease the plant's existence. The decrease in plant density per unit in pastures causes erosion over time. The destruction of the lands and excessive and untimely grazing activities have increased the natural rate of erosion, causing significant soil loss in the field and infertility of the area over time (Balabanlı et al., 2005). This problem encountered in the field is one of the general problems of animal husbandry in Turkey. Turkey is one of the countries with the most expensive meat production in the world in terms of purchasing power. It has been stated in many studies that the misuse of pastures has a significant role in production costs.

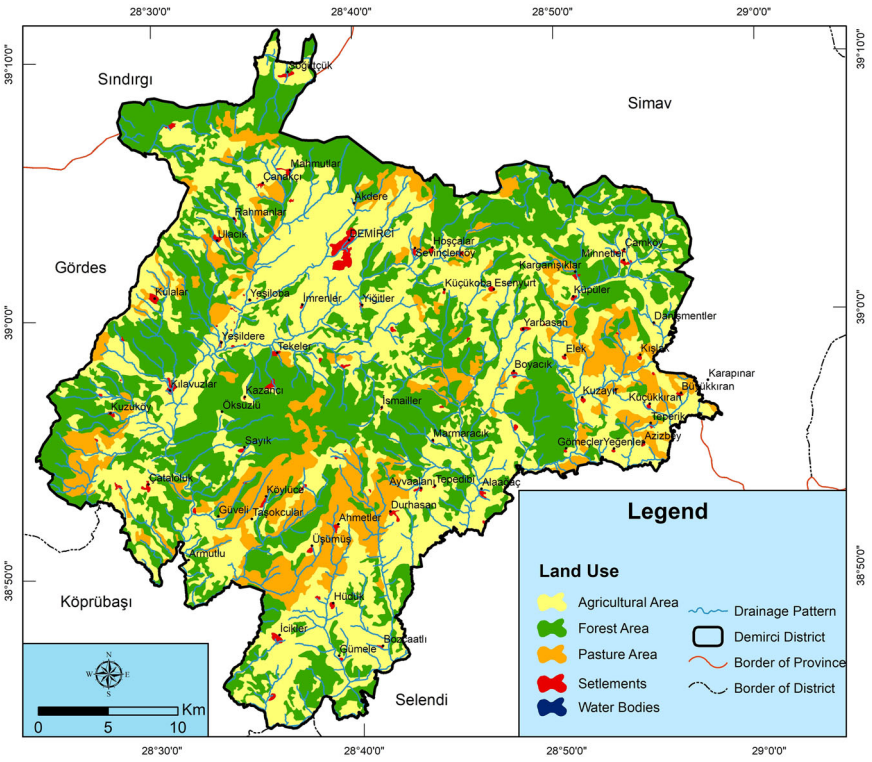

Fig. 7 Present land use of Demirci District. This figure is covered by the Creative Commons Attribution 4.0 International License. Copyright © the authors, all rights reserved.

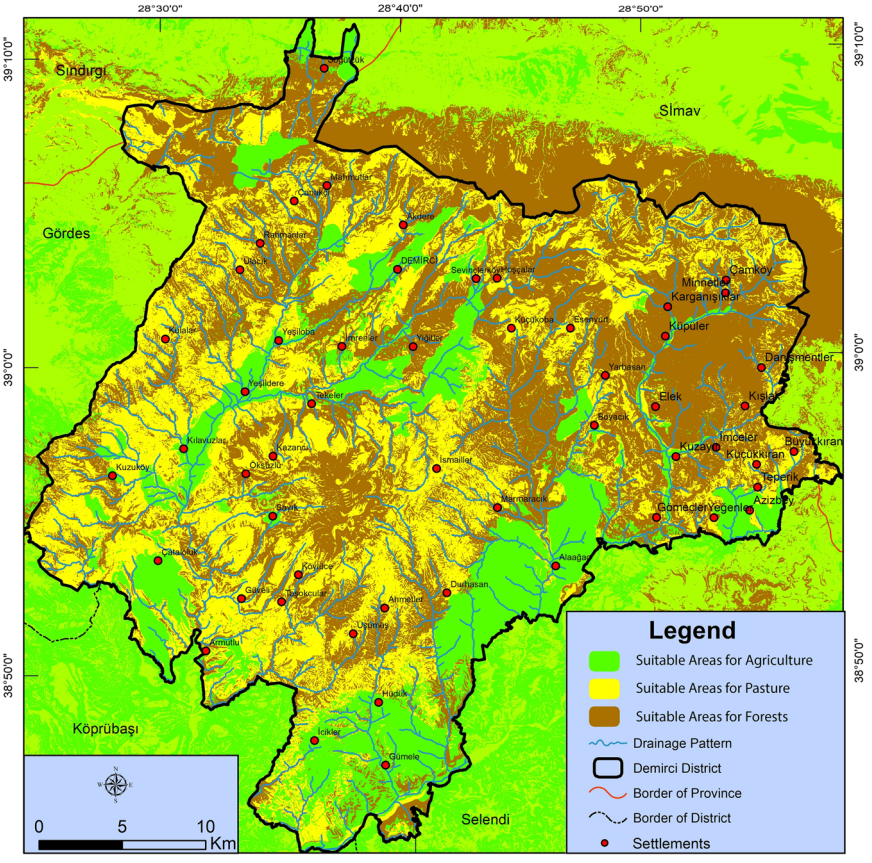

Fig. 8 Land use suitability map of Demirci District. This figure is covered by the Creative Commons Attribution 4.0 International License. Copyright © the authors, all rights reserved.

(Cevger and Sakarya, 2006; Kuşvuran et al., 2011; Gökkuş, 2018). The use of pasture fields for different purposes creates a shortage of pasture and increases the cost of animal husbandry.

When the current land use of the district and the suitable land use created as a result of the analysis are compared, it is seen that the most important problem of the district is that the pastures have been opened to agriculture. Pastures are very valuable in the district where around 100,000 cattles (sheep and goats) are. In order to carry out livestock activities more efficiently and less costly, the areas suitable for pastures should be converted to their original form. In addition, it is very important to inform the farmers, especially those dealing with ovine breeding, on the use of pasture.

In the district, It is striking that most of the fields are unsuitable for agricultural activities. Although opening the areas with high slopes and erosion to agriculture does not cause problems in production in the first years, the yield decreases over time, and the land becomes unusable. In order to avoid unsuitable land use in the study area, it is very significant not to convert the areas that are unsuitable for agricultural land into pastures and forests for the economy of the district and the preservation of the existence of natural environments. The fields suitable for agriculture include only 19%. In agricultural activities in these areas, it is very important to carry out agriculture with modern methods, to choose suitable products, to apply modern irrigation methods, and to leave the land fallow at the right time. However, even if all the conditions are provided, agricultural production will not exceed the yield to be obtained from the pastures due to the natural characteristics. In addition, materials such as fertilizers and pesticides used to increase yield also increase costs.

The results of the suitability analyses are similar to those detected in the CORINE 2018 data and field observations for mountainous areas. There are three different mountainous areas within the boundaries of the research area. These are the Simav-Demirci Mountains that form the northern border of the district, Çomaklı Mountain in the west, and Asi Hill in the east of Demirci Stream. When the land use suitability map is examined, it has been determined that these mountainous areas are suitable for forest areas. However, it has been detected in observations and suitability analysis that the forest areas created by the pine planting works carried out in the north of Yeşildere and Yeşiloba villages by the Demirci Forestry Directorate in the last 20 years are suitable areas for forestry.

Today, forestry activities are carried out on 512.73 km^2, which is 41.2% of the existing land. The areas where optimum forestry can be made constitute 42.65% of the land with 531.24 km^2. In this case, it is striking that the difference between the potential areas where forestry can be made and the present forestry areas is as little as 1.5%. Therefore, it can be said that there is no significant problem regarding the distribution of forest areas. It is beneficial to popularize the use of modern techniques to increase forestry incomes in the research field.

There are many suitable forest areas in the district. Nevertheless, forestry incomes are not very high. Income from forest activities in 2019 was around 1,400,000 TL (250,000$) (İzmir OBM, 2011). Considering the abundance of forest areas, the amount is quite low. More income could be generated through cooperation with villages and related institutions in forest areas. The rural population should be encouraged to produce non-wood forest products (NWFPs) such as resin, kindling, pine nuts, mushrooms, and cones, in addition to primary forest products in these areas. When the land cover changes in the district since 2003 are considered, it is seen that there are great differences in the field, especially in agriculture and pasture areas. Agricultural areas, which were 440 km^2 in 2003 (Aydın, 2004), have increased to 553.5 km^2 today. While 19% of the area is suitable for agriculture, agricultural areas which were 35.7% in 2003 (Aydın, 2004) have increased to 44.4% in the present. When the change in forest areas is examined, the forest area, which was 603,600 km^2 in 2003 (Aydın, 2004), has decreased to 90 km^2 in the current situation. Seeing the differences between 2003 and the results of the analysis, it can be said that the fields suitable for pasture were used as forest areas in 2003 as they are today. The meadow-pasture areas, where the greatest change was experienced in the field, were 25 km^2 (Aydın, 2004) in 2003, and today it has increased to 167.7 km^2. Meadow-pasture areas constituted only 2% of the field in 2003, while it is 13.46% today. Considering the results of the analysis, an area of 477.8 km^2, which corresponds to 38.4% of the field, is suitable for the meadow-pasture area. As a result, it can be said that even though the pasture areas have increased since 2003, the fields suitable for the meadow-pasture area are still used inappropriately as agricultural areas.

One of the problems faced in rural areas in Turkey is migration. While migration from rural to urban causes many socio-economic problems in Turkey, population pressure on cities also brings environmental troubles. This study contributes to the partial reduction of migration by preventing the non-suitable use of agricultural lands in the research area, where the rural economy is the main sector.

In the study, suitable areas for settlement were not determined because the district was constantly losing population and the expansion rate of the settlements was almost non-existent. It is thought that urban and rural settlements with a low sprawl rate will be concentrated in their existing places and will not diffuse in the form of relocation, but they will expand at the peripheries of the settlements. For this reason, if necessary, settlement suitability can be included in the analysis in future studies that can be done for different purposes.

Data availability

The datasets generated during and/or analyzed during the current study are available from Mustafa Topuz on reasonable request.

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The authors declare no competing interests.

Ethical approval

This article does not contain any studies with human participants performed by any of the authors.

Informed consent

This article does not contain any studies with human participants performed by any of the authors. Since this article includes spatial analysis processes that do not require data collection from humans, consent was not required.

Additional information

Correspondence and requests for materials should be addressed to Mustafa Topuz.

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