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HOW CAN GIS AND AHP ASSIST IN LAND ASSESSMENT FOR THE SELECTED DENDROFLORA? THE EVIDENCE FROM TÜRKİYE'S ESKIŞEHIR PROVINCE

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Abstract: This study aims to present a transferable model for land assessment using the example of *Ziziphus jujuba (Z. jujuba)* cultivation, which has high economic value and value-added product development potential. For this purpose, ten criteria that influence the cultivation of *Z. jujuba* were initially identified: major soil groups, soil depth, land capability class, land capability subclass, slope, aspect, temperature, precipitation, elevation, and erosion. Eskişehir Province in Turkey, with its diverse terrain, climate conditions, and soil characteristics, has been selected as the study area. Within the scope of the Analytic Hierarchy Process (AHP), ten expert opinions were obtained, the weights of each criterion were calculated, and reclassification was carried out. Poorly drained or insufficiently drained areas, rocky and stony lands, bare rock-rubble areas and river floodplains found in the land capability subclass, urban centers and built-up areas, streams, dam and lake areas, and roads were considered as limiting factors and excluded from the suitability map. According to the weighted overlay analysis, land suitability for *Z. jujuba* cultivation in Eskişehir Province was categorized as 4.8% highly suitable, 21.2% suitable, 1.7% moderately suitable, and 72.3% restricted. The practical contribution of this study is that it provides a transferable model for land assessment suitable for high-value-added crops, such as *Z. jujuba*. This model can contribute to rural development by guiding the planning and spatial allocation of commercially valuable agricultural products.

Keywords: land suitability; Z. *jujuba*; GIS; AHP; Türkiye

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1. Introduction

Urbanization is rapidly transforming forests, pastures, wetlands, and agricultural lands into built-up areas. Both population growth and the encroachment of settlement areas into agricultural lands are triggering problems related to food production, food distribution, food security, and food assurance (Abu Hatab et al., 2019; Ruel et al., 2017). To reduce global land pressure, it is essential to develop land use plans and land management policies (Prato, 2007). Land-use planning, in this sense, should aim to balance the growing demands, needs, and expectations of the population with the need to preserve the productivity of ecosystems for the present and the future. Achieving sustainable land use will only be possible by acting according to scientific principles and identifying areas with high production potential (Randolph, 2004). Cultivating high-value agricultural products can serve as a catalyst for the revitalization of rural areas. Therefore, efforts are needed to cultivate high-value agricultural products with long shelf lives in areas where the highest yield can be obtained, in order to revitalize rural areas (Haggblade et al., 1991; Harriss, 1987; Ogen, 2007). A prerequisite for land-use planning is the assessment of land suitability (Mokarram & Aminzadeh, 2010). Assessing the suitability of land for a specific use requires the simultaneous consideration of multiple criteria. Various methods are used to determine the weights and scores of sub-criteria (Mugiyo et al., 2021). It is essential to determine the precise suitability of various sectors based on biophysical, social, economic, cultural, and environmental variables, and to integrate these data into the most appropriate land-use plans and maps.

The market for *Z. jujuba* fruits was valued at approximately $3.45 billion in 2024. This market is expected to grow at a compound annual growth rate of 7.45% from 2025 to 2033, reaching $6.53 billion (Data Horizzon Research, 2024). Accordingly, this study aims to provide a sustainable model for land evaluation by addressing the cultivation of *Z. jujuba*, which has high economic value and potential for developing value-added products. The questions addressed in this study are which areas in Eskişehir Province have the most suitable combination of biophysical, climatic, and land capacity characteristics for growing *Z. jujuba*, and how the Spatial Multi-Criteria Evaluation-Analytic Hierarchy Process (AHP) methodology can guide high-value crop planning in semi-arid zones? The study presents a site selection analysis model specifically designed for *Z. jujuba* cultivation. For this reason, Eskişehir Province in Türkiye, which was previously identified as having suitable conditions, was selected as the study area. The practical contribution of the study is to guide the planning of commercially important agricultural products by offering site selection opportunities for high value-added products.

1.1. Z. jujuba: cultivation and uses

Z. jujuba, which originated in China, is now cultivated in regions such as Russia, India, the Middle East, Southern Europe, and Africa (Liu et al., 2016). It produces sweet, apple-like fruits and is recognized as an easy-to-grow, resilient tree, bearing fruit annually. With a maximum height of seven meters and tolerance to drought and poor soil conditions, it is well-suited to semi-arid climates (Kumar Sishu et al., 2023; Liu et al., 2020). The tree's natural self-pruning and adaptability to stress factors further enhance its agronomic appeal (Guo et al., 2017; Khadivi & Beigi, 2022; Wang et al., 2016).

Z. jujuba, used in Chinese medicine for over 2,500 years, is known for its properties of nourishing the blood, strengthening immunity, promoting digestion, and calming the mind

(Edo et al., 2025; Wang et al., 2016; Zhu et al., 2024). This plant provides antioxidant, anti-inflammatory, and neuroprotective benefits, containing vitamin C, flavonoids, triterpenic acids, and minerals (Agrawal et al., 2023; Gao et al., 2013; Shahrajabian et al., 2019). The wood of this plant is also durable and is used in the manufacture of musical instruments and ships (Outlaw et al., 2002). Traditional and modern products derived from its fruit include *Z. jujuba* jam, liqueur, tea, powder, extract, and even beer (Liu, 2004; Liu, personal communication, October 11, 2018). Due to its taste and health benefits, *Z. jujuba* has significant economic and ecological significance. From a consumer's perspective, fruits such as *Z. jujuba*, which are tasty and nutritious, are appealing (Wu et al., 2025). For marketers, products that are easy to transport and have a long shelf life are also preferred. *Z. jujuba* fruits are long-lasting because they can be consumed both fresh and dried. They also have high industrial value in terms of processing. Their use as herbal medicine, versatility in fresh and dried forms, ease of processing, added value, and therefore income-generating potential offer significant opportunities (Sarkar & Jyoshna, 2020).

2. Literature review

Studies carried out within the context of land evaluation for agricultural activities vary depending on the criteria used, the study area, the data, and the crop addressed. Agricultural land suitability analysis has been the focus of many studies, utilizing methodological frameworks that vary based on geographical context, spatial data availability, and crops of interest (Table 1). Criteria widely used in these evaluations have included soil-related factors (e.g., major soil groups [MSG], soil depth, drainage, erosion), topographic variables (e.g., slope, aspect, elevation), climate indicators (e.g., temperature, precipitation), and spatial affinity to hydrological or infrastructural features.

Şahin and Toroğlu (2020) incorporated a variety of parameters such as MSG, land capacity class (LCC), land capacity subclass (LCS), soil depth, drainage, erosion, slope, aspect, temperature, precipitation, proximity to main and tributary rivers, elevation, and other soil characteristics (OSC). Sönmez et al. (2019) also utilized a comprehensive data set of soil and topographic factors. Altun and Demir (2015) emphasized the role of vegetation cover in addition to typical soil and terrain characteristics. Bathrellos et al. (2013) conducted a study that also included distances to flood-prone areas, roads, and settlements.

Research conducted by Akıncı et al. (2012), Karabacak (2021), and Mercan and Arpağ (2020) highlight slope, soil depth, and erosion as recurring indicators of suitability. In comparison, Alevkayalı and Tağıl (2020) reflect a more integrated landscape assessment approach by including indices of environmental sensitivity in their models. The diversity of criteria across studies underscores the necessity of context-specific yet scientifically grounded models for agricultural land use planning. In addition, several other studies (e.g., Akbulak, 2010; Çelikyay et al., 2015; Mishra et al., 2015; Saykılı et al., 2017; etc.) have employed similar criteria within diverse spatial contexts (Table 1).

Climatic data and soil characteristics are commonly used in studies that aim to determine agricultural land suitability. Within the scope of this research, ten criteria were identified as influential for the cultivation of *Z. jujuba*: MSG, soil depth, LCC, LCS, slope, aspect, temperature, precipitation, elevation, and erosion. OSC, land types, and areas designated for settlements and infrastructure were identified as limiting factors.

Table 1. Comparison of agricultural land evaluation studies

	Şahin and Toroğlu (2020)	Sönmez et al. (2019)	Demir et al. (2011)	Saykılı et al. (2017)	Akıncı et al. (2012)	Bathrellos et al. (2013)	Mishra et al. (2015)	Akbulak (2010)	Çelikyay et al. (2015)	Alevkayalı and Tağıl (2020)	Karabacak (2021)	Mercan and Arpağ (2020)
MSG	X	X		X	X		X					X
Land Capability	X	X			X		X	X	X		X	X
Soil depth	X	X	X	X	X				X	X	X	X
Drainage	X						X					
Erosion	X	X	X	X	X	X		X	X			X
Slope	X	X	X	X	X	X	X	X	X	X	X	X
Aspect	X	X	X	X	X	X		X	X		X	X
Temperature	X	X	X									
Precipitation	X		X									
Distance to rivers and tributaries	X					X				X		
Elevation	X	X	X		X	X		X				X
OSC	X	X	X		X		X					
LCS		X			X		X	X			X	
Vegetation Cover			X									
Distance from flood events						X						
Lithology						X						
Distance to villages						X						
Proximity to road network / accessibility							X	X	X			
Environmental sensitivity Index										X		
Land use										X		X

In addition to applications in agricultural planning, AHP has also been utilized in diverse domains to support spatial decision-making. For instance, Azoune and Cherrared (2022) employed an integrated AHP and Failure Mode, Effect and Criticality Analysis (FMECA) framework to prioritize intervention points within Bejaia's stormwater drainage system. This study, which combines expert assessments, historical flood data, and mapping techniques, has provided a repeatable approach for flood risk assessment by effectively classifying critical overflow points. Similarly, in a study by Djouani et al. (2022), the AHP and Geographic Information System (GIS) approaches were integrated to evaluate the efficiency and spatial performance of tram lines in the city of Setif, Algeria. The researchers identified transport-relevant criteria such as service coverage, accessibility, and proximity to commercial and residential zones, weighted them using AHP, and spatialized the results in GIS.

3. Materials and methods

This section presents the data used in the study, the methods of data acquisition, and detailed information about the used datasets. This study hypothesizes that integrating agroecological suitability with AHP-based spatial analysis will allow for the precise identification of cultivation zones that both maximize yield potential and economic return while minimizing environmental constraints.

3.1. Study area

The study area is in Eskişehir Province, Türkiye (Figure 1). Eskişehir is located in the northwestern part of the Central Anatolia Region, between 29°–32° E longitudes and 39°–40° N latitudes. Eskişehir covers an area of 13,902 km^2 and has an average elevation of 792 m a. s. l. (Bursa Eskişehir Bilecik Development Agency, 2025). The region mainly has a semi-arid climate, with some semi-humid and Mediterranean transitional zones. The area includes mountains and high plains. Vegetation is mostly steppe, with forests in the north and southwest (Meteorology General Directorate, 2025). According to the Turkish State Meteorological Service, the long-term averages for the period 1991–2024 indicate a mean annual temperature of 11.1 °C and mean annual precipitation of 355.9 mm (Meteorology General Directorate, 2025).

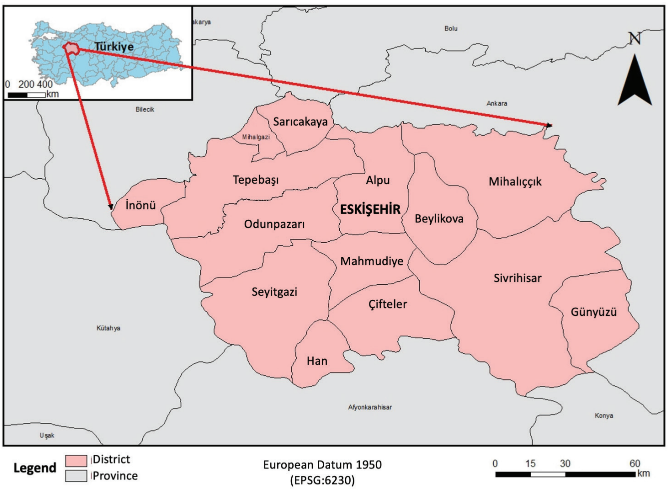

Figure 1. Location map of the study area.

Eskişehir was selected as the study area for *Z. jujuba* cultivation due to its climatic suitability for drought-tolerant crops, availability of marginal lands, and ongoing regional initiatives to diversify agricultural production. Notably, the Eskişehir Provincial Directorate of Agriculture and Forestry has promoted the crop under the distributing 825 jujube seedlings to local farmers in 2022 (Eskişehir Provincial Directorate of Agriculture and Forestry, 2022).

Statistical data from the Turkish Statistical Institute (TÜİK, 2025a) indicate a gradual increase in cultivation. In 2022, the number of fruit-bearing *Z. jujuba* trees was 215, rising to 365 in 2023 and 465 in 2024. The total orchard area expanded from 3.5 ha in 2022 to 7.4 ha in 2024. Average yield per fruit-bearing tree ranged from 15–19 kg, and total production rose from 4 t in 2022 to 7 t in 2024. These trends indicate both farmers' interest and growing regional experience in *Z. jujuba* cultivation, reinforcing the relevance of a systematic land suitability assessment for this crop.

3.2. Data and methods

Climate variables used in this study were obtained from long-term observation records of 11 stations in Eskişehir, produced by the Meteorology General Directorate (DMI), covering the years 1991–2024. A 30-m resolution digital elevation model (DEM) from the DMI dataset provided by the TÜBİTAK 112K405 Project (Günay Aktaş, 2013) with a vertical accuracy of ±2 m was used to derive elevation, slope, and aspect layers. Using this DEM, point-based climate data at the provincial level were spatially interpolated via the Inverse Distance Weighting (IDW) method in ArcGIS Pro 2.5 to generate area-based climate maps, which were subsequently integrated with other limiting factors such as settlements. Land use data were obtained from the CORINE Land Cover 2018 dataset provided by the Corine Project (Ministry of Agriculture and Forestry of Türkiye, 2018). Additionally, MSG, soil depth, LCC, LCS, and erosion data were generated from 1:25,000 scale soil maps (Ministry of Agriculture and Forestry, 2022). To validate the suitability analysis results, the predicted suitable areas were compared with the current CORINE 2018 land use models. Twenty horticulture experts registered with the Chamber of Agricultural Engineers were interviewed for expert opinions, and 10 responded. The purpose of the study was explained to the experts, and they were asked to contribute voluntarily. They were then given an interview form containing criteria determined based on literature and asked to weigh them accordingly. The experts completed the forms at their own convenience.

In this study, the AHP model and GIS tools were employed to identify suitable areas for the cultivation of *Z. jujuba* in Eskişehir Province. The maps derived from the dataset were converted into raster format with a pixel size of 30 m in order to perform suitability analysis. Subsequently, weighted values for each parameter were determined using the AHP method. Based on the obtained weights, a weighted overlay analysis was conducted using GIS software.

Decision analysis is used to evaluate alternatives under various conditions (Ram et al., 2011). Multi-Criteria Decision-Making (MCDM) is a selection process carried out by one or more decision-makers using at least two criteria to choose among a potentially infinite set of quantifiable or non-quantifiable alternatives. MCDM methods can be used to identify the best option or a subset of optimal options, to rank alternatives from best to worst, or to classify alternatives based on specific norms (Köse, 2003). When there are only a few criteria or alternatives, decision-making may be relatively straightforward; however, as the number of criteria increases, the decision-making process becomes more complex (Curina, 2016).

The primary objective of the MCDM approach is to assist decision-makers in organizing and synthesizing the available information related to a decision, ensuring satisfaction by considering all criteria, and minimizing potential regret following the chosen decision. There are several MCDM methods; AHP was used in this study.

Developed in the 1970s, AHP is a method that simplifies decision-making by analyzing both quantitative and qualitative factors (Saaty, 1980, 1986). This method examines MCDM problems using a hierarchical model. In the process, the primary objective is defined, followed by the identification of relevant criteria and sub-criteria, and finally, the decision alternatives are determined. The keystone of the AHP method is pairwise comparison. A pairwise comparison matrix is constructed to compare each criterion against every other criterion with respect to the overall goal. A fundamental relative importance scale ranging from 1 to 9 is utilized for these comparisons, where 1 indicates equal importance and 9 indicates extreme importance of one element over another (Table 2).

Table 2. AHP pairwise comparison scale

Importance	Definition	Explanation
1	Equal importance	Both options are equally important.
3	Slightly important	One criterion is slightly more important than the other.
5	Moderately important	One criterion is considered much more important than the other.
7	Very important	It is definitely much more important than the other criterion.
9	Extremely important	It is considered extremely important according to various sources.
2-4-6-8	Intermediate values	Represents intermediate values for degrees of importance.

Note. Adapted from "The analytic hierarchy and analytic network measurement processes: Applications to decisions under Risk" by T. L. Saaty, 2008, *European Journal of Pure and Applied Mathematics, 1*(1), p. 125 (https://doi.org/10.29020/nybg.ejpam.v1i1.6). CC BY-NC 4.0.

Following the construction of the pairwise comparison matrix, the matrix is normalized, and a priority vector is calculated for each criterion. This vector represents the relative weights of the criteria, which sum to one, indicating their perceived importance. A critical step in the AHP is verifying the consistency of the decision-makers' judgments. Given the complexity of pairwise comparisons, perfect consistency is seldom achieved. To assess the reliability of the judgments, a Consistency Ratio (CR) is calculated. This involves deriving a Consistency Index (CI) from the comparison matrix and comparing it to a Random Index (RI)—a benchmark value representing the average consistency of randomly generated matrices of the same size (n). In the continuation of the study, the RI values suggested by Saaty (1980) and corresponding to the following matrix dimensions were used: $n = 1.2 \rightarrow 0$; $n = 3 \rightarrow 0.58$; $n = 4 \rightarrow 0.90$; $n = 5 \rightarrow 1.12$; $n = 6 \rightarrow 1.24$; $n = 7 \rightarrow 1.32$; $n = 8 \rightarrow 1.41$; $n = 9 \rightarrow 1.45$; $n = 10 \rightarrow 1.49$; $n = 11 \rightarrow 1.51$; $n = 12 \rightarrow 1.53$ (Saaty, 1980, p. 21). After determining the CI and RI values are determined, the Consistency Ratio (CR) is calculated as $CR = CI/RI$. If the consistency ratio is less than 0.10, the comparison matrix is considered consistent (Saaty, 1980).

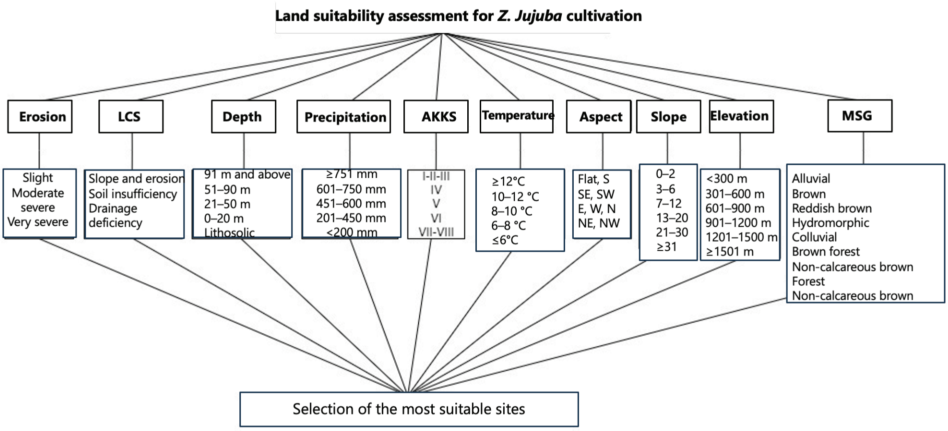

Figure 2. Criteria and sub-units for land suitability assessment for *Z. jujuba* cultivation.

A total of ten criteria were used as parameters in the analysis conducted within the scope of this study: erosion, soil depth, precipitation, temperature, LCC, LCS, aspect, slope, elevation, and MSG (Figure 2). Initially, maps of all variables were created in vector format at the reclassification stage of the study. These vector maps were then converted into raster format with a pixel size of 30 m. Using GIS software, the raster maps were reclassified based on sub-units or variable-specific criteria classes in accordance with expert opinions, in order to enable the weighted overlay analysis. As a result, maps with a resolution of 30 m were generated.

4. Results

4.1. Weighting of criteria for land suitability assessment for Z. jujuba cultivation

Suitability values of the parameters determined for *Z. jujuba* cultivation were evaluated and scored on a 9-point scale. Values are presented in Table 3.

Table 3. Scores assigned to the selected criteria and sub-criteria for land suitability assessment of *Z. jujuba* cultivation

Criteria	Sub-criterion	Score	Criteria	Sub-criterion	Score
	I	9		Alluvial soil	9
	II	9		Brown soil	7
	III	9		Reddish brown soil	3
LCC	IV	7	MSG	Hydromorphic soil	1
	V	5		Colluvial soil	1
	VI	3		Brown forest soil	7
	VII	1		Non-calcareous brown	5
	VIII	1		Non-calcareous brown	3

Table 3. Scores assigned to the selected criteria and sub-criteria for land suitability assessment of *Z. jujuba* cultivation (*continued*)

Criteria	Sub-criterion	Score	Criteria	Sub-criterion	Score
Soil depth (m)	90+	9	Annual average precipitation (mm)	Above 750	9
	50–90	7		600–750	7
	20–50	5		450–600	5
	0–20	3		200–450	3
	Lithosolic	1		Below 200	1
Slope degree	0–2	9	Elevation (m)	Below 300	9
	2–6	7		300–600	7
	6–12	5		600–900	7
	12–20	3		900–1200	5
	20–30	1		1200–1500	3
	30–60	1		Above 1500	1
Annual average temperature (°C)	12+	9	LCS	e	3
	10–12	7		es	1
	8–10	5		s	3
	6–8	3		sw	3
	≤6	1		w	5
Aspect	Flat	9	Erosion severity		
	N	1			
	NE	3		1 (None or very little)	9
	E	7		2 (Moderate)	7
	KE	7		3 (Severe)	3
	S	9		4 (Very severe)	1
	SW	7			
	W	7			
	GW	3			

For each parameter, a pairwise comparison matrix was created by comparing its importance relative to the other parameters. Since no parameter is compared with itself, the diagonal elements of the matrix were assigned a value of 1. The relative importance values were determined through expert judgment, using a scale from 1 to 9 (Table 4).

Table 4. Pairwise comparison matrix for land suitability of *Z. jujuba* cultivation

	K1	K2	K3	K4	K5	K6	K7	K8	K9	K10
K1	1									
K2	1	1								
K3	1	1	1							
K4	1	1	1	1						
K5	1	1	1	1	1					
K6	3	3	3	3	3	1				
K7	3	3	3	3	3	1	1			
K8	3	3	3	3	3	1	1	1		
K9	5	5	5	5	5	3	3	1	1	
K10	5	5	5	5	5	3	3	3	1	1

Note. λmax = 10,1; CI = 0.012; CR = 0.0077; K1 = Erosion, K2 = ATS, K3 = Elevation, K4 = Aspect; K5 = Slope; K6 = Temperature; K7 = Precipitation; K8 = Depth; K9 = MSG; K10 = LCC

The weight values of each parameter were calculated using the relevant formulas based on the pairwise comparison matrix (Saaty, 1980, 1986). Based on these findings, the criteria to be used in the study were ranked by weight as follows: erosion, LCS, slope, aspect, elevation, soil depth, precipitation, temperature, LCC, and MSG. These calculated weights were subsequently used in the weighted overlay analysis (Table 5).

Table 5. Parameter weights calculated by AHP

Criteria	Weight (w)	v	λ (w/v)	%
Erosion	0.0402	0.404	10.0415	4.02
LCS	0.0402	0.404	10.0415	4.02
Slope	0.0402	0.404	10.0415	4.02
Aspect	0.0402	0.404	10.0415	4.02
Elevation	0.0402	0.404	10.0415	4.02
Soil depth	0.1073	1.084	10.1036	10.73
Precipitation	0.1073	1.084	10.1036	10.73
Temperature	0.1073	1.084	10.1036	10.73
LCC	0.2385	2.448	10.262	23.85
MSG	0.2385	2.448	10.262	23.85

It was concluded that the most important criteria for *Z. jujuba* cultivation are LCC and MSG, both with a weight of 0.2385. Other significant criteria include soil depth (0.1073), precipitation (0.1073), and temperature (0.1073). The remaining parameters, elevation (0.0402), aspect (0.0402), slope (0.0402), LCS, and erosion (0.0402), were found to have lower weight (Table 6).

4.2. Reclassification

As detailed in the method section, raster maps were first generated from vector maps and reclassified based on expert opinions. Through this process, the necessary maps for conducting the land suitability assessment of *Z. jujuba* cultivation in Eskişehir Province were completed (Figure 3). As a result of the applied process, a weighted overlay analysis was performed, and final pixel values were generated for the suitability map. Accordingly, areas for growing *Z. jujuba* were classified as most suitable, suitable, moderately suitable, and restricted according to land capability. According to the resulting suitability map (Figure 6), 4.8% of the study area was identified as most suitable, 21.2% as suitable, and 1.7% as moderately suitable for *Z. jujuba* cultivation. However, generating this suitability map alone is not sufficient; it is also necessary to consider restrictive factors. Poorly and insufficiently drained areas, rocky and stony terrains, bare rock and rubble zones found in the LCS, floodplains, urban centers and built-up areas, rivers, streams, dams, lakes, and road networks were considered as restrictive factors and were excluded from the suitability map (Figure 4). As a result, 72.3% of the study area was identified as unsuitable for *Z. jujuba* cultivation due to these restrictive factors.

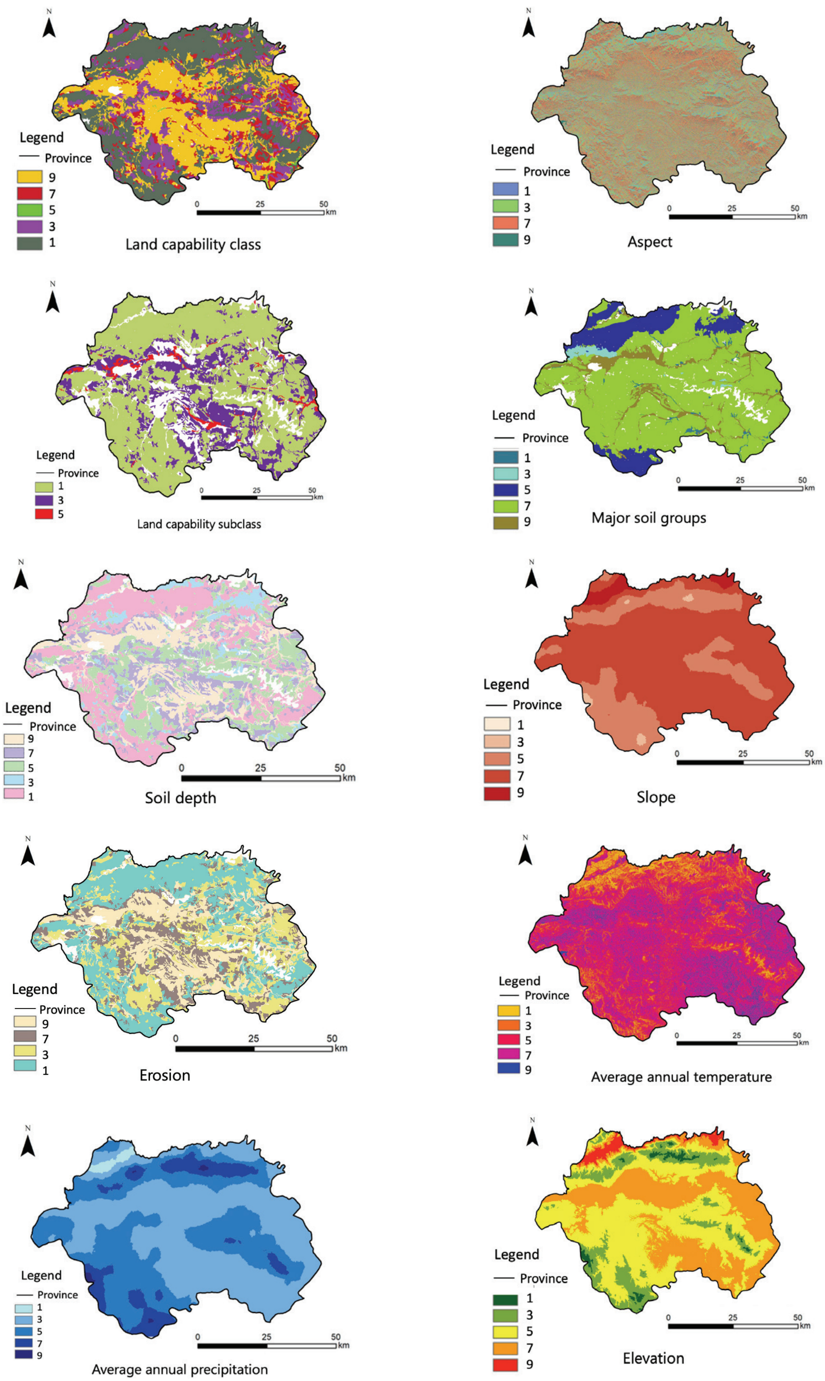

Figure 3. Classification maps.

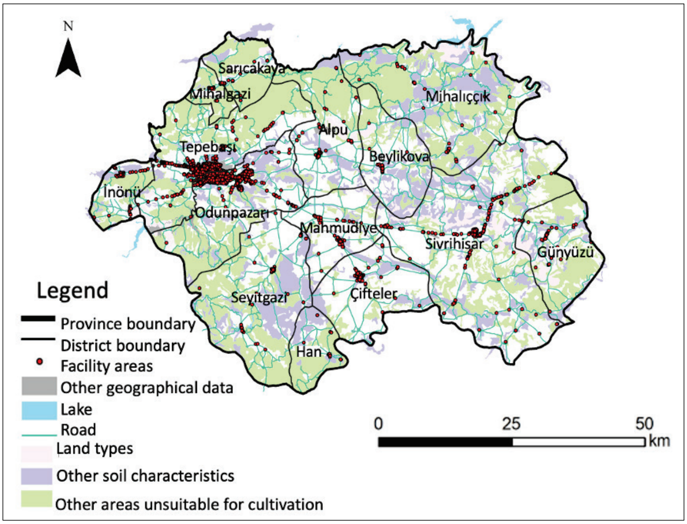

Figure 4. Map of restricted areas for *Z. jujuba*.

The obtained analysis results were compared with the agricultural areas in the region. For current land use data, the CORINE 2018 dataset was utilized (Figure 5). The analysis results assess the overlap between areas suitable for *Z. jujuba* cultivation and the agricultural land use data. The discrepancy between the two maps is due to the temporal and usage-based variations in agricultural areas.

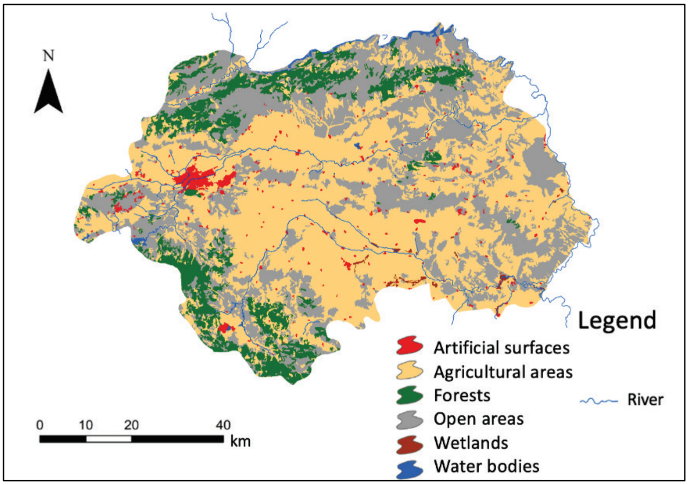

Figure 5. Land use map of *Z. jujuba* cultivation in Eskişehir Province.

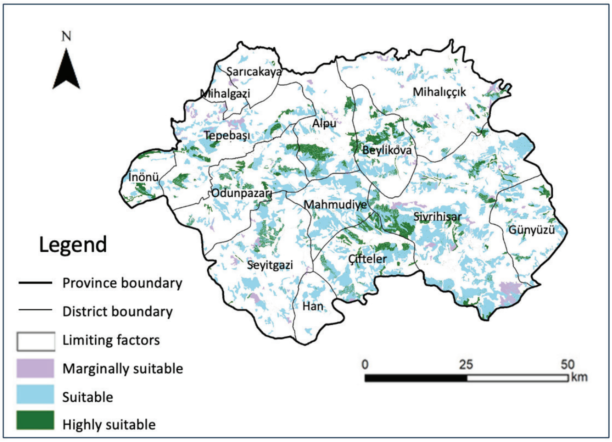

Figure 6. Suitability map for *Z. jujuba* cultivation in Eskişehir province.

The analysis results identified areas suitable for *Z. jujuba* cultivation. The most suitable areas are shown in green, while suitable areas are represented in blue (Figure 6).

5. Discussion

This study revealed the spatial distribution of suitable areas for *Z. jujuba* cultivation in Eskişehir Province by integrating GIS-based spatial analysis with AHP. According to the classification, 4.8% of the provincial lands were identified as highly suitable, 21.2% as suitable, and 1.7% as moderately suitable. This means that approximately one-fourth of Eskişehir is suitable. This agrees with studies using similar methods (Akıncı et al., 2012; Şahin & Toroğlu, 2020). The spatial distribution of suitable areas overlaps highly with Eskişehir's agricultural lands. They are characterized by deep alluvial soils, favorable LCC, gentle slopes, and annual precipitation (> 600 mm) and temperature (> 10 °C). The model results are consistent with the existing agricultural lands in the CORINE 2018 dataset.

This model is consistent with the conditions of *Z. jujuba*, which is drought-tolerant, grows in well-drained and deep soils (Kumar Sishu et al., 2023; Liu et al., 2020). The results showed that soil structure and conditions such as erosion and slope are more influential than minor variations in rainfall or temperature. This result is consistent with studies highlighting soil depth and quality as the limiting factors in the cultivation of perennial fruit trees in semi-arid areas (Akıncı et al., 2012; Mugiyo et al., 2021).

In terms of existing agricultural land, the districts of Tepebaşı and Odunpazarı constitute areas where urban agriculture based on vegetable cultivation requiring high amounts of irrigation is practiced (Ateş, 2024). Vegetable cultivation is preferred because it generates high income for farmers. However, due to intensive water use, groundwater levels have decreased in these areas, causing irrigation wells to reach depths of 100–120 m (Ateş, 2024). For this reason, farmers engaged in urban agriculture have begun to move further east to the Alpu Plain. When similar uses are considered, the risk of groundwater depletion also applies to the Alpu Plain. Sinkholes are also formed in agricultural lands in the south due to excessive groundwater use. *Z. Jujuba* cultivation offers farmers a high-income option that does not require large amounts of irrigation. *Z. jujuba* cultivation can be considered a promising product in agricultural planning in terms of protecting groundwater.

The population density in the rural areas of Eskişehir Province is very low (TÜİK, 2025b). Due to the migration of young people to the city, the majority of the population in rural areas consists of elderly people, with 45–65 years accounting for 36.07% and 65+ for 32.22% (TÜİK, 2025b). Expanding the cultivation of resistant species such as *Z. jujuba* on marginally suitable land could be a catalyst for rural development. The fact that *Z. jujuba* cultivation is easier than high-income vegetable types and is drought-resistant may be a factor of preference for middle-aged farmers or retirees who may return to rural areas to farm. Following pilot studies on such lands, *Z. jujuba* cultivation can be encouraged in regions where positive responses are received.

This model depends on expert judgment in the selection of thresholds and weights. Limitations of the study include the use of a dataset derived from DEM and the limited number of experts available for AHP weighting. In addition, validation was based on CORINE 2018 land use data, which may not reflect recent land cover changes. Even with these limitations, the research offers a transferable model for crop suitability mapping. The framework can be adapted to other fruit tree species by modifying input layers, adjusting reclassification thresholds based on crop ecological requirements, and recalibrating AHP weights in consultation with species-specific experts. The transferability of the model is one of its most important key strengths.

6. Conclusion

This research shows the effectiveness of integrating GIS with the AHP method to conduct spatially explicit suitability evaluations for agricultural planning. The research, focusing on *Z. jujuba* in Eskişehir Province, presents a clear and multi-criteria evaluation that transforms complex biophysical and climatic data into a practical suitability map. The results indicate that about 27% of the land has potential for jujube cultivation, despite a large portion of the province being unsuitable due to biophysical and climatic constraints. This study's major contribution is two-fold. Firstly, by determining specific areas where *Z. jujuba* cultivation is economically most viable and environmentally most sustainable, it provides a concrete decision support tool for local agricultural planners and farmers in Eskişehir. Secondly, the research offers a transferable methodological approach. The step-by-step process, from criteria selection and weighting by experts to spatial overlap and exclusion of limiting factors, can be adapted to evaluate the relevance of other high-value, drought-resistant crops in semi-arid regions worldwide.

In sum, this paper fills the gap between geographic information technologies and agricultural decision-making processes, providing a strategic way to optimize land use, improve agricultural efficiency, and promote the cultivation of economically promising species such as *Z. jujuba* in Turkey and other semi-arid regions. Future studies should incorporate sensitivity analyses, broader expert participation, and high-resolution climate projections to enhance the accuracy and applicability of the model under the changing environmental conditions.

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