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Determination of Suitable Lands for Sugar Beet Cultivation Using GIS and FUCOM

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ABSTRACT
The primary objective of this study is to evaluate the suitability of sugar beet lands using Geographic Information Systems (GIS) and the Multi-Criteria Decision Making (MCDM) method, due to the limited number of crop-based land suitability studies on sugar beet cultivation in the literature. The research was conducted in the central and northern parts of the Karamenderes Plain, covering approximately 52,000 ha in NW Türkiye, where farmers have recently shifted to sugar beet cultivation for economic reasons but lack spatial decision-support tools. In the study, eight soil and land characteristics were evaluated: soil texture, pH, electrical conductivity (EC), soil depth, organic carbon content, slope, drainage, and the Soil Fertility Index Score (nitrogen, phosphorus, and potassium) (SFIS). The Full Consistency Method (FUCOM) was used to determine the weighted values of soil and land characteristics. Present assessments revealed that of the evaluated lands, 28047,50 ha was highly suitable, 21290,10 ha moderately suitable, 394,42 ha marginally suitable, and 2105,16 ha not suitable for sugar beet cultivation. The combined use of FUCOM and GIS to determine suitable land for sugar beet cultivation facilitated assessments and provided significant advantages in terms of time and economic aspects. In addition to identifying suitable areas for sugar beet cultivation, the findings provide a practical decision-support approach for land-use planning and agricultural policymaking by enabling more efficient, sustainable use of land resources. The proposed model can be used under similar or different environmental conditions.

Keywords: Site selection, FUCOM, Spatial analysis, Land and soil characteristics, Sugar beet, Türkiye

1. Introduction

The rapid increase in global population, urbanization, industrialization, and demand for secondary housing put pressure on agricultural lands, causing the degradation of already limited land resources. While millions of people today face significant difficulties in accessing clean and safe food, this degradation and unplanned use of land will further exacerbate this situation in the future. In recent years, pandemics, wars, and natural disasters have once again reminded humanity of the crucial importance of agricultural production and food supply.

Soils are nonrenewable natural resources that form over very long periods. Therefore, humans must implement practical measures to protect this vital resource and ensure its optimal, sustainable use (Navidi et al. 2022). Rational plans must be implemented to effectively manage natural resources (Kaymaz et al. 2021; Everest et al. 2022a). The fundamental principle for managing agricultural lands is the use of reliable plans that ensure their sustainable use. One of these methods is evaluating land-use suitability for specific agricultural crops. In addition, land-use suitability is a focused tool for making the most appropriate plans for current and future land use. Also, land-use suitability is a methodology that determines the potential of land and provides sustainable guidance for different uses. Land suitability analysis evaluates specific requirements for a particular type of use (George 2005; Özkan et al. 2020; Everest & Gür 2022). In land-use suitability analysis, various land characteristics, climatic conditions, and morphological features are considered. Multi-Criteria Decision-Making (MCDM) methods are frequently used to analyze these characteristics (Elkadeem et al. 2021; Alaboz et al. 2023; Sarğın et al. 2025). MCDM approaches facilitate the evaluation of large amounts of data and the generation of solutions by identifying potential alternatives. Recently, these approaches have become frequently used in assessing agricultural land suitability. One of these approaches is FUCOM. As a novel MCDM method, FUCOM has recently been preferred by planners due to its transparency in parameter weighting and its ability to make prioritization more efficient by reducing computational intensity (Everest et al. 2024; Yener et al. 2025). In land evaluation studies, the development of computer technologies has significantly contributed to the preparation of acceptable plans. GIS-based suitability analyses have played a central role in investigating land suitability. GIS provides the accuracy of spatial data, more detailed analysis, and assists in data accessibility (El Baroudy 2016). The ability to overlay multiple maps or datasets within a GIS environment has made this technology indispensable for land evaluation studies. In particular, with the development of diverse and effective MCDM methods, the importance and prioritization of different parameters can be analyzed more easily, and the integration of these two methods has enabled the production of suitability maps for precision agriculture (Qu et al. 2013).

There are numerous studies in the literature that use various MCDMs for different plants. Banana (Koca et al. 2025), coffee (Liu et al. 2025), hazelnut (Tercan et al. 2022), pistachio (Everest 2021), maize (Kaya & Dengiz 2024), tobacco (Zhang et al. 2015), paddy (Özkan et al. 2019; Everest et al. 2022a), grapevine (Uyan et al. 2023), canola (Everest et al. 2022b; Moradi et al. 2024). Focusing specifically on sugar beet land suitability, there are limited studies in the literature (Vilček & Torma 2016; Deegala et al. 2022; Shahbazi et al. 2009; Mandere et al. 2010; Bagherzadeh & Gholizadeh 2016). Additionally, Mandere et al. (2010) emphasized the need for more detailed research to improve land suitability assessments for sugar beet cultivation. In the Karamenderes Plain, farmers have recently begun cultivating sugar beet to increase economic returns; however, they lack a reliable source of spatial information to guide land-use decisions. The present study aims to address this gap by supporting sustainable and economically efficient production and by presenting an FUCOM-based model for sugar beet cultivation. A detailed review of the global literature further shows that FUCOM has been applied in several fields, such as manufacturing facilities (Ulutaş & Karakuş 2021), landfill assessment (Badi & Kridish 2020), groundwater potential (Akbari et al. 2021), energy planting (Cao et al. 2019; Ecer 2021), and mineral inventory (Feizi et al. 2021). However, FUCOM-based agricultural land suitability studies remain very limited globally, with only a few examples, such as Everest et al. (2024) for maize, Yener et al. (2025) for peach, and Mercan (2025) for almond cultivation. On the other hand, to the best of the author's knowledge, there is a lack of studies addressing the presence of land suitability analysis in Türkiye for sugar beet cultivation. This gap serves as the primary motivation for the present study. Therefore, this research provides a clear and explicit methodological contribution by introducing the first FUCOM–GIS integration for sugar beet cultivation. In this context, the main contributions of this study can be summarized as follows:

i. This study could provide essential background for the sustainable use and management of lands with many characteristics.
ii. This proposed model was developed for sugar beet cultivation, which is economically valuable for Türkiye and globally, and will provide strategic planning, sustainable land use planning, and contribute to the Sustainable Development Goals of the United Nations.
iii. The model can assist farmers, decision makers, and planners in the management of sugar beet cultivation and related policy.
iv. Additionally, as one of its most significant contributions, a land management approach will be presented using technology and software, based on a land evaluation model integrated with a novel and distinctive MCDM (FUCOM).

2. Material

The study area covers the central and northern parts of the Karamenderes Plain. It is located between latitudes 39°53′55″ – 40°00′24″ N and longitudes 26°10′31″ – 26°15′45″ E and covers a total area of 51837.18 ha (Figure 1). According to Soil Taxonomy, the majority of the soil resources in the study area are Entisols, while the others are Vertisols and Inceptisols (Everest, 2015). The study area has a transitional climate between the Mediterranean and Marmara climates. The study area is cool and rainy in winter and hot and dry in summer. According to Turkish General Directorate of Meteorology, the average temperature is 15.2 °C, total precipitation is 623 mm, and the total number of rainy days is 83. In the study area, Quaternary-age alluviums transported by the Karamenderes River, as well as Miocene-age calcareous terrestrial clastics and their weathering products, constitute the basic geological units. The study area is an intensive agricultural production region. Cereals (wheat, barley, maize, and rice), fodder crops (maize and alfalfa), and vegetables (tomato and pepper) are widely grown in the area. Moreover, small-scale initiatives for sugar beet cultivation began in 2023. According to TURKSTAT data, sugar beet was cultivated on 4790 da in the region in 2023. The agricultural products grown in the area contribute to meeting the food demand of the Marmara Region, which has the highest population in Türkiye.

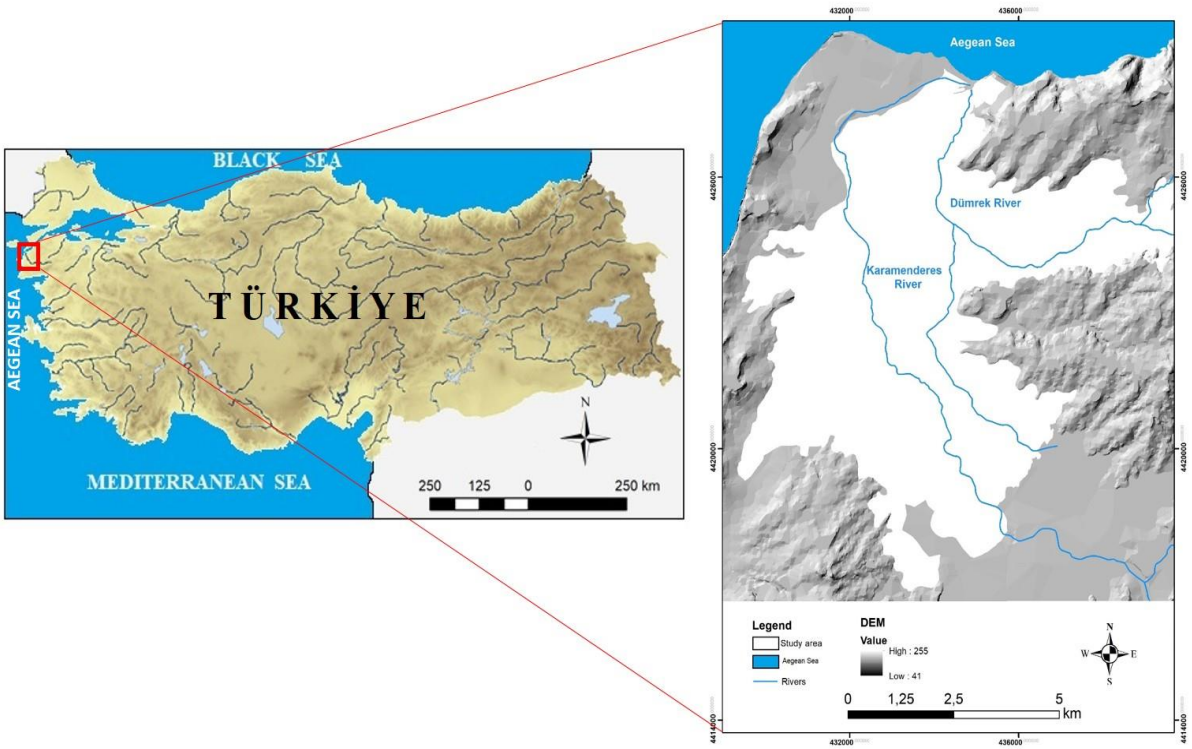


Figure 1- Study area

3. Methods

The study flowchart is presented in Figure 2. Within this framework, the crop requirements of sugar beet were examined in a deep literature review (Table 1). For this purpose, the EcoCrop Portal (the sugar beet data sheet) of the Food and Agriculture Organization (FAO 2025) and the studies of Constantini (2009), Mandere (2010), and Vilček & Torma (2016) were utilized. Within the study, eight different land characteristics were evaluated. The evaluated land characteristics were obtained from the detailed soil survey and mapping report produced by Everest (2015). These characteristics include soil texture, pH, electrical conductivity (EC), soil depth, organic carbon content, slope, drainage, and the Soil Fertility Index Score (nitrogen, phosphorus, and potassium) (SFIS) (Figure 3). Plant nutrients were optimized and assessed using SFIS (Table 2). The related SFI calculation is provided below:

$$SFIS = \left[Rmax\ x \sqrt{\frac{A}{100}\ x\ \frac{B}{100}\ x \frac{C}{100}} \right] x\ 100$$

Where: SFIS, Soil Fertility Index Score; Rmax, Maximum ratio: (A+B+C) / 3

The scoring criteria are provided in Table 1. The equation specified in Dedeoğlu & Dengiz (2019) and Tunçay et al. (2021) was used in SFIS calculations. The evaluated characteristics were scored on a 1-4 scale (Table 1). Here, a score of 4 represents the most suitable conditions for sugar beet cultivation, while a score of 1 indicates the least suitable conditions. In the study, the slope map was derived from 10 × 10 m-resolution DEM data. ArcMap 10.4 was used for the interpretation of mapping units, data visualization, and land evaluation processes.

Table 1- Land characteristics and scoring table

No	*Parameter*	*Sub criteria*	*Score*
1	Texture	Coarser textured (S, LS, SL)	4
		Medium textured (L, Si, SiL)	3
		Moderately-fine textured (CL, SiCL,SCL)	2
		Fine textured (SC, C, SiC)	1
2	Depth (cm)	100 – 150 +	4
		50 - 100	3
		20 - 50	2
		20 <	1
3	Drainage	Excess	4
		Moderate	3
		Poor	2
		Very Poor	1
4	EC (dS m^{-1})	0 – 2	4
		2 – 4	3
		4 - 8	2
		8 – 16	1
5	Slope (%)	0 - 2	4
		2 - 6	3
		6 - 12	2
		12 - 18 +	1
6	pH	6.0 - 7.0	4
		5.5 - 6.0, 7.0 - 8.0	3
		5.0 - 5.5, 8.0 - 8.2	2
		< 5.0 and 8.2 <	1
7	Organic carbon (%)	< 1.5	4
		1.5 - 1.0	3
		1.0 - 0.6	2
		0.6 <	1
8	SFIS	75 <	4
		75 - 50	3
		50 - 25	2
		< 25	1

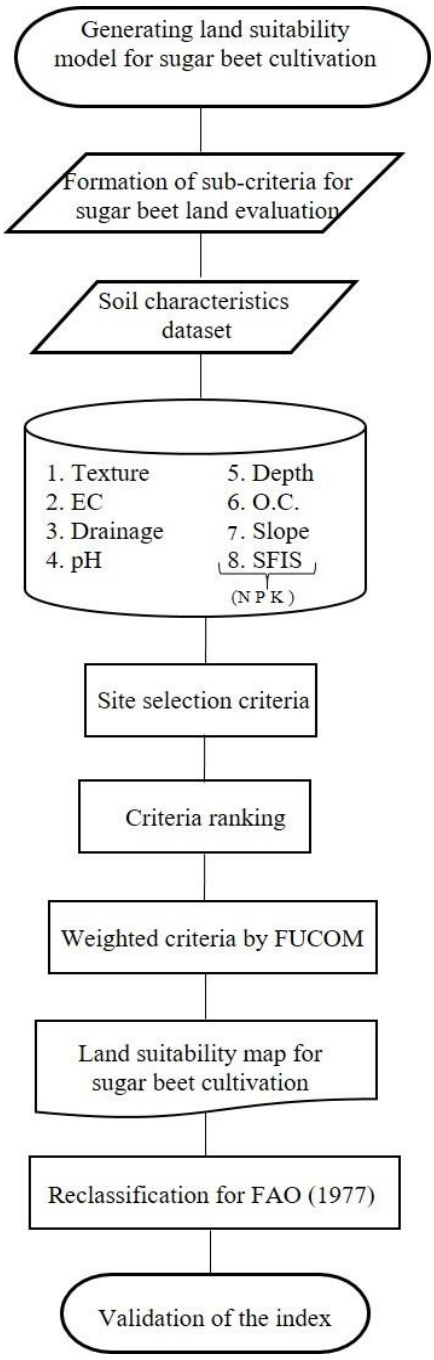


Figure 2- Flow diagram of the research

Table 2- SFIS values

Characteristics	*Unit*	*Ratio*			
		100	*75*	*50*	*25*
A - Total Nitrogen	%	0.25 <	0.15 - 0.25	0.05 - 0.15	< 0.05
B - Available phosphorous	mg kg^{-1}	25 <	10 - 25	5 - 10	< 5
C - Available potassium	mg kg^{-1}	60 <	30 - 60	10 - 30	< 10

3.1. FUCOM MCDM

MCDMs facilitate the assessment of multiple criteria in the decision-making process (Abdullah et al. 2022; Yener et al. 2025). In this study, FUCOM Pamučar et al. (2018) was employed to identify weighted values of land characteristics. Details of the FUCOM calculation steps were provided below (Pamučar et al. 2018);

- In the 1st step, the criteria were ranked according to their priority (Table 3). The most significant criterion is ranked 1st, and the criterion with the lowest effect is ranked last in the expression (1).

$$C_{j(1)} > C_{j(2)} > \ldots > C_{j(k)} \quad (1)$$

Table 3- Priority criteria for FUCOM

Criteria no	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*
Criteria	Texture	Depth	Drainage	EC	Slope	pH	OC	SFIS
Priority	1	2	3	4	5	6	7	8

- In the 2nd step, the criteria are compared (Table 4), and the priority of the assessment criteria $\left(\varphi_{k/(k+1)}\right)$ is defined. The vector of the priority is obtained with expression (2)

$$\phi = \left(\varphi_{1/2}, \varphi_{2/3}, \varphi_{3/4}, \ldots, \varphi_{k/(k+1)}\right) \quad (2)$$

Where: the value $\varphi_{k/(k+1)}$ represents a superiority of the $C_{j(k)}$ rank criterion over the $C_{j(k+1)}$ rank. In the FUCOM, the decision-maker(s) can use integers, decimals, or values of certain scales to compare criteria. This provides flexibility to decision-makers in the evaluation of criteria.

Table 4- Comparisons in FUCOM

Criteria according to rank	*Texture*	*Depth*	*Drainage*	*EC*	*Slope*	*pH*	*OC*	*SFIS*
Comparisons	1	2	3	4	4	5	6	7

In the 3rd step, weighted coefficients $\omega 1$, $\omega 2$,..., T are determined. The coefficients must provide these two statuses:

i. The proportion of the weight coefficients given in expression (3) is equal to the comparative priority of the criteria determined in Step 2.

$$\frac{\omega_k}{\omega_{k+1}} = \varphi_{k/(k+1)} \quad (3)$$

ii. The weight coefficients must satisfy the mathematical transitivity condition. It is;

$\varphi_{k/(k+1)} \times \varphi_{(k+1)/(k+2)} = \varphi_{k/(k+2)}$. Since $\varphi_{k/(k+1)} = \frac{\omega_k}{\omega_{k+1}}$ and $\varphi_{(k+1)/(k+2)} = \frac{\omega_{k+1}}{\omega_{k+2}}$, that $\frac{\omega_k}{\omega_{k+1}} \times \frac{\omega_{k+1}}{\omega_{k+2}} = \frac{\omega_k}{\omega_{k+2}}$ is obtained. Therefore, another requirement that the final values of the weight coefficients of the evaluation criteria need to satisfy is obtained as shown in following expression (4).

$$\frac{\omega_k}{\omega_{k+2}} = \varphi_{k/(k+1)} \times \varphi_{(k+1)/(k+2)} \quad (4)$$

Full consistency is attained when the constraints specified in expressions (3) and (4) are met. Under these conditions, the Deviation from full consistency (DFC) is minimized. Consequently, the requirement for maximum consistency is fulfilled, resulting in a DFC value of χ=0 for the derived weight coefficients. The final values of the evaluation criteria weight coefficients are determined by solving the linear programming model presented in expression (5). The study revealed a deviation from the full consistency value of $\chi = 0.00$.

$$
\begin{gathered}
Min\ \chi \\
\left|\frac{\omega_{j(k)}}{\omega_{j(k+1)}} - \varphi_{k/(k+1)}\right| \leq \chi, \forall j \\
\left|\frac{\omega_{j(k)}}{\omega_{j(k+2)}} - \varphi_{k/(k+1)} \times \varphi_{(k+1)/(k+2)}\right| \leq \chi, \forall j \\
\sum_{j=1}^{n} \omega_j = 1 \\
\omega_j \geq 0, \forall j
\end{gathered} \tag{5}
$$

After the calculation, the final weighted values are specified (Table 5). The weighted coefficients obtained from the model were used in ArcGIS' Model Builder to perform overlay analysis. Land suitability assessment was conducted via a Weighted Overlay analysis, with weighting coefficients determined by FUCOM. For this purpose, vector data for each evaluated criterion was converted to a raster layer using the "Conservation tool". During this conversion process, the WGS 1984 UTM Zone 35N coordinate system and a 30 m cell size were defined as common parameters for all output layers, ensuring the production of a naturally aligned raster dataset with uniform resolution and projection. This standardized geographic framework guaranteed the pixel-to-pixel alignment of all layers required for the Weighted Overlay analysis. Then, sub-criteria scores were transferred into the Weighted Overlay table, and the weighted coefficients for the main criteria were assigned to produce a suitability map. The resulting map was classified according to FAO (1977) guidelines, and the final sugar beet suitability map was produced.

Table 5- Weighted values obtained from FUCOM calculations

No	*Criteria*	*Weight (%)*
1	Texture	34
2	Depth	18
3	Drainage	12
4	EC	9
5	Slope	9
6	pH	7
7	OC	6
8	SFIS	5

4. Results and Discussion

The descriptive statistics of the evaluated parameters are given in Table 6. According to the table, soil pH values varied between 7.33 and 8.01, with an average value of 7.67 ± 0.19, indicating moderately alkaline soils in the research area (Soil Survey Division Staff 1993). The EC varied between (0,07 - 15,27 dS m^{-1}) with an average of 0,99 ± 3,20 dS m^{-1}, indicating that the salinity problem in the delta part of the study area (FAO 2006). Soil organic carbon content was low (0.95% ± 0.14) (Ulgen & Yurtsever 1995), and soils generally had moderate and low $CaCO_3$ levels (FAO 2006). The soil texture varies from sandy loam to clay loam. In the FUCOM-based land evaluation study conducted in Çanakkale Karamenderes, the suitability of land for sugar beet cultivation was assessed by considering soil texture, pH, EC, depth, organic carbon, slope, drainage, and SFI parameters (Figure 4). In the study, soil texture (0.34) was evaluated as the most effective factor, and SFI (0.05) was evaluated as the parameter with the least effect (Table 5). This is due to the inherited and dynamic properties of these soils. Textural composition and mineral content, in particular, are inherited properties, whereas cultural practices (such as fertilization, irrigation, and activities involving agricultural machinery) are dynamic (Karaca et. al. 2021). The importance of soil texture in sugar beet cultivation has also been reported by various researchers (Avcı 1993; Vilček & Torma 2016). Coarser soil warms up quickly, facilitating the germination of sugar beet seedlings and promoting rapid growth. During harvest, they allow the beet to be lifted cleanly and without damage. Heavy clayey soils, which restrict tuber development and present difficulties during harvesting, are therefore not preferred for sugar beet cultivation (Avcı 1993). According to the calculations, the second most effective factor was soil depth. Sugar beet roots extend deeply, and the crop exhibits good development in soils with a depth greater than 150 cm (Mandere et al. 2010). Shallow soils are not suitable for sugar beet cultivation. The drainage parameter was also considered the third most important factor. Well-drained soils are highly suitable for sugar beet cultivation, whereas poorly drained soils can cause root rot, thereby limiting crop growth (Mandere et al. 2010). Although sugar beet is moderately tolerant to soil salinity (Hajiboland et al. 2009), high salinity restricts cultivation. EC values of >16 dS m^{-1} inhibit germination (Mostafavi 2012). In land suitability studies for sugar beet cultivation, slope parameters should always be included among the evaluated parameters. Flatter lands are preferred, particularly for optimizing mechanization and irrigation practices. Additionally, slope is a critical factor in preventing erosion caused by surface runoff on steeper terrain (Mandere et al. 2010). Furthermore, Jones et al. (2005) highlighted that even on low and moderate slopes, the risk of water erosion in sugar beet fields can occur depending on the soil texture (Laufer et al. 2016). Although the pH range for sugar beet cultivation is 5.5 to 8.0, the optimal production occurs between pH 6.0 and 7.0. Additionally, soils with a pH below 5.5 can still support cultivation with appropriate lime application (Mandere et al. 2010; Vilček & Torma 2016). Soil organic matter has positive effects on the physical, chemical, and biological properties of soils. Researchers have also demonstrated the benefits of organic matter in sugar beet cultivation (Gemtos & Lellis 1997; Hlisnikovský et al. 2021). Nitrogen contributes to the formation of plant organs through protein synthesis and is a key component of

chlorophyll. It is also essential for sucrose synthesis and its use as an energy source for growth and cell maintenance. Phosphorus is essential for energy storage and transfer; it is a structural component of nucleic acids, coenzymes, phosphoproteins, and sugar phosphates. It promotes root growth and improves sugar accumulation through photosynthesis. Potassium promotes photosynthesis by carbohydrate metabolism, osmotic regulation, nitrogen uptake, and protein synthesis. It also affects respiration, transpiration, energy transformation, and enzyme actions. Potassium also enhances juice quality and sugar recovery (El-Shafai 2000; Ismail & El-Ghait 2004).

Table 6- Descriptive statistics of studied soils

Parameter	*Unit*	*Min.*	*Max.*	*Mean*	*Std. Dev.*	*Variance*	*CV*
Clay	%	3.65	46.44	18.91	12.91	166.64	146.48
Silt	%	5.37	74.06	32.15	17.12	293.20	187.79
Sand	%	20.31	73.31	48.94	17.14	293.86	285.53
EC	dS m^{-1}	0.07	15.27	0.99	3.20	10.25	30.94
pH	-	7.33	8.01	7.67	0.19	0.04	4036.84
$CaCO_3$	%	1.13	18.38	5.17	4.45	19.80	116.18
Org. Carbon	%	0.28	1.78	0.95	0.38	0.14	250.00
N	%	0.09	0.49	0.22	0.12	0.01	183.33
P_2O_5	mg kg^{-1}	5.85	29.87	12.36	5.12	26.21	241.41
K_2O	mg kg^{-1}	98.75	258.22	195.27	40.32	1625.70	484.30

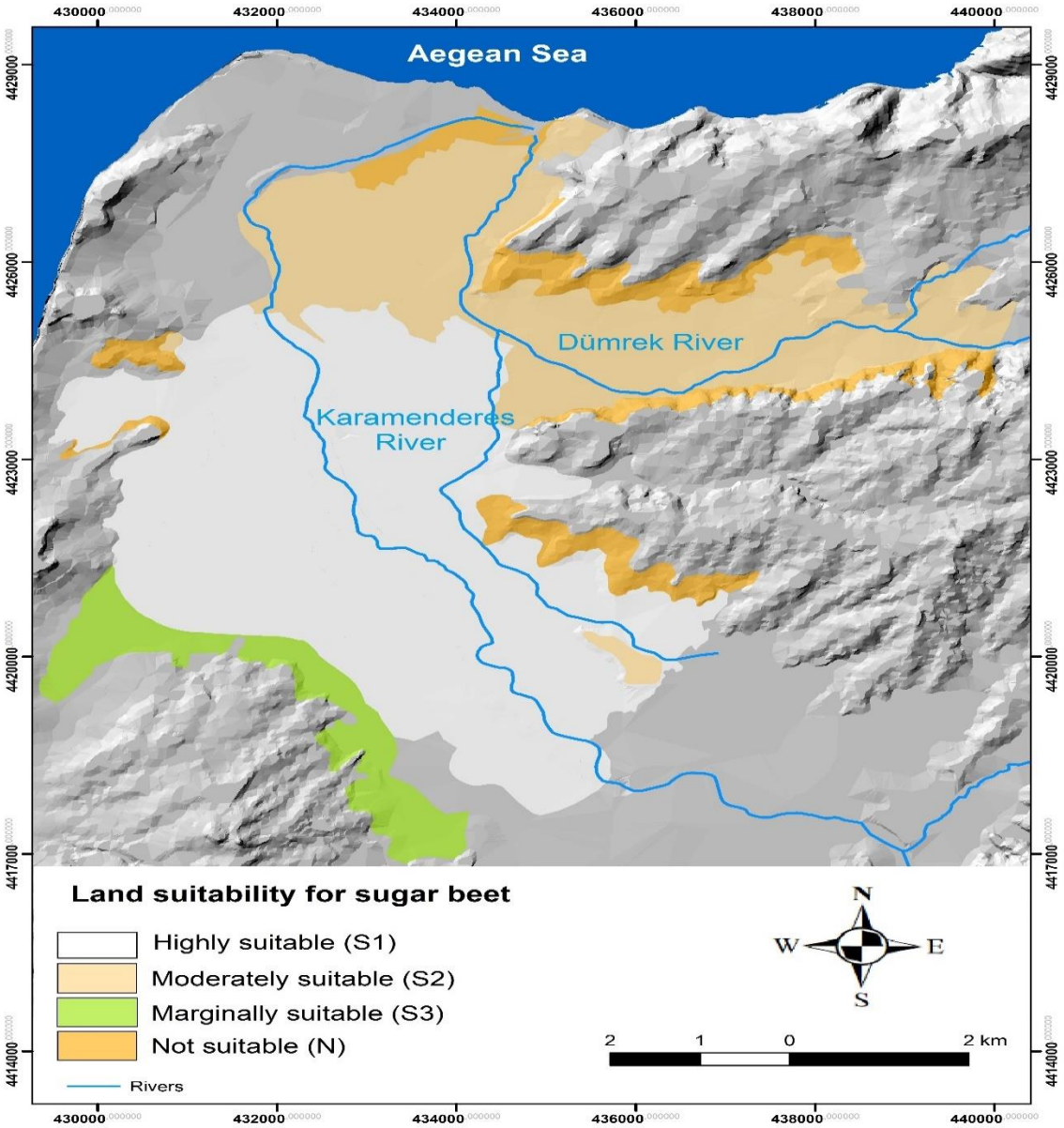


Figure 4- Land suitability for sugar beet cultivation

According to the land suitability assessment for sugar beet cultivation, 54.07% of the study area was classified as highly suitable (S1), 40.76% as moderately suitable (S2), 0.76% as marginally suitable (S3), and 4.41% as not suitable (N) (Table 7). Lands classified as S1 represent ideal areas that provide nearly all the favorable conditions required for sugar beet cultivation. These lands are deep, well-drained, have no slope or salinity problems, are optimal in organic matter and plant nutrients, and have suitable pH and textural conditions (Figure 3). Lands classified as S2 are affected by some limiting factors compared to S1 areas. The most important of these is moderately heavy-textured soils. Similarly, Vilček & Torma (2016) classified moderately heavy soils in Slovakia as 'moderately suitable,' supporting this study's findings. Additionally, slightly to moderately alkaline pH levels in these areas further reduce their suitability class. Lands classified as S3 are affected by multiple limiting factors. Although these lands are flat or nearly flat, the high content (>55%) of 2:1 type clay and moderate drainage have resulted in their classification as S3. The lands classified as N near the delta are primarily limited due to extreme soil salinity, very poor drainage, and shallow depth. Additionally, in the western and eastern parts of the study area, lands classified as N are primarily affected by steep slopes, shallow soil depth, low organic matter content, and low plant nutrient availability. The applicability of the proposed model can also be interpreted with soil classification. The soils of the study area are predominantly classified as Entisols, Vertisols, and Inceptisols within an alluvial plain. Highly suitable areas were primarily associated with deep, well-drained Entisols and Inceptisols with favorable texture and pH conditions. Marginally suitable lands were largely associated with Vertisols with high clay content and poor drainage. Not-suitable lands are found in Typic Fluvaquents, mostly in wet areas on deltaic floodplains. For these reasons, the results of this study can be effectively transferred to other regions with comparable soil classes and environmental conditions. This soil-based interpretation enhances the model's practical usability beyond the study area and strengthens its contribution to land-use planning and sustainable agricultural management.

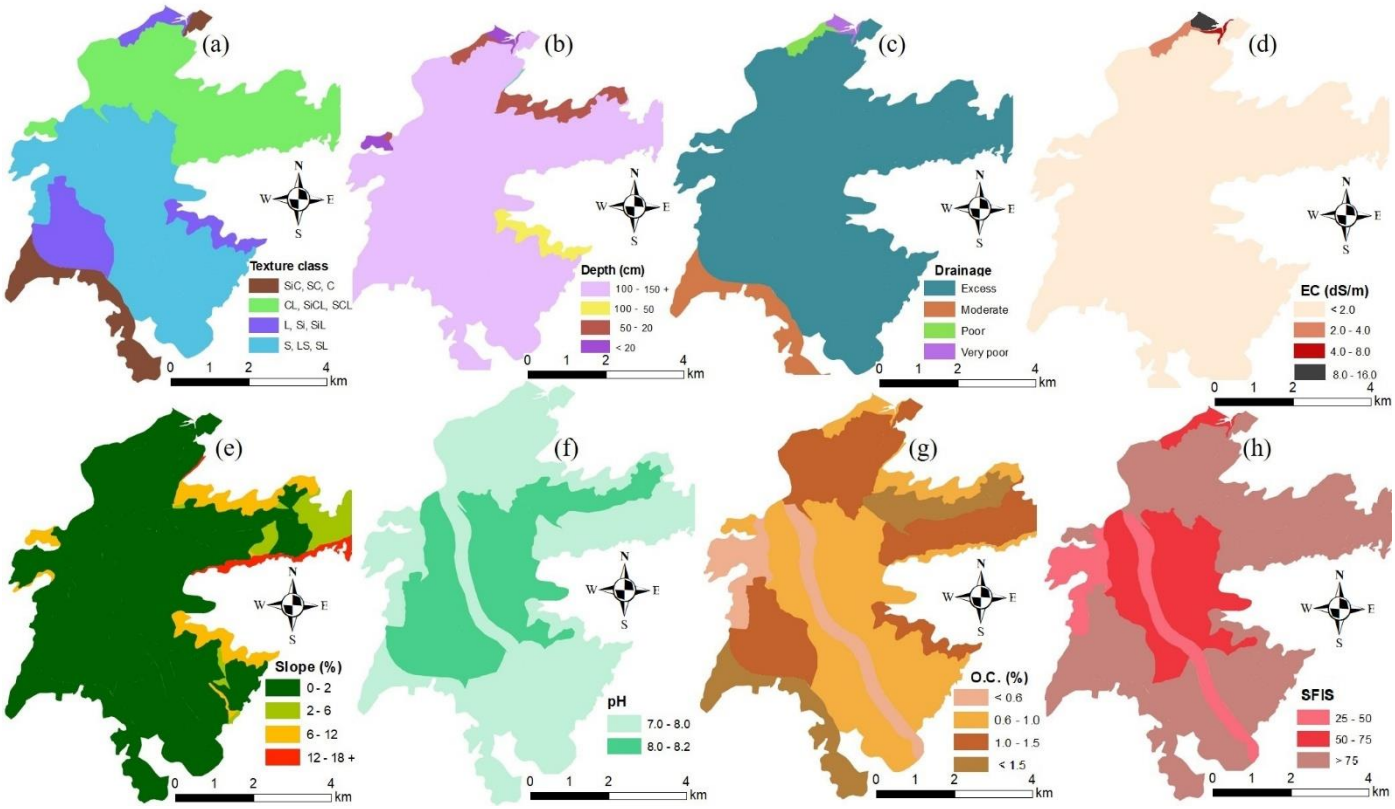


Figure 3- Evaluated land characteristics a) soil texture, b) depth, c) drainage, d) Electrical Conductivity (EC), e) slope, f) pH, g) organic carbon (OC), h) Soil Fertility Index Score (SFIS)

Table 7- Land suitability classification results

Suitability classification	*Code*	*Area (ha)*	*(%)*
Highly suitable	S1	28028.90	54.07
Moderately suitable	S2	21129.24	40.76
Marginally suitable	S3	394.42	0.76
Not suitable	N	2284.62	4.41
Total		51837.18	100

Different studies in the literature provide essential information. For example, Zakarya et al. (2021) also identified suitable land for farmers. The main difference in this study, which was conducted in Karamenderes Plain, is that it offers a methodological

advancement. By integrating the FUCOM, this study ensures full consistency in criterion weights, producing a reliable suitability map explicitly designed for field-level planning in the Karamenderes Plain. Similarly, Dornik et al. (2024) conducted a large-scale land evaluation study covering 21 European countries and produced suitability maps for various crops, including sugar beet. However, while their research reveals general trends at the country level, this current study focuses on an alluvial plain scale at a much higher resolution. This micro-scale approach enables more detailed consideration of land characteristics and topographic conditions, providing directly applicable, concrete results for farmers and local planners.

According to TURKSTAT (2025) data, the average sugar beet yield in land within the Çanakkale borders was 6395 kg in 2023 year, while the average yield in land within the Ezine borders was 4924 kg. This especially shows that agricultural activity in highly suitable areas provided relatively higher yields, while cultivation in moderately suitable areas yielded lower sugar beet. This official statistical information demonstrates that the study's results are reliable and consistent with the land. In this context, the developed guideline is expected to promote planned agricultural production and support sustainable land management.

The use of FUCOM, particularly in agricultural land suitability studies, is quite limited in the literature (Everest et al. 2024; Yener et al. 2025; Mercan 2025). Notably, these studies also emphasized FUCOM as a suitable tool for sustainable agricultural practices and planning, and researchers recommended increasing its use. This sustainability-oriented advantage is further highlighted by other studies (Akbari et al. 2021; Biswas et al. 2021; Zhou et al. 2024; Moslem et al. 2024; Mercan & Acıbuca 2025), which point to the superior capabilities of the FUCOM. These capabilities are defined as reducing processing intensity by determining parameters through prioritization with fewer pairwise comparisons, thereby yielding more consistent and reliable results-a key attribute for robust and sustainable decision-making.

According to OECD/FAO (2021) reports, the lands of sugarcane and sugar beet are expected to increase rapidly worldwide over the next decade. Therefore, this situation should be managed sustainably through planned, informed, and rational policies using technology and knowledge. In this context, the model developed in this study can enable decision-makers, policymakers, farmer organizations, and sugar beet producers to make informed decisions and select suitable locations. Additionally, Sharma et al. (2018) emphasize the need to enrich the literature with crop-specific land-suitability studies.

5. Conclusions

Selecting suitable land is critical, taking into consideration global concerns such as land degradation, climate change, and sustainability. The integration of GIS, computer technology, and FUCOM in land suitability analysis provides an opportunity for sugar beet cultivation in the study area by presenting the crucial data with this study. As a result of the evaluations, nearly half of the lands were found to be suitable for sugar beet cultivation. Ensuring that farmers utilize these lands is essential for establishing an economically viable and sustainable system. Due to the wide range of uses of sugar beets, such as sugar production for human consumption, use as animal feed, and use in crop rotation systems, etc., identifying suitable lands for its cultivation has essential importance. A key limitation is the lack of deeper yield data for precise validation in this study. While acceptable agricultural statistics with current sugar beet fields were demonstrated, future studies could be strengthened by correlating suitability scores with different validation methods (NDVI, ROC-AUC analysis, or kappa statistics, etc.). Additionally, it is recommended that the model presented in this study be applied under similar and different climatic conditions. The knowledge generated from this study can guide the sustainable management of land resources.

Author Declarations

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