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IDENTIFY SUITABLE AREAS FOR PEANUT CULTIVATION IN OSMANIYE PROVINCE THROUGH THE AHP METHOD

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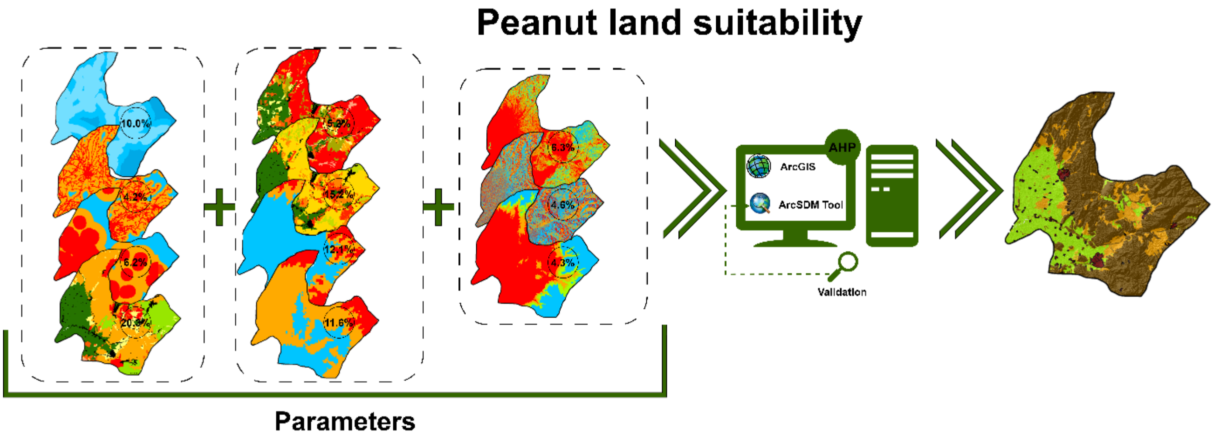
Highlights

- The goal of sustainable agriculture has been embraced.
- RS&GIS-based AHP method has been utilized for this purpose.
- A suitability analysis for peanut cultivation has been conducted.

Graphical Abstract



Flowchart of peanut land suitability

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ABSTRACT: Osmaniye is a province in the Mediterranean Region of Türkiye that stands out with its fertile agricultural lands and suitable climate conditions. Among the agricultural activities that form the basis of the regional economy, peanut production has an important economic and social place. Sustainable agricultural practices aim at the efficient use of agricultural lands and the protection of natural resources. In this context, determining suitable areas for cultivating strategic products such as peanuts is critical for protecting long-term agricultural production and ecosystem balance. In this study, 11 parameters were determined using the remote sensing & geographic information systems (RS&GIS)-based analytical hierarchy process (AHP) method to determine suitable areas for peanut cultivation in Osmaniye province. The receiver operating characteristic (ROC) curve was used to verify the produced model, and the area under the curve (AUC) value was 78.5%. Consequently, the analysis performed was found to be consistent and reliable. The study findings showed that Osmaniye allows peanut cultivation to be carried out sustainably and is strategically important for this species.

Keywords: *Peanut, Land Suitability, AHP, Sustainable Agriculture*

1. INTRODUCTION

The pressure on land is increasing due to human factors, including the ongoing global population growth, the diversification of needs with technological advancements, and the rise in industrialization. However, lands, which are irreplaceable resources, are seriously threatened due to floods, inundations, droughts, and fires due to global climate change. The regions where human factors have the most significant impact are developing countries. Because these countries tend to develop in areas such as industry, technology, and construction with the breakthrough policies and practices they have put forward, these activities are currently being carried out in many countries. As a result, the use and cover of land are changing rapidly. In particular, agricultural lands are seriously faced with the risk of urbanization (housing, industry, etc.). In many urban areas, agricultural lands are being opened to construction through zoning plans. In addition, unplanned and incorrect land use in rural areas also negatively affects agricultural lands. While agricultural lands covered 4.872 billion hectares (ha) worldwide in 2000, they decreased by approximately 1.87% to 4.781 billion ha by 2022 [1]. In Türkiye, among the developing countries, it is possible to discuss a decrease in agricultural lands, similar to the global average. While there were 38.757 million ha of agricultural land in 2000, the area decreased by 0.66% to 38.501 million ha by 2022 [2]. The situations expressed in both urban and rural areas pose a serious threat to land pieces, mainly agricultural areas. Due to these, agricultural areas are decreasing, and the yield of agricultural products is decreasing. As a result of all these, sustainable agriculture is in danger.

As is well known, the United Nations wants to ensure the sustainability of agriculture within the framework of the Sustainable Development Goals (SDGs) [3]. In particular, it is possible to state that sustainable agriculture is related to the principles of (a) Zero Hunger (SDGs 2), (b) Responsible Consumption and Production (SDGs 12), and (c) Climate Action (SDGs 13). Protecting agricultural lands will ensure that the food supply continues uninterruptedly and that hunger is reduced and ended. In

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this context, agricultural activities must continue sustainably in agricultural areas. At this point, consistent agricultural policies should be developed under the umbrella of sustainable agriculture management, and suitable agricultural products should be determined according to soil and climate requirements. Thus, the intended agricultural goal can be realized. This study conducted an agricultural suitability analysis of peanuts, which have ideal features for Osmaniye. Hence, it was intended to achieve sustainable agriculture.

It is known that for agriculture to continue uninterruptedly, agricultural crop patterns should be determined according to the soil structure (texture and depth, etc.) and climate characteristics of agricultural areas. In other words, a suitable location analysis should be carried out for these products. Several methods and parameters are employed in carrying out this analysis. Analytical Hierarchy Process (AHP) method based on the remote sensing (RS) and Geographic Information Systems (GIS) is generally preferred [4]–[6]. Although this technique is time-consuming, it is frequently used due to its high reliability [7]–[10]. Unlike the AHP method, logistic regression model (LGM) [11], [12], fuzzy logic (FL) [13], frequency ratio (FR) [14], random forest (RF) [15], [16], and support vector machines (SVM) [17] are preferred from machine learning (ML) methods. In addition, convolutional neural networks (CNN) [18] and recurrent neural networks (RNN) [19] have started to be used from deep learning (DL) techniques. [20] determined suitable places for peanut cultivation in Vietnam using the AHP method in the study conducted. In the study conducted by [14], land suitability analysis was carried out in the Krishna (India) region using AHP, FR, Shannon entropy (SE), and evidential belief function (EBF) techniques. In the study by [21], peanut drought zones in Shandong Province, China, were determined using the AHP technique. [22] utilized the AHP approach to identify ideal areas for peanut growing. The Borno State of Nigeria was chosen as the study area.

The literature states that different methods are preferred for peanut suitability analysis. At this point, it would not be wrong to say that peanuts have a vital place as an agricultural product. As of the end of 2022, peanut-planted areas in the world were 30,536,263 ha, and the production amount was 54,238,560 tons [23]. China (18,329,500 tons), India (10,134,990 tons), and Nigeria (4,284,000 tons) hold approximately 60.38% of the market with their production amounts. In Türkiye, as of the identical year, there was a production of 186,340 tons in an area of 45,701 ha [23], [24]. Türkiye has a share of 0.34% in the peanut market in production. In this context, it is difficult to say that it is still in a significant position in the global market. However, in the last 60 years, peanut planting areas in Türkiye have increased 6 times and production amounts by 9. In the same period, peanut planting areas increased by 1.9 times, and product amounts increased by 3.8 worldwide. In this regard, peanuts are probably more critical in Türkiye than other countries. In addition, peanut yield in Türkiye is almost 2.5 times the world average, approximately 400 kg/da, because peanuts are planted in fertile coastal plains that can be irrigated [25].

Osmaniye, which is geographically located in the Mediterranean region and permits peanut cultivation, was picked as the study area in this research. Osmaniye accounts for 25.94% (48,330 tons) of the peanuts produced in Türkiye in 2022, while approximately one-fourth of the peanut-cultivated areas (25.34%-11,582 ha) are located in Osmaniye [24]. In addition, although the largest cultivated area is in Adana, Osmaniye is the center of the peanut trade. The economic volume of peanuts here is estimated to be around ₺2 billion [26]. However, factors such as relatively narrow peanut cultivation areas in Osmaniye, difficulty harvesting, time-consuming, and producers not having sufficient knowledge about selecting appropriate parameters in peanut cultivation negatively affect the sustainability of peanut cultivation. However, another important problem is that the agricultural lands in the study area are under pressure from urban transformation projects. Because the peanut cultivation area is relatively small, it would not be wrong to say that these projects negatively affect it. The situations mentioned played a significant role in the study's conduct. This study was carried out to continue the sustainable agricultural application of peanuts, which are extremely valuable for Osmaniye. The suitable place analysis for peanuts was determined with the AHP method, which used 11 parameters, including the study area's soil and climate (temperature, precipitation) characteristics. The study anticipates that its findings will contribute to sustainable agriculture in Osmaniye and, to a broader extent, in Türkiye. The scarcity of comprehensive information regarding peanut cultivation in Osmaniye prompted the initiation of this critical research.

What makes this study distinctive is its integrated emphasis on both the local context and methodological rigor. While peanut cultivation holds global significance, there has been a marked absence of spatially explicit, parameter-based suitability analyses for peanut farming in Türkiye, particularly in high-yield yet vulnerable areas such as Osmaniye. Most previous research employing AHP or similar techniques has concentrated on different crops or regions altogether.

- This study not only addresses that geographic gap but also provides a replicable model by incorporating 11 agro-environmental parameters within a GIS-based AHP framework.
- Furthermore, the research highlights the intersection of land use pressure and crop sustainability—a perspective that is seldom explored together in land suitability literature.
- In doing so, it bridges the divide between agricultural planning and land policy, viewed through the lens of sustainable development.

2. MATERIAL AND METHODS

2.1. Peanut

Peanut (Arachis hypogaea) is a warm-climate plant belonging to the legume family, which includes beans, peas, and other similar crops. It is cultivated as an annual summer crop. Notably, there is a distinction between the fruit that forms underground and the plant parts that develop above ground. Classified as an oilseed crop, peanuts are valued for their seeds, which contain a high oil content. Peanut production is widely favored across various sectors, including food, health, animal feed, and cosmetics. Approximately half of the total production (49%) is used for oil, 41% for food consumption, and 10% for seeds, feed, and other applications [27].

Peanuts thrive in warm climates, predominantly during the summer months. They can be cultivated in soils with good drainage, a loose structure, and rich organic matter. While peanuts enjoy optimal growing conditions across various climates and soil types, the soil's characteristics are crucial for successful cultivation. The ideal soils for peanut planting are light-structured, sandy, pH between 6.0 and 6.4, well-drained, moderately rich in organic matter, and high in calcium. Highly acidic or alkaline soils are unsuitable for this crop [25]. Peanuts grown in tropical and subtropical regions prefer warmth. For quick germination, the soil temperature must reach at least 20°C. When the soil temperature is between 25-30°C at planting time, seeds typically complete germination within 7-8 days. Regular irrigation is essential for peanuts, especially during germination, growth, and yielding phases. This study highlights an agricultural suitability analysis for peanuts, emphasizing their significance in the study area due to their critical characteristics and economic value.

2.2. Study Area

Osmaniye is situated in the Mediterranean region, east of Çukurova. Geographically, it lies between 35°30′ and 36°30' North latitude and 37° and 37°30' East longitude (Figure 1). It is bordered to the west by Gaziantep, to the north by Hatay, to the east by Adana, and the southwest by Kahramanmaraş. With a surface area of 3,279.82 km², Osmaniye is located 20 km from the Mediterranean Sea and has an altitude of 121 meters. The province encompasses an agricultural area of 126,515.20 ha [2]. Osmaniye is notable for its diverse landforms; agricultural lands expand from the south towards the east and north. To the west of Osmaniye province, plains are extending eastward toward Adana. The Taurus Mountains rise north and northwest, while the Amanos Mountains extend southward from the Gulf of Iskenderun. In the east, it will find the Düldül, Dumanlı, and Tırtıl Mountains. There are gently sloping areas between these mountainous regions and the plains. The city center and Toprakkale, Kadirli, and Düziçi districts are located within these plains [28].

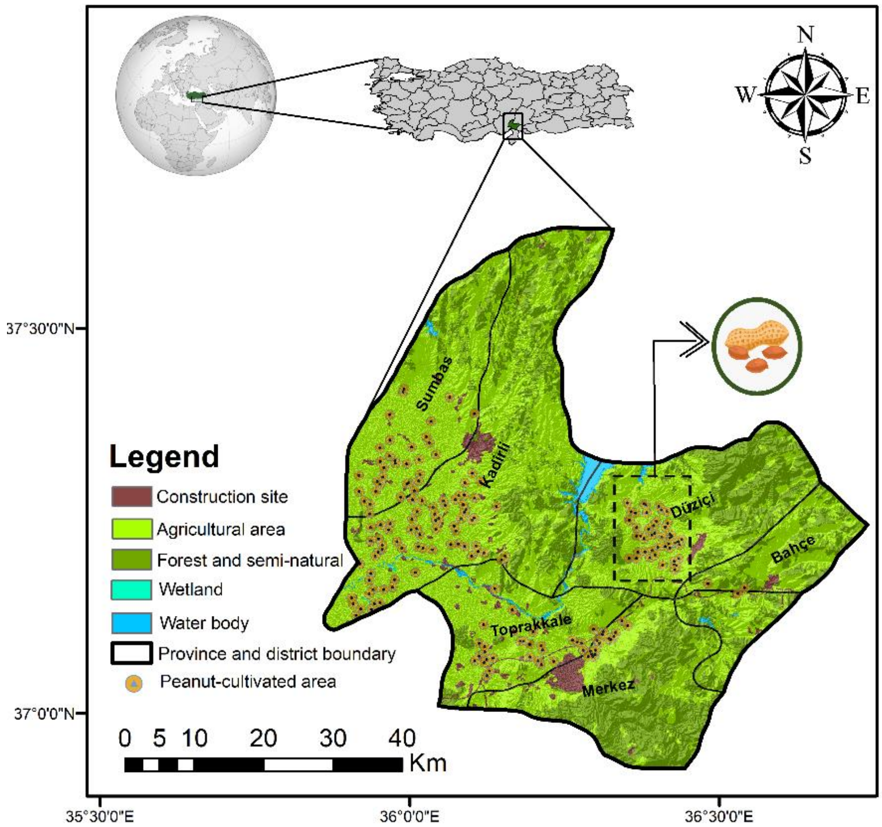

Figure 1. Study area

Osmaniye consists of 7 districts, including the city center. It includes 14 municipalities, 136 neighborhoods, and 159 villages (Table 1). 65 villages are located in the forests, 27 on the edge of the forest, and 66 on the plains.

Table 1. Number of administrative units and population for Osmaniye [2]

Districts	Number of Village	Population (2024)	Number of Neighborhoods	Total Count of Administrative Units
Merkez	38	282,645	40	78
Bahçe	15	23,069	11	26
Düziçi	25	86,929	45	70
Hasanbeyli	6	5,003	4	10
Kadirli	60	127,657	20	80
Sumbas	13	13,240	6	19
Toprakkale	3	22,518	13	16
Total	**158**	**561,061**	**139**	**299**

The climate and soil structure of Osmaniye are pretty suitable for peanut farming. This produces high yield and quality [29]. Osmaniye was selected as the study area due to these features.

2.1. Material

To identify suitable areas for peanut cultivation, which is the focus of this study, 11 parameters related to soil and climate characteristics were utilized (Table 2). These parameters were cropped and modified based on the study area. Data on great soil groups (GSG), land use capability (LUC), and soil depth were sourced from Tadportal [30]. Climate data, including temperature and precipitation, were obtained from WorldClim [31]. DEM data were provided by the Copernicus Land Monitoring Service [32]. The remaining parameters were generated within a me environment. All parameters were successfully converted to raster format before the analysis, ensuring a final resolution of 30 meters.

Table 2. Parameters used for peanut suitability analysis

Parameters	Scale/resolution	Last resolution	Data	Source
(A) Proximity to stream (km)	30 m		Raster	Production
(B) Proximity to road (km)	30 m		Raster	Production
(C) Proximity to settlement (km)	30 m		Raster	Production
(D) GSG	1/100,000		Vector	TadPortal
(E) LUC	1/100,000		Vector	TadPortal
(F) Soil depth (cm)	1/100,000	30 m	Vector	TadPortal
(G) Mean annual temp. (°C)	30°x30°		Raster	WorldClim
(H) Mean annual prep. (mm)	30°x30°		Raster	WorldClim
(I) Slope (%)	30 m		Raster	Production
(J) Aspect	30 m		Raster	Production
(K) DEM (m)	30 m		Raster	CLMS

The determination of meters areas for peanut cultivation was based on 11 parameters, classified into four categories: "Unsuitable (1)", "marginally suitable (2)", "moderately suitable (3)", and "highly suitable (4)." These classifications were informed by relevant literature, insights from three expert agricultural engineers, and feedback from local producers (Table 3). Additionally, specific parameters—including parts of the GSG, LUC, soil depth, slope, and DEM—were classified as "unsuitable" and were excluded from the analysis, along with the settlement parameter of the study area.

Once the parameters were meticulously classified, detailed maps were generated in ArcGIS (Figure 2). This crucial step marked the beginning of the analysis to identify potential distribution areas suitable for peanut cultivation.

2.3.1. Proximity to Stream

In peanut production, both brutal and sprinkler irrigation methods are commonly used. Proximity to water sources reduces irrigation costs, with producers favoring flood irrigation near streams, leading to lower expenses and higher yields. Out of 126,515.20 ha of cultivated land, 85,958 ha are suitable for irrigation, and 71,172 ha are currently irrigated. Of the irrigable land, 88.5% uses surface methods, 10% uses sprinklers, and 1.5% uses drip irrigation. Therefore, being within 1 km of a stream greatly benefits peanut cultivation (Figure2a).

2.3.2. Proximity to Road

Rising production costs lead producers to favor lands near roads for better fuel efficiency and ease of marketing. Farmland proximity to roads reduces transportation expenses, enhancing product value by allowing quicker and cheaper access to consumers. Conversely, fragmented lands far from roads are at a disadvantage. Consequently, agricultural production is often concentrated within 0-2 kilometers of roads, as illustrated in the road proximity map for the study area (Figure 2b).

2.3.3. Proximity to Settlement

In agricultural production, being close to roads is beneficial, while the ideal distance from settlements depends on the activity; generally, more remote areas are favored. The suitability analysis for peanut cultivation shows that areas over 10 km from settlements are preferred for optimal growth and post-harvest logistics (Figure 2c).

2.3.4. Great Soil Group (GSG)

When deciding on the suitability of plant production, the soil class in that region must be known

[33], [34]. The soil group in the study area mainly consists of alluvial (783.68 km^2), colluvial (224.30 km^2), brown (1367.73 km^2), and TerraRosa (160.66 km^2) types (Figure 2d).

Table 3. Sub-weights and importance values of the parameters

Parameters	Subclass	Value
(A) Proximity to stream (km)	0-1	4
	1-3	3
	>3	2
(B) Proximity to road (km)	0-2	4
	2-5	3
	>5	2
(C) Proximity to settlement (km)	0-2	2
	2-10	3
	>10	4
(D) GSG	A, E, O	4
	M, N, T	3
	K	2
	X, Unclassified	1
(E) LUC	I, II	4
	III, V	3
	IV	2
	VI, VII, VIII, Unclassified	1
(F) Soil depth (cm)	Lithosolic	1
	0-20	2
	20-50	3
	>50	4
(G) Mean annual temp. (°C)	6.9-12	2
	12-15	3
	>15	4
(H) Mean annual temp. (mm)	661-750	2
	750-805	3
	805-891	4
(I) Slope (%)	0-10	4
	10-20	3
	20-30	2
	>30	1
(J) Aspect	S, SE,	4
	SW, ED	3
	N, NE, W	2
(K) DEM (m)	9-400	4
	400-650	3
	650-900	2
	>900	1

2.3.5. Land Use Capacity (LUC)

Understanding soil structure and usage capacity is essential in agricultural suitability analysis. Land use capacity (LUC) significantly impacts the reliability of the analysis, indicating whether land can support various crops. Products related to LUC are categorized by their limitations, production risk, and soil management practices [33]. The study area primarily consists of Class VII land, covering 1,619.09 km^2, followed by Class I at 679.93 km^2, Class VI at 255.14 km^2, and Class VIII at 68.73 km^2 (Figure 2e).

2.3.6. Soil Depth

Soil depth refers to the volume of soil available for plant root development, impacting water and nutrient access. The ideal depth for peanut cultivation is over 50 cm, while lithozolic soil is not suitable. In the study area, 1251 km² has a soil depth of 0-20 cm, and 822.74 km² has depths greater than 50 cm. This indicates a significant portion of the area is suitable for peanut farming based on soil depth (Figure 2f).

2.3.7. Mean Annual Temperature

One essential factor in agriculture is the climate requirements of plants. In Türkiye, known for its plant diversity, the total temperature needed for crops impacts their growth. Peanuts, typically grown in tropical and subtropical areas, thrive in warm climates and are sensitive to cold. The annual average temperature in most study areas exceeds 15°C and rarely drops below 7°C, creating favorable conditions for peanut cultivation (Figure 2g).

2.3.8. Mean Annual Precipitation

Water is crucial for agriculture, especially irrigated farming, as reliable water sources are necessary for crop growth. In Türkiye and globally, precipitation is often the primary water source. For example, peanuts need adequate precipitation. In the study area, most precipitation occurs in winter and autumn, averaging about 816.8 mm annually (Figure 2h).

2.3.9. Slope

The slope factor is crucial in Türkiye's agriculture, particularly for peanuts, as lands with low slopes are more suitable. Major issues in sloping areas include landslides and challenges with irrigation and planting. In the study area, slopes range from 0-10% to over 20%, indicating a mix of plains and mountainous regions (Figure 2ı).

2.3.9. Aspect

Aspect is crucial in plant production. In regions with favorable aspects, the sun's rays are more direct, the duration of sunshine is longer, and plants have shorter growth periods. In Türkiye, the southern slopes receive more sunlight and heat up quicker than the northern slopes. Since peanuts thrive in hot regions, the southern slopes of the study area are more suitable for their growth (Figure 2j).

2.3.10. DEM

Elevation has a direct effect on peanut cultivation. As the land rises, climate requirements change. The temperature requirements required for peanut cultivation decrease, and production decreases accordingly. In addition, the ruggedness of the land is not a preferred situation, as it makes peanut harvesting difficult. Although the elevation of the study area varies between 9-900 m, peanut production is currently carried out mainly in places where the elevation is low (0-650 m) (Figure 2k).

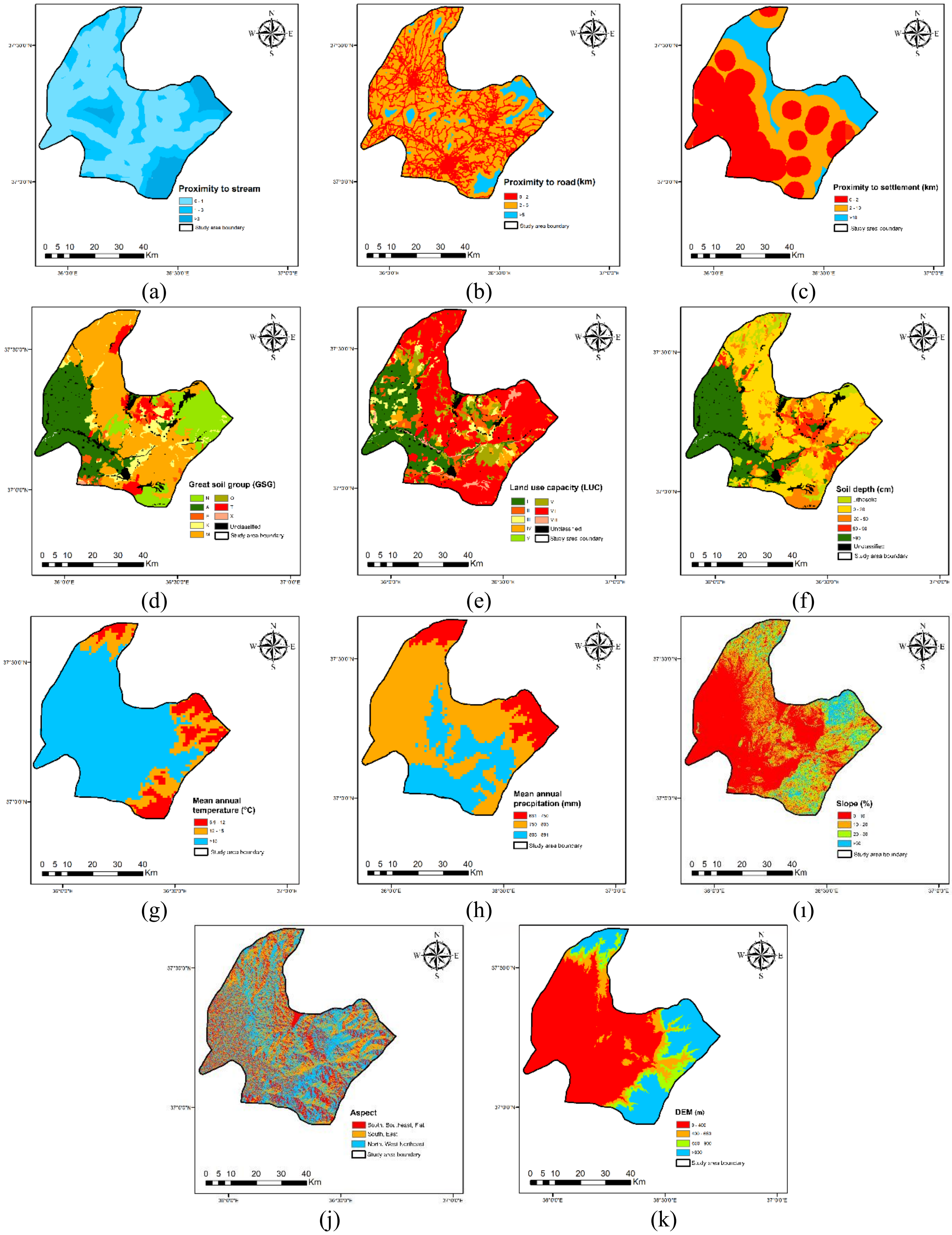

Figure 2. Parameters utilized in the study

2.4. Method

It employed the AHP, a commonly used method in suitability analysis, to identify suitable locations for growing peanuts in the study area. This approach involves assigning weights to the relevant parameters. Once the weights are established, the Weighted Overlay Technique (WOT) is applied to analyze the layers.

Analytical Hierarchy Process (AHP)

Analytic Hierarchy Process (AHP) is a multi-criteria decision-making technique that, when needed, incorporates expert opinions to establish rankings and weights through a pairwise comparison matrix. This method is highly effective for solving multi-parameter problems. Within AHP framework, the weights of the parameters are determined based on their relative importance. This approach was utilized to assess land suitability, which is one of the key objectives of the study.

AHP was refined by Saaty in 1977 [35] as a model for analyzing problems in multi-criteria decision-making [36]. The application of the AHP method follows three key principles: (1) defining the problem and establishing a hierarchical structure, (2) developing the binary comparison matrix, and (3) determining the priorities through normalized weights [8].

Once the parameters have been established, a pairwise comparison matrix will be developed. This matrix, which will be of size n x n, is generated by conducting n(n-1)/2 comparisons among n parameters. In comparing these parameters, the significance scale will be utilized, ranging from 1 to 9, as recommended by [37] (Table 4).

Table 4. Satty's significance scale [37]

Significance level	Description
1	Equal importance
3	1st criterion is slightly more important than 2nd
5	1st criterion is more important than 2nd
7	1st criterion is much more important than 2nd
9	1st criterion extremely important than 2nd
2, 4, 6, 8	Intermediate values

After the comparison matrix, the normalized weights are determined. This is calculated by the geometric mean of the parameters (Equation 1).

$$W_n = \frac{G_m}{\sum_{i-1}^{n} G_m} \tag{1}$$

Where W is the weight vector, G_m is the geometric mean.

Consistency analysis is conducted to verify the reliability of AHP results. This analysis utilizes the Consistency Index (CI) and Consistency Ratio (CR). CR of 0.1 or lower indicates that the comparison matrix is consistent. If the ratio exceeds 0.1, the comparison matrix should be re-evaluated. In this study, the consistency ratio was 0.06 (Table 5).

Table 5. Pairwise comparison matrix (λmax), consistency index (CI), random index (RI), and consistency ratio (CR) for peanut

	λmax	CI	RI	CR
Peanut	11.943	0.094	1.52	0.062

The pairwise comparison matrix, which is found to be consistent, is created (Table 6). After establishing the pairwise comparison matrix and determining the weights of the parameters, the next step involves generating the peanut suitability map by combining these parameters, as shown in Table 7. At this juncture, the WOT was employed. Consequently, the suitability index for peanuts was developed by summing the parameters, as indicated in Equation 2.

$$Fısıtık_i = \sum_{i-1}^{n} w_i r_i \quad (2)$$

Where n represents the number of parameters, w_i typifies the weight of i parameters, and r_i is the level of parameters.

Table 6. Pairwise comparison matrices and weights

Parameter	A	B	C	D	E	F	G	H	I	J	K	Weight (%)
A	1											10.0
B	1/5	1										4.2
C	1/4	1	1									6.2
D	4	4	4	1								20.3
E	1/3	2	1	1/3	1							5.2
F	3	3	3	1/2	3	1						15.2
G	3	3	2	1/2	2	1/2	1					12.1
H	3	3	3	1/2	3	1	1/2	1				11.6
I	1/2	1	1/2	1/3	1	1/3	1/2	1	1			6.3
J	1/2	1	1/2	1/3	1	1/3	1/2	1/2	1/2	1		4.6
K	1/2	1	1/2	1/4	1	1/3	1/2	1/2	1/2	1	1	4.3

2.4.2. Validation

Validation is crucial for ensuring scientific studies' reliability, performance, and consistency [38], [39]. Following the analysis, the receiver operating characteristic (ROC) curve was chosen, as it is commonly used in many studies to validate and evaluate the performance of models [40], [41]. The area under the curve (AUC) reflects the accuracy of the estimations [42]. In the ROC curve, the y-axis represents the true positive rate, while the x-axis represents the true negative rate. The AUC value ranges from 0 to 1; values nearing 1 indicate superior model performance and high reliability. In this study, the validation process of the analysis performed with the AHP method was performed using the ROC curve.

3. RESULTS

This study conducted a land suitability analysis for peanut cultivation using the AHP method, assessing 11 parameters. Upon examining the contributions of these parameters to the analysis, GSG emerged as the most significant, accounting for 20.3%. Other key parameters included soil depth at 15.2%, mean annual temperature at 12.1%, and mean annual precipitation at 11.6% (Figure 3).

The study first determined the potential distribution areas of agricultural products for the provincial border of Osmaniye, which constitutes the study area according to these parameters (Figure 4).

The land suitability analysis conducted for peanut cultivation in Osmaniye province highlights the area's agricultural potential for this crop. The analysis determined that 25.11% (823.45 km^2) of the study area falls into the "highly suitable" category, whereas 63.59% (2085.71 km^2) is classified as "unsuitable" (Figure 5). Furthermore, when the potential distribution of peanut classes for the Osmaniye provincial border is examined, it is understood that the southwestern parts are predominantly "highly suitable" for this species. In contrast, the higher-altitude, mountainous, and rugged areas are deemed mainly "unsuitable."

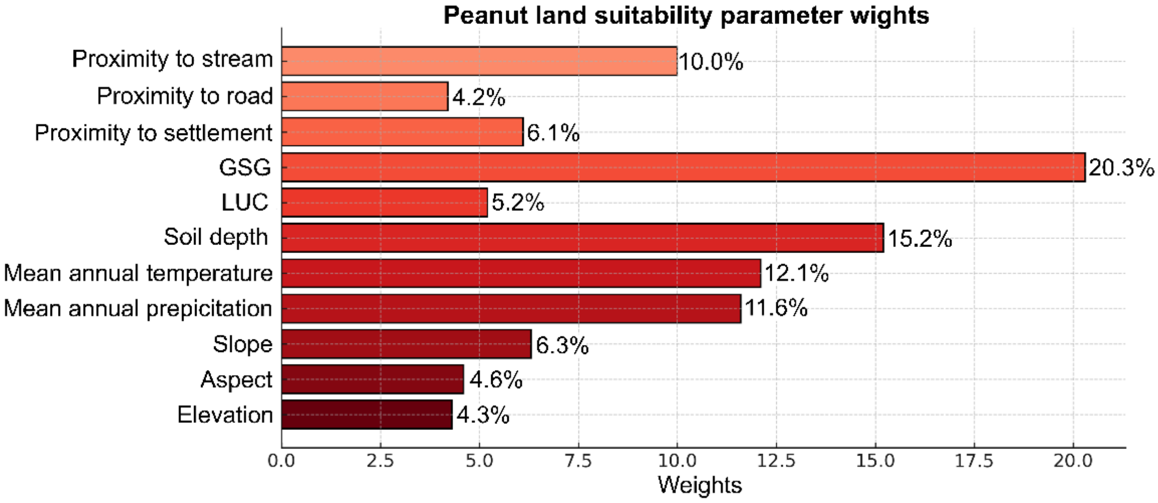

Figure 3. Significance levels of parameters utilized for peanut suitability

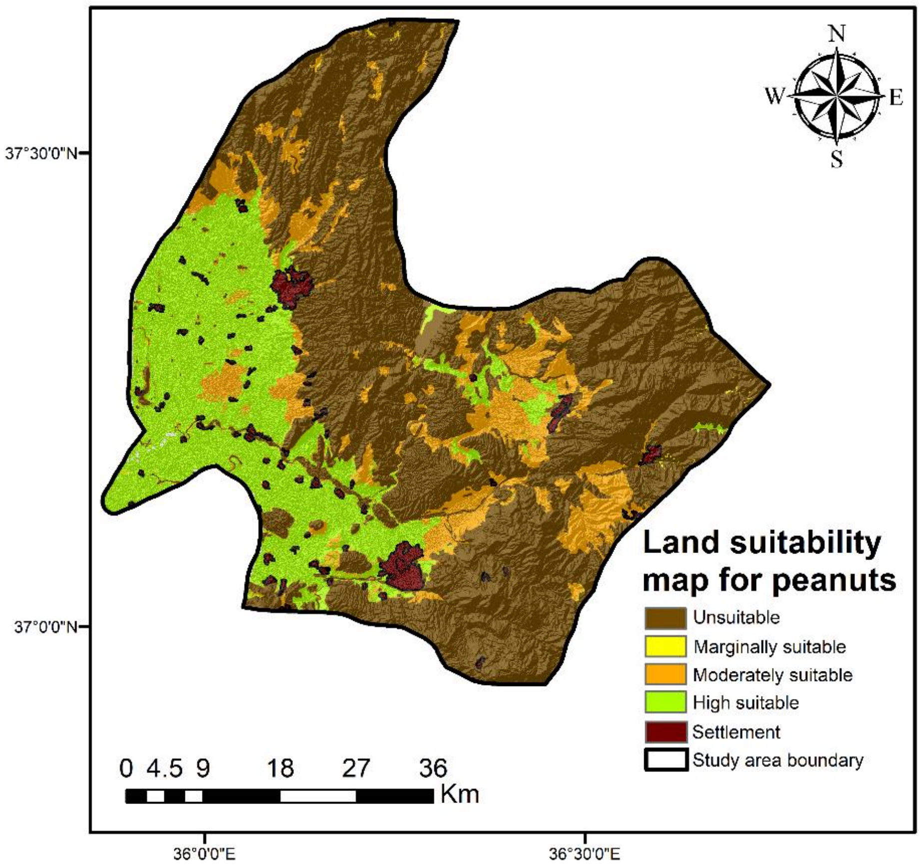

Figure 4. Land suitability map for peanut cultivation in Osmaniye province

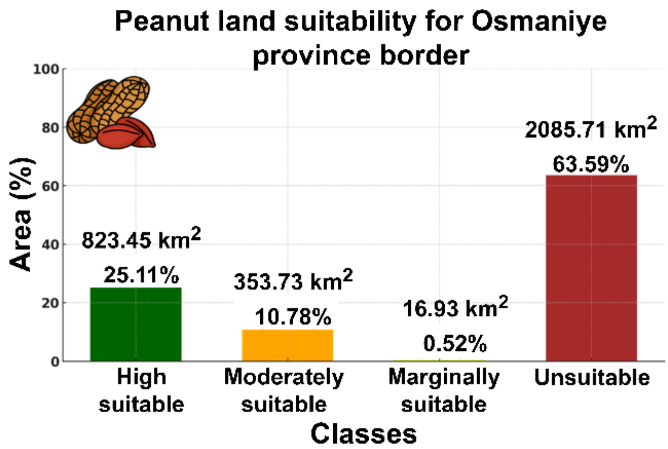

Figure 5. Suitability class distributions for peanuts in Osmaniye province

The agricultural suitability map generated for the border of Osmaniye province provides a comprehensive overview of the study area. Similar processes were conducted for each of the 7 districts within Osmaniye to enhance the analysis, creating district-specific agricultural suitability maps (Figure 6).

The total surface area of Sumbas district is 465.98 km², and the "highly suitable" areas cover a total of 204.62 km² (43.91%) (Figure 6a). This category has the most significant area among all classifications. Conversely, the "marginally suitable" category has the smallest area, totaling just 19.33 km², representing 4.15% (Figure 7a). Notably, the southern part of the district is conducive to peanut cultivation due to its relatively flat terrain and fertile soil, supporting the classification of these regions as "highly suitable." In contrast, the northern parts of the district are characterized by mountainous and rugged terrain, resulting in their classification as "unsuitable."

After Sumbas district, the findings belonging to Kadirli, which is the largest in terms of surface area (1002.32 km²) of Osmaniye, are included (Figure 6b). Accordingly, 27.93% (279.94 km²) of Kadirli district is in the "highly suitable" class, and more than half (60.45%) is in the "unsuitable" class (Figure 7b). While the district's southwest offers suitable opportunities for this species, the north and northeast have unsuitable conditions due to their mountainous and high structure.

Thirdly, suitable areas for peanut cultivation in Düziçi district have been identified (Figure 6c). It is seen that the district is generally not very suitable for peanuts. The findings also support this situation. Accordingly, only 5.74% (34.82 km²) of the district is in the "highly suitable" class (Figure 7c). However, the fact that the "moderately suitable" class covers more than one-third of the district (36.18%) shows that this species can be cultivated in Düziçi. Most of the district (%58.01-351.75 km²) is in the "unsuitable" class. In light of these values, it has been determined that the middle parts of the district are more suitable for peanuts. The high and mountainous parts are pretty unsuitable for the agricultural activities of this species due to soil structure and other environmental limitations.

After Düziçi, analysis was conducted for peanuts in Bahçe district, which is the border of here, and the peanut suitability map of the district was produced (Figure 6d). Bahçe, the smallest district after Hasanbeyli in terms of surface area (207.82 km²), has low area values of the classes accordingly (Figure 7d). Most of the district (93.67%) is in the "unsuitable" class. The fact that the topography of the district is mainly mountainous and rugged is highly effective in forming this situation. Only 1.44% (3.00 km²) of the area is in the "highly suitable" class. The district's south and southwest offer relatively good peanut cultivation opportunities.

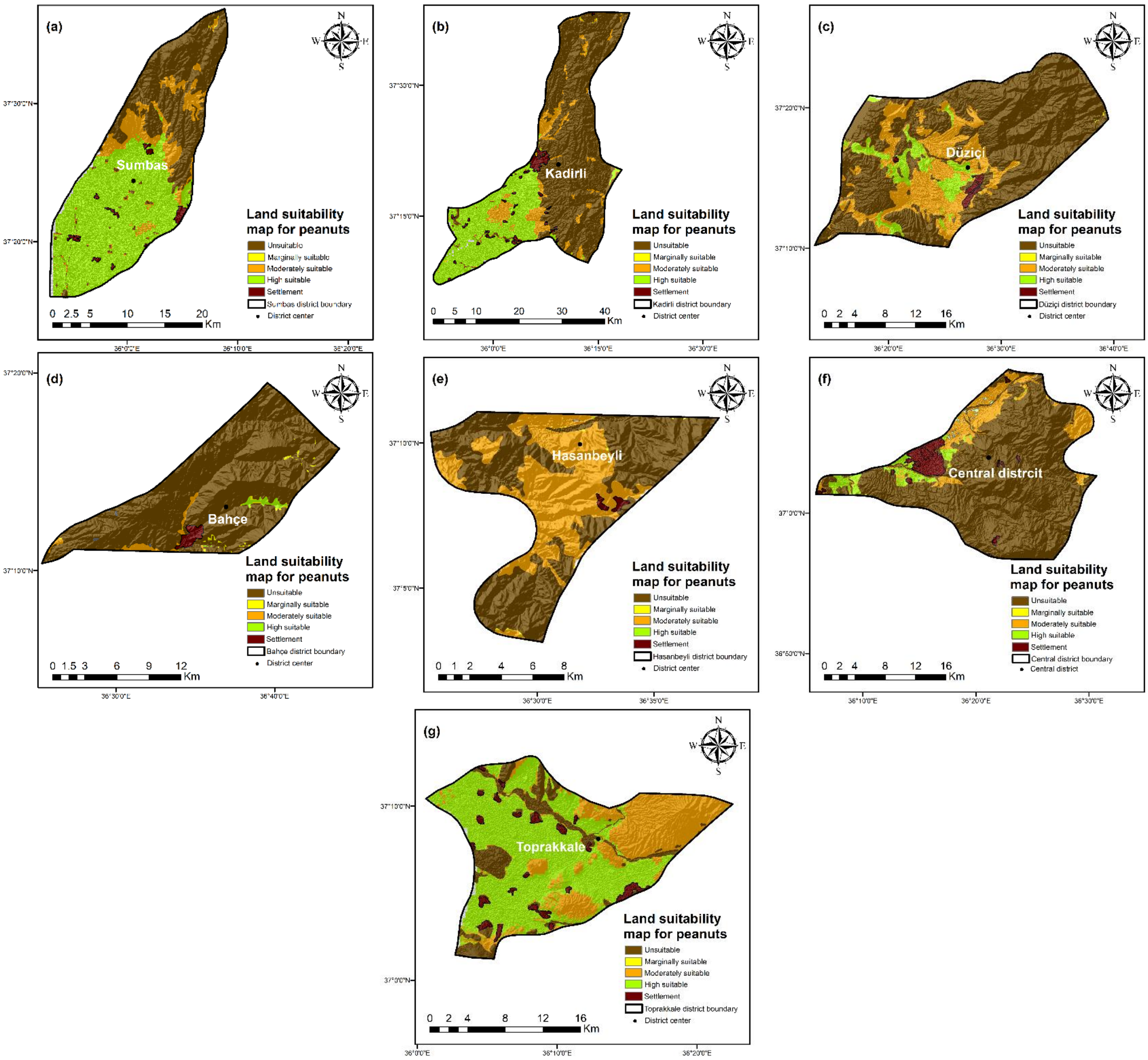

Figure 6. Land suitability map for peanut cultivation in Osmaniye districts

Hasanbeyli, a small district (131.90 km^2) like Bahçe, does not have very suitable conditions for this species (Figure 6e). While 88.28% of the region is in the "unsuitable" class, only 0.04% is in the "highly suitable" class (Figure 7e). When this value is considered, it is understood that the district offers the least suitable place among the other districts. However, it is possible to say that the central and northern parts of the district have relatively suitable opportunities.

After Bahçe, an analysis was also conducted for the Central District (Figure 6f). Osmaniye is where the population (282,645) and construction are the highest. Accordingly, it is possible to state that agricultural activities are under pressure. The findings obtained from the analysis also support this situation. Accordingly, 79.59% (387.45 km^2) of the district is in the “unsuitable” class (Figure 7f). Based on this, 7.30% (35.54 km^2) of the district is in the “highly suitable” class. Nevertheless, almost one-fifth of the region (18.64%) offers suitable areas for peanuts at a reasonable level (“highly suitable” and “moderately suitable”). It was determined that the southwest-northwest line of the district is more suitable for this species.

Toprakkale district offers suitable conditions for peanuts as a region where intensive agricultural activities are carried out (Figure 6g). More than half of the district (58.15-220.15 km2) is “highly suitable” for this species. Accordingly, it is the district with the least (23.52%) “unsuitable” class among all districts in proportion to its surface area (Figure 7g). While the "highly suitable" class has a high percentage here, the "moderately suitable" class is also a considerable value (18.08%). Only 0.25% (0.96 km2) of the district is in the "marginally suitable" class. While the northeast of Toprakkale is notable as an unsuitable region, other parts essentially allow agricultural activities of this species.

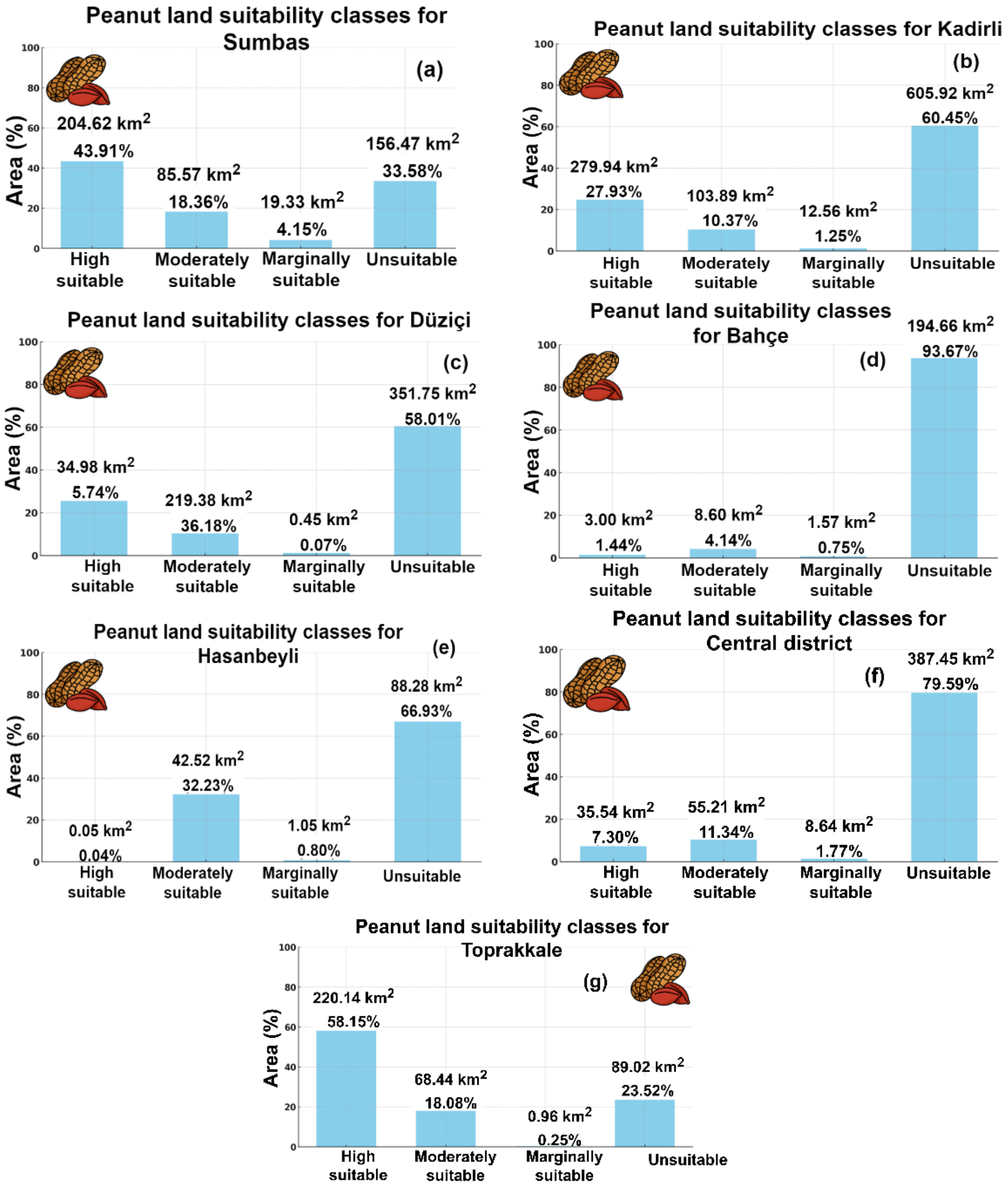

Figure 7. Distribution of land suitability classes for peanut cultivation in Osmaniye districts

The primary goal of this study is to identify suitable areas for peanut cultivation. To assess the accuracy of our agricultural suitability analysis, we utilized data from currently cultivated peanut areas (Figure 8). For the validation process, 200 points (peanut-cultivated regions) were identified by considering the soil and climate characteristics required for peanut cultivation, as well as through field interviews with farmers.

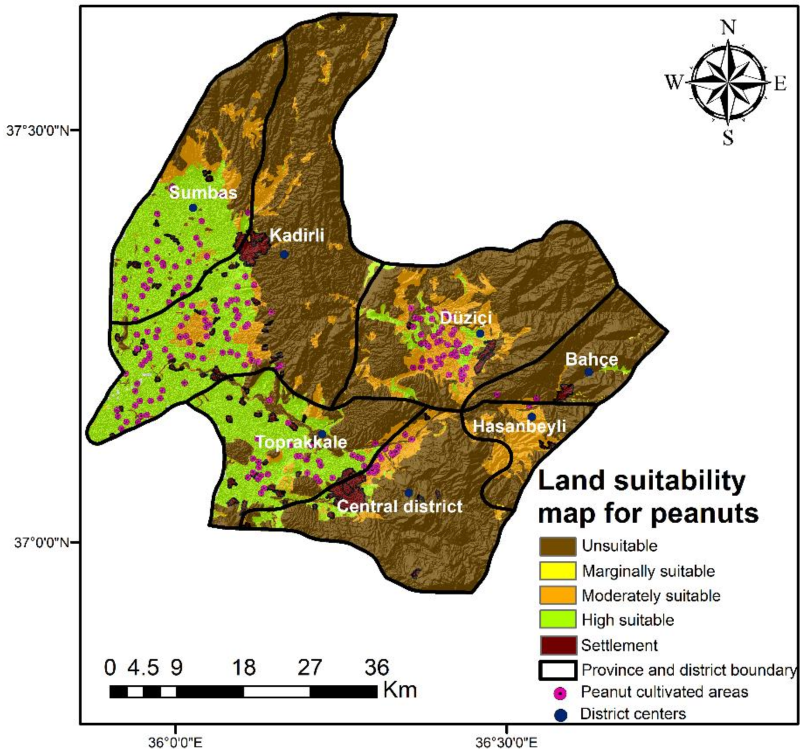

Figure 8. Peanut production areas and land suitability status in Osmaniye province

First of all, with 200 records (peanut) data, the compatibility of classes was determined (Figure 9). 89.5% of the peanut-planted areas are in the "highly suitable" and "moderately suitable" classes. 24.5% are in the "marginally suitable" class, and only 4% are in the "unsuitable" class. Then, the model was validated using the ROC curve (Figure 10). Accordingly, the AUC value was calculated as 78.5%. This case shows that the analysis performed is quite consistent and reliable.

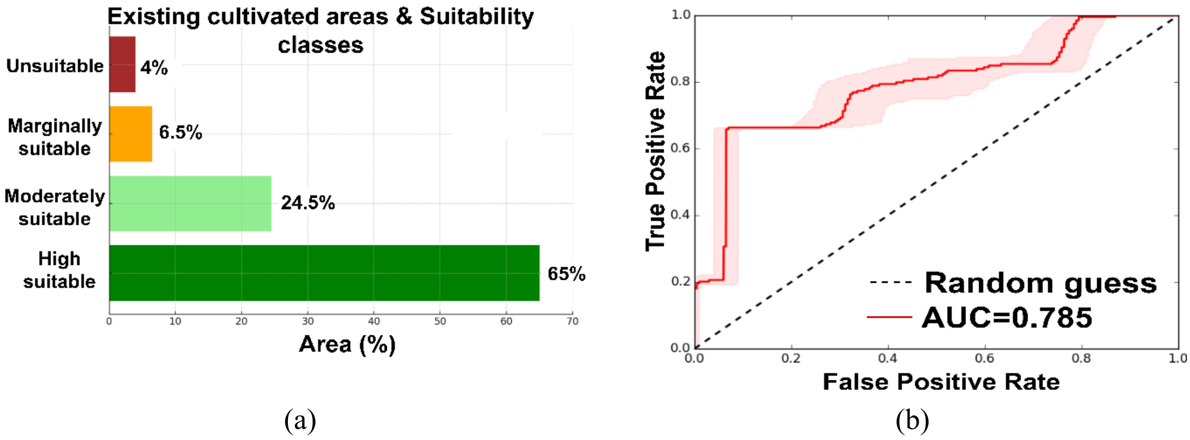

Figure 9. (a) Distribution of peanut plantations according to land suitability classes, (b) ROC curve

4. DISCUSSION

When the model produced for Osmaniye as a result of agricultural suitability analysis is evaluated, it is possible to state that the model yielded a successful outcome. In this context, it would not be wrong to say that the AHP method and the preferred parameters (11) suit the selected agricultural product. According to the map produced, the southwest of the study area offers quite suitable opportunities for peanut cultivation in general. It has been determined that mountainous, rugged, and high areas are unsuitable; however, the slope is low, and the alluvial soil structure is more suitable for this species. In this context, it is thought that peanut cultivation in the regions with the "highly suitable" and "marginally suitable" classes will significantly contribute to achieving the sustainable agriculture target. Different agricultural product patterns should be preferred in the "unsuitable" and "marginally suitable" classes. Thus, by ensuring product-location compatibility, the region where agricultural activities are carried out on a lower scale will contribute to the economy of Türkiye on a higher scale. Ultimately, the sustainability of agriculture will be ensured.

In addition to interpreting the findings obtained as a result of the analysis carried out in the study, it is extremely important to compare a scientific study with similar studies in the literature and to reveal its strengths and weaknesses. In this context, it is known that many different methods are used in studies to determine agricultural suitability. Nonetheless, the RS&GIS-based AHP method is often preferred due to its reliability. In the research by [20], suitable areas for peanuts were determined by the AHP method. In the study by [21], peanut drought zones were determined by the AHP technique. [43] conducted a peanut suitability analysis for Ghana using the AHP method. [44] determined the suitability of soil in Niayes/Senegal for 3 different species (peanut, rice, and cassava) by 2 methods (parametric and non-parametric). In the study conducted by [45], agricultural suitability analysis was carried out for many species, including peanuts, and the AHP method was preferred. In this context, it is possible to say that the manuscript is compatible with the literature and that it is current.

In this study, where agricultural suitability analysis was carried out for peanuts, parameters including climate and soil properties were preferred. As emphasized by [41], [46], and [47] climate and soil parameters are mainly used in suitability analyses. In particular, GSG, soil depth, mean annual temperature, and mean annual precipitation parameters were the main elements determining peanut production efficiency. [20] carried out the analysis with 6 parameters, [48] 8, and [49] 8 parameters. 11 variables were used in this study. This research differs from the literature regarding the types and number of parameters.

The study aimed to achieve the sustainable agriculture objective while conducting a suitability analysis. By supporting research at a local level and aligning with Türkiye's broader agricultural vision, this study offers recommendations to enhance the continuity and efficiency of agricultural practices. In this regard, it makes a valuable contribution to the existing literature.

The study presents a fresh perspective for the academic community regarding the preferred methodology, types, and number of parameters, as well as the sustainability of agriculture. However, it does possess some limitations. (1) The analysis focused on a single agricultural product, with the concept of sustainable agriculture introduced within this context. This approach falls short, as addressing the continuity of agriculture for an entire country or region based on just one product is inadequate. Since the research was conducted in a more constrained area, referring to sustainable agriculture in Osmaniye is more appropriate. (2) The parameters utilized in the study are limited in their resolution (30 m), which may result in less precise and reliable outcomes for applications in smaller regions. Nevertheless, this resolution allows for rapid analysis across larger areas.

5. CONCLUSIONS

Peanuts are an oilseed crop of significant economic value globally and in Türkiye. The cultivation of peanuts in Türkiye has gained prominence due to their adaptability to the country's hot and humid climate, particularly in the Mediterranean Region. Within this context, Osmaniye province serves as a vital hub for peanut production in Türkiye. This study utilized 11 parameters and the RS&GIS-based AHP method to identify the most suitable areas for peanut cultivation in Osmaniye province. The findings highlight the importance of accurately determining optimal cultivation areas to promote sustainable agricultural practices.

Implementing strategic measures to enhance the sustainability and efficiency of peanut production is essential. These measures should include optimizing the utilization of production zones, enhancing agronomically viable areas, implementing alternative cropping strategies, optimizing soil health and climatic conditions, and reinforcing local agricultural policies. These approaches should focus on precision agriculture techniques and integrated soil fertility management to maximize yield potential while minimizing environmental impact.

Effective Utilization of "Highly Suitable" Areas: Modern agricultural techniques should be implemented in the "highly suitable" regions located in the northwest, with efforts made to enhance production potential through improvements in irrigation infrastructure. The suitable areas of the Sumbas, Kadirli, and Toprakkale districts should be prioritized as agricultural areas.

Improvement of "Moderately Suitable" Areas: To bring areas in the "moderately suitable" class into production, soil arrangement works, drainage system development, and irrigation projects can be carried out. These areas in Düziçi and Toprakkale districts have significant potential for increasing agricultural productivity.

Encouraging Alternative Economic Activities in "Unsuitable" Areas: Initiatives such as ecotourism, animal husbandry, and greenhouse farming should be promoted in the "unsuitable" lands in Hasanbeyli, Bahçe districts, and the Center. Given these areas' topographical characteristics and limitations, non-agricultural ventures may offer a more sustainable solution.

Enhancement of Soil and Climate Conditions: Agricultural improvement strategies, including drainage, soil enrichment, and deepening, can be implemented in areas where the soil is unsuitable for peanut cultivation. Additionally, practical water management approaches, such as irrigation planning and rainwater harvesting, should be developed to reduce the impacts of climate change.

Supporting Local Agricultural Policies: Local governments and agricultural cooperatives can increase production capacity by training farmers in modern agricultural techniques. In addition, infrastructure and logistics support should be provided in regions with intense peanut production.

Peanut cultivation presents economic and environmental benefits from the perspective of sustainable agriculture. Adopting modern agricultural practices and efficient management of agricultural lands in alignment with natural resources will enhance sustainable development in agriculture-focused regions such as Osmaniye. Additionally, expanding and diversifying peanut production in Osmaniye in the future will contribute to Türkiye's achievement of its agricultural export targets.

Declaration of Ethical Standards

The authors declare that all ethical guidelines including authorship, citation, data reporting, and publishing original research.

Credit Authorship Contribution Statement

Osman Orhan: Investigation, Conceptualization, Writing-review and editing

Mehmet Özgür Çelik: Investigation, Data curation, Analysis, Visualization, Writing-original draft preparation, Writing-review and editing.

Nagihan Karataş: Investigation, Conceptualization, Writing-original draft preparation, disputes and facilitating collaboration.

Declaration of Competing Interest

The authors declare that there is no conflict of interest.

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Data Availability

The data utilized in the study are available from the corresponding author upon request.

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