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Research Article

Determination of the Agricultural Land in the Zamanti Sub-basin in Türkiye Using GIS and Analytical Hierarchy Process

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Abstract

This study assessed the suitability of agricultural land within the Zamantı Watershed, located in the Seyhan Basin of Türkiye, using multi-criteria decision analysis (MCDA) within a geographic information system (GIS) framework and Analytical Hierarchy Process (AHP). Eight criteria, including elevation, soil, land use, slope, precipitation, drainage density, aspect, and water source proximity, were used to evaluate different regions within the basin. Data from various sources, such as the Digital Elevation Model (DEM), CORINE Land Cover (CLC) database, rainfall data from the Türkiye General Directorate of Meteorology, and soil data from the Food and Agricultural Organization (FOA), were utilized. The AHP methodology determines the relative importance of the criteria and sub-parameters through pairwise comparison, and the Consistency Ratio (CR) is used to analyze the consistency of the pairwise comparison matrix. The results indicated that 78% of the study area was suitable for agricultural production, with 14.72% being highly suitable, 34.38% moderately suitable, 29.44% typically suitable, 17.93% unsuitable, and 3.53% permanently unsuitable. The highly suitable areas had a flat topography and suitable soil. The average elevation of the basin ranges between 1,000 and 2,000 m, resulting in slopes that are suitable for agricultural activities. The shape of the basin boundary allowed easy irrigation of the farm areas, because the most remote areas of the basin were located less than 25 km away. This study provides a comprehensive assessment of the suitability of the Zamantı Watershed for agricultural production and can be used for agricultural development in this region.

Keywords: MCDA, Agricultural land, AHP, GIS, Suitability analysis

Introduction

Geographic Information Systems (GIS) are crucial tools for land use planning, integrating spatial data for evaluation and decision-making, particularly in suitability analysis, based on biophysical data and economic considerations (reference). The Analytical Hierarchy Process (Saaty, 1980), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) (Hwang et al., 1981), VIKOR (VIseversa compromise solution for Kriterium OR) (Opricovic and Tzeng, 2004), ELECTRE (Roy, 1968), and PROMETHEE (Brans and Vincke, 1985) are the most popular multi-criteria decision analysis (MCDA) methods. AHP is used to weigh factors from a system (Savun-Hekimoğlu, et al., 2021; Everest et al., 2021). GIS and AHP integration have become a cornerstone in the field of land use suitability (Tolche et al., 2022). In the literature, GIS is utilized for land-use suitability in various fields, such as ecology (Store Kangas, 2001; Ying et al., 2007; Hekimoğlu et al., 2022), geology (Bonham-Carter, 1994), agriculture (Akıncı et al., 2013; Kalogirou, 2002), landscape, change detection (Miller et al., 1998; Wulder Franklin, 2006), groundwater (Aykut, 2021; Thakuriah, 2023), flood hazard mapping (Atik and Safi, 2024; Ghosh Kar, 2018; Wu et al., 2011), tourism (Mahdi Esztergár-Kiss, 2021), and urban planning (Aburas et al., 2016). GIS and AHP are two potent methods for land suitability assessment to the degree that they both combine spatial and non-spatial land-use factors, based on which agricultural site suitability is assessed (Hopkins, 1977; Malczewski, 2004). The former implies the spatial orbit necessary for the analysis and representation of geographic data, whereas the latter implies the multi-criterion process of weighing and ranking the considered land suitability factors (Bozdağ et al., 2016).

Agriculture is the backbone of many economies, providing food security and contributing significantly to rural livelihoods. The selection of suitable land for agricultural activities is crucial for maximizing crop yield, minimizing environmental degradation, and ensuring long-term sustainability (FAO, 1976). Land suitability analysis helps identify areas with optimal conditions for specific crops, considering factors such as soil fertility, climate, topography, and water availability (Yohannes and Soromessa, 2018). In Türkiye, a substantial portion of the land, excluding grazing fields and meadows, holds significant potential for cultivation (Bellitürk, 2018). Türkiye's land spans approximately 77.95 million hectares, with nearly 35.98% dedicated to agriculture, translating to approximately 28.05 million hectares (Yanmaz, 2018). According to data from the World Bank (2020), nearly half of Türkiye's land (49.1%) is used for farming activities. Notably, 55.9% of Türkiye's landscape is characterized by elevations over 1000 m and slopes greater than 15%, contributing to its diverse topographical features. Influenced by the Black Sea, northern winds, and its maritime location, Türkiye experiences a variety of regional climates and microclimates shaped by its unique physical and climatic conditions. However, the diminishing use of land for agriculture in recent years has underscored the urgency for sustainable land management strategies to address these evolving challenges (Taneja Ozen, 2023).

Several studies have used GIS and Multi-criteria decision analysis (MCDA) methodologies to examine land suitability. Akıncı et al. (2013) explored agricultural land suitability in Türkiye's Yusufeli District by employing AHP using parameters including soil group, land use capability class, land use capability sub-class, soil depth, slope, aspect, elevation, erosion degree, and other soil properties. Purnamasari et al., 2019 evaluated agricultural land in Serang City, Indonesia for cassava production, considering factors such as land cover, aspect, slope, altitude, soil, rainfall, proximity to waterways, roads, and vegetation indices through AHP. Seyedmohammadi et al. (2019) assessed a 12,000-hectare agricultural expanse in Iran's Ardabil Province for barley cultivation constraints using AHP, focusing on parameters such as soil depth, slope, climatic conditions, pH levels, electrical conductivity, sodium exchange percentage, calcium carbonate content, and gypsum presence. Ustaoglu et al. (2021) developed a spatial framework for evaluating land suitability for peri-urban agriculture in Istanbul's Pendik District by integrating GIS, fuzzy logic, AHP, and TOPSIS with parameters including physical attributes, land usage, natural resources, accessibility, geological features, and soil properties. Razvanchy and Fayyadh, (2022) applied GIS and AHP in Erbil Province, Iraq to assess land suitability based on factors such as soil erosion, elevation, slope, aspect ratio, and land use and cover, underscoring their efficacy in ascertaining agricultural land suitability.

In this study, GIS and AHP were employed to examine the suitability of agricultural activity within the Zamanti Catchment in the Seyhan Basin, Türkiye. This approach allows the integration of various parameters and criteria related to agricultural land suitability, including topography, soil, land use, and climate, which are considered important. This study aims to provide insight into potential areas that are most suitable for agricultural development within the Zamanti Catchment.

Materials and Methods

Study area

This study is conducted in the Zamantı catchment of the Seyhan Basin. The catchment begins in the Uzunyayla region, situated roughly 1500 meters above sea level in the district of Pınarbaşı, Kayseri. Its course runs through several districts—Pınarbaşı, Tomarza, Develi, and Yahyalı—sculpting the western edge of the Tahtalı Mountains with deep, slender valleys. The Zamantı Stream ultimately joins the Göksu Stream near Mount Akinek's foothills in the Aladağ district, culminating in the formation of the Seyhan River. The Zamantı Basin boasts an abundance of natural, historical, and cultural treasures. Geographically, this catchment is located at 37°38'14″ N- 39°12'03″ N latitude and 35°8'26.459″ E–36°54'50″ E longitude (Yazici et al., 2013).

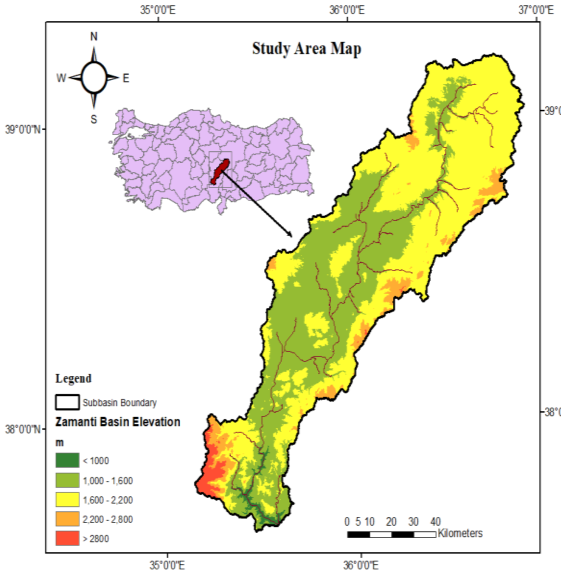

Fig. 1: The map of the Study area

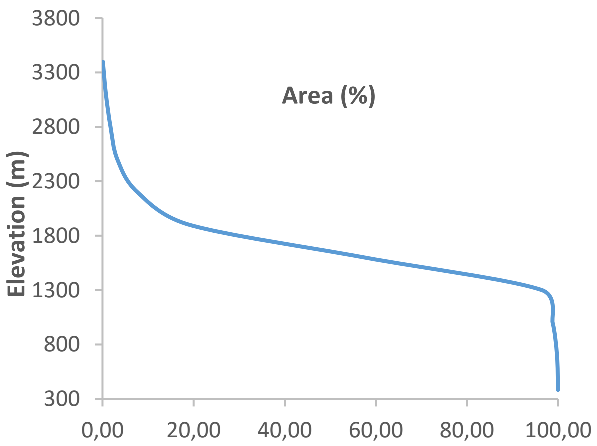

Fig. 2: The Hypsometric Curve of Zamantı Watershed

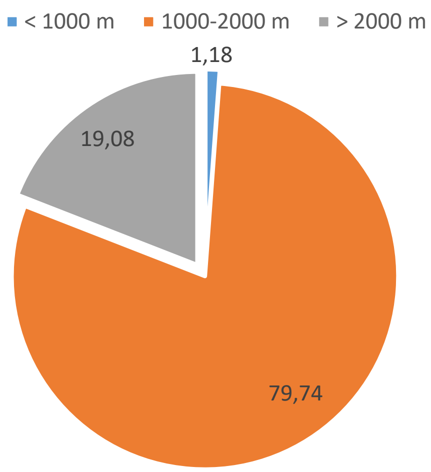

Fig. 3: Elevation Distribution of Zamantı Watershed

The elevation of this study area ranges from 382 to 3704 m. Analysis of the hypsometric curve of the basin showed that 81% of the elevation is below 2,000 m, whereas the remaining 19% exceeded this threshold. A hypsometric curve is a graphical representation of the elevation distribution within a given area. (Petersen et al., 2013)

Data

Eight parameter criteria were used to determine land suitability for cultivation and agriculture: elevation, soil, land use, slope, precipitation, drainage density, aspect, and proximity to water sources. The data used in this study were extracted from various sources as listed in the following table.

Table 1: Sources of the Data

Data	Type	Source
Elevation	DEM (30m x 30m)	Earth, NASA
Slope	30m x 30m	Extracted from DEM
Aspect	30m x 30m	Extracted from DEM
Drainage Density	30m x 30m	Extracted from a stream using line density
Soil	Shapefile	FOA
LULC	100m x 100m	The CORINE Land Cover (CLC)
Rainfall	Five stations as excel	Türkiye General Directorate of Meteorology
Water Source Proximity	30m x 30m	Extracted from basin stream.
Basin Boundary	shapefile	Delineated from the DEM

Elevation
A Digital Elevation Model with 30m resolution was downloaded from Earth, NASA (USGS), and used to analyze the elevation of the watershed. Higher elevations are more prone to erosion risks owing to steep slopes and higher rainfall. Soil erosion negatively affects agricultural yields by reducing the rooting depth, degrading the soil structure, decreasing plant-available water reserves, and depleting soil nutrients (Liu et al., 2014).

Water Source Proximity
The basin's Digital Elevation Model (DEM) was used to extract the flow direction and flow accumulation, allowing for identification of the river's stream network. The proximity of the stream makes the land highly suitable for irrigation, making it ideal for agricultural activities. In addition, water and sediment carried by rivers can deposit nutrient-rich soil, making land more fertile and productive. To determine the route of the Zamantı River, a flow accumulation raster is used to extract the stream from the basin source to its outlet. Subsequently, the effect of the river on the basin was determined using the inverse distance weighting method in GIS.

LULC
Land use and cover are crucial elements for assessing the suitability of land for specific purposes, such as agriculture. The analysis of land use and cover can provide important information on current and potential land use and how it affects the physical characteristics of the land, which can help make decisions regarding land use planning, management, and conservation.

The LULC data used in this study were downloaded from the CORINE Land Cover (CLC) (https://land.copernicus.eu/), a European-wide land cover database. LULC was then classified into urban, industrial, mining and construction, arable land, permanent vegetation, pasture, natural vegetation, forest, open space, and rock and water courses.

Aspect and Slope
Aspects and slopes are important factors for determining land suitability, particularly in the context of agricultural production. South-facing slopes tend to be warmer and drier than north-facing slopes, which can affect the crop growth and water availability. Similarly, steep slopes are prone to erosion, landslides, and runoff, which can negatively affect the soil fertility and crop productivity.
The slope and aspect of the basin were obtained from the digital elevation model of the basin and subsequently classified into a system that follows the previously established literature.

Soil
Soil is a crucial factor for determining the suitability of land for agricultural production. Soil characteristics such as texture, structure, pH, fertility, and water-holding capacity can greatly influence the growth and productivity of crops. Soil data used in this study were obtained from the Food and Agriculture Organization (FOA) (https://www.fao.org/).

Rainfall
The amount of rainfall received by a specific area is a crucial parameter for determining its suitability for agricultural production. To obtain data on the annual rainfall depth within and around the basin, information was retrieved from the Türkiye General Directorate of Meteorology (www.mgm.gov.tr) for five stations located inside and near the basin. The average rainfall depth from these stations was then distributed to the basin using the inverse distance weighted method in the GIS. The resulting raster map was subsequently classified into five categories and used in the analysis to assess the suitability of the land for agriculture.

Analytical Hierarchy Process (AHP) Method

The Analytic Hierarchy Process (AHP) is a methodology for multi-criteria decision making, first introduced by Saaty in 1977.

AHP is a widely recognized and utilized method for multi-criteria analysis, allowing individuals to establish the relative importance of various parameters in addressing a multi-criteria problem. This method employs a hierarchical structure comprising objectives, criteria, sub-criteria, and alternatives specific to each problem being addressed (Saaty, 1977).

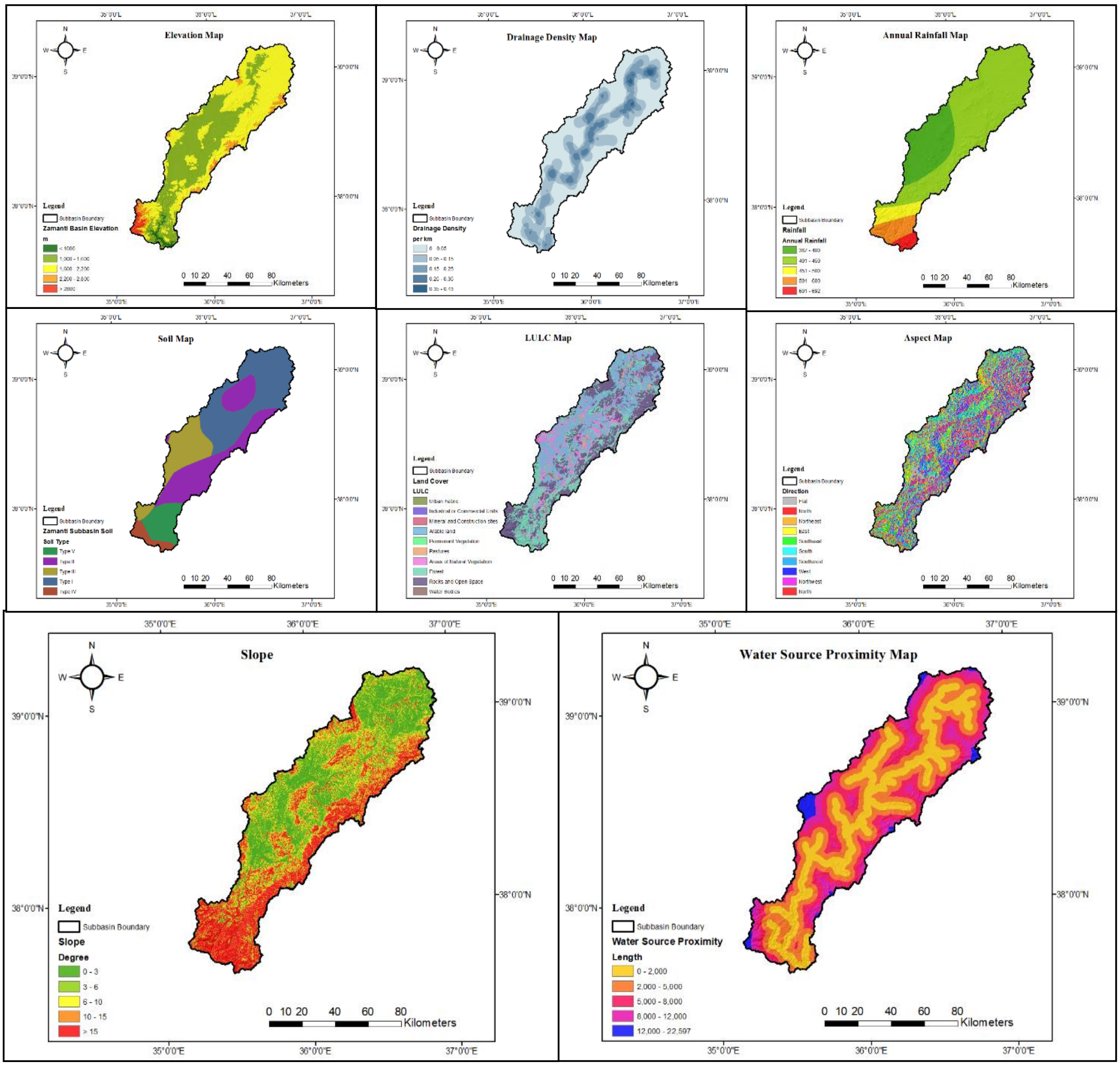

Fig. 4: The eight criteria used for suitability analysis of agricultural land in the Zamantı Watershed: elevation, drainage density, annual rainfall, soil, land use/land cover (LULC), aspect, slope, and water source proximity.

The parameters of the problem are organized in a hierarchical structure once they have been identified. A scoring system developed by Saaty (1980) was used to determine the relative importance of criteria within the hierarchy. The scoring systems used are listed in Table 4. The row elements in the resulting matrix were then added, and the total value was divided by the number of row elements. This technique produces a priority vector or weight vector. The weights ranged from 0 to 1 and the sum was 1. After obtaining the weights of each parameter, the sub- parameters were scored from 1 to 100. The scoring was performed according to a previous study conducted in a different region. Following the determination of the weights for each parameter using AHP, the sub-parameters were also evaluated using a scoring system. This scoring method involves assigning a value between 1 and 100 to each sub-parameter based on the literature and previous research studies conducted in related fields. The results displayed in Table 4 demonstrate the weight of each parameter as well as the individual scores of the sub-parameters examined in the study.

Table 2: Pair-wise Comparison Matrix

	Aspect	Drainage Density	Elevation	LULC	Rainfall	Slope	Water Proximity	Soil
Aspect	**1**	1/2	1/3	1/4	1/5	1/5	1/6	1/7
Drainage Density	2	**1**	1/2	1/3	1/4	1/4	1/5	1/6
Elevation	3	2	**1**	1/2	1/3	1/3	1/4	1/5
LULC	4	3	2	**1**	1/2	1/2	1/3	1/4
Rainfall	5	4	3	2	**1**	1	1/2	1/3
Slope	5	4	3	2	1	1	1/2	1/3
Water Proximity	6	5	4	3	3	2	**1**	1/2
Soil	7	6	5	4	4	3	2	**1**
Weights	**33.00**	**25.50**	**18.83**	**13.08**	**10.28**	**8.28**	**4.95**	**2.93**

Table 3: Pair-wise Comparison Matrix

	Aspect	Drainage Density	Elevation	LULC	Rainfall	Slope	Water Proximity	Soil
Aspect	0.03	0.02	0.02	0.02	0.02	0.02	0.03	0.05
Drainage Density	0.06	0.04	0.03	0.03	0.02	0.03	0.04	0.06
Elevation	0.09	0.08	0.05	0.04	0.03	0.04	0.05	0.07
LULC	0.12	0.12	0.11	0.08	0.05	0.06	0.07	0.09
Rainfall	0.15	0.16	0.16	0.15	0.10	0.12	0.10	0.11
Slope	0.15	0.16	0.16	0.15	0.10	0.12	0.10	0.11
Water Proximity	0.18	0.20	0.21	0.23	0.29	0.24	0.20	0.17
Soil	0.21	0.24	0.27	0.31	0.39	0.36	0.40	0.34

Table 4: Comparison Scale (Saaty, 1980)

Intensity of Importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective.
3	Weak importance of one over another	Experience and judgment slightly favor one activity over another.
5	Essential or strong importance	Experience and judgment strongly favor one activity over another.
7	Demonstrated importance	Activity is strongly favored, and its dominance is demonstrated in practice. The evidence favoring one activity over another is of the highest possible order of affirmation.
2, 4, 6, 8	Intermediate values between the two adjacent judgments	When compromise is needed.
9	Absolute importance	The evidence favoring one activity over another is of the highest possible order of affirmation.

Consistency Evaluation

The use of pairwise comparisons depends on a subjective assessment, which has the potential to result in arbitrary outcomes influenced by bias. Therefore, assessment is required. The AHP approach employs the Consistency Ratio (CR), a numerical indicator, to analyze the consistency of the pairwise comparison matrix (Saaty, 1977).

$$C_r = \frac{C_i}{R_i} \quad \text{(Eq.1)}$$

where Ci is the consistency index, and Ri is the random index. The random indices for the different criteria are listed in Table 5.

Table 5: Random indices for different criteria (Saaty, 1977).

Number of Criteria	2	3	4	5	6	7	8
Random Index	0	0.52	0.9	1.12	1.24	1.34	1.41

The Consistency index was also calculated using:

$$C_i = \frac{\lambda_{max} - n}{n-1} \quad \text{(Eq.2)}$$

Lamda max, λmax, is the greatest eigenvalue of the preference matrix and n is the number of parameters used. The maximum eigenvalue of the matrix was 8.46. Thus, the Consistency Index was calculated to be 0.066.

$$C_r = \frac{0.066}{1.41} = 0.047 \quad \text{(Eq.3)}$$

According to Saaty (1977), the consistency ratio (CR) was evaluated by comparing it with 0.1, which serves as the upper limit for acceptability in pairwise comparison matrices. In this case, the calculated CR value was less than 0.1, indicating that the consistency of the matrix was acceptable.

Table 6: Weights and scores of the criteria and sub-criteria for the suitability analysis of agricultural land in the Zamantı Watershed based on the AHP method.

Criteria	Weight	Sub-parameter	Score
Soil	0.31	Type I	100
		Type II	80
		Type III	80
		Type IV	60
		Type V	100
Water Proximity	0.22	0 – 2000 m	100
		2,000 – 5,000 m	80
		5,000 – 8,000 m	60
		8,000 – 12,000 m	40
		> 12,000 m	20
Slope	0.13	0 – 3 m	100
		3 – 6 m	80
		6 – 10 m	60
		10 – 15 m	40
		> 15 m	20
Rainfall	0.13	367 – 400 mm	20
		400 – 450 mm	40
		450 – 500 mm	60
		500 – 600 mm	80
		> 600 mm	100
Aspect	0.03	Flat	100
		Northwest	80
		North	100
		Northeast	80
		East	60
		Southeast	40
		South	20
		Southwest	40
		West	60
LULC	0.09	Urban	20
		Industrial	20
		Mining And Construction	20
		Arable Land	100
		Permanent Vegetation	100
		Pasture	100
		Area of Natural Vegetation	80
		Forest	60
		Open Space and Rocks	40
		Water Courses	20
Elevation	0.06	382 – 1000 m	100
		1,000 – 1,600 m	80
		1,600 – 2,200 m	60
		2,200 – 2,800 m	40
		2,800 – 3,704 m	20
Drainage Density	0.04	0 – 0.05 m	20
		0.05 – 0.15 m	40
		0.15 – 0.25 m	60
		0.25 – 0.35 m	80
		0.35 – 0.43 m	100

Reclassification of the Parameters

The Weighted Overlay method is a technique utilized in overlay analysis to address multi-criteria issues such as determining the optimal location for a specific purpose or evaluating suitability models. Given that the input criteria layers are represented by various numerical systems with varying ranges, this method involves reclassifying each cell for each criterion into a standardized preference scale in Table 4, which ranges from 1 to 100, with 100 indicating the highest level of suitability.

Overlay Weighted Analysis

GIS allows decision makers to identify a list that meets a predefined set of criteria using the overlay process (Saini .S.P, 2012). The suitability of the land for agriculture in the study area was evaluated using the overlay weighting method, in which predefined parameters were employed for the analysis. This method involved assigning weights to each raster layer and subsequently overlaying them. The suitability value of each raster cell was then multiplied by the corresponding weight of its layer and the resulting values were summed to derive the overall suitability score.

These calculated scores were subsequently recorded for new cells within the output layer. The weights in table 7 are used for the overlay analysis in the study.

Results and Discussion

As previously described, a classification system was used to establish the suitability of multiple regions within the basin. These areas were classified as extremely, moderately suitable, unsuitable, and permanently unsuitable. The classification system results are shown in Table 8, which provides an overview of the categorization of the basin locations based on their level of appropriateness.

Following the overlay analysis, a map illustrating the agricultural suitability of the Zamantı sub-basin was generated. The results of this analysis indicate that 1,289 square kilometers of land within the sub-basin possesses optimal conditions for cultivation and agriculture. This was primarily attributed to the flat topography and the predominance of clay and clay loam soil types within the region.

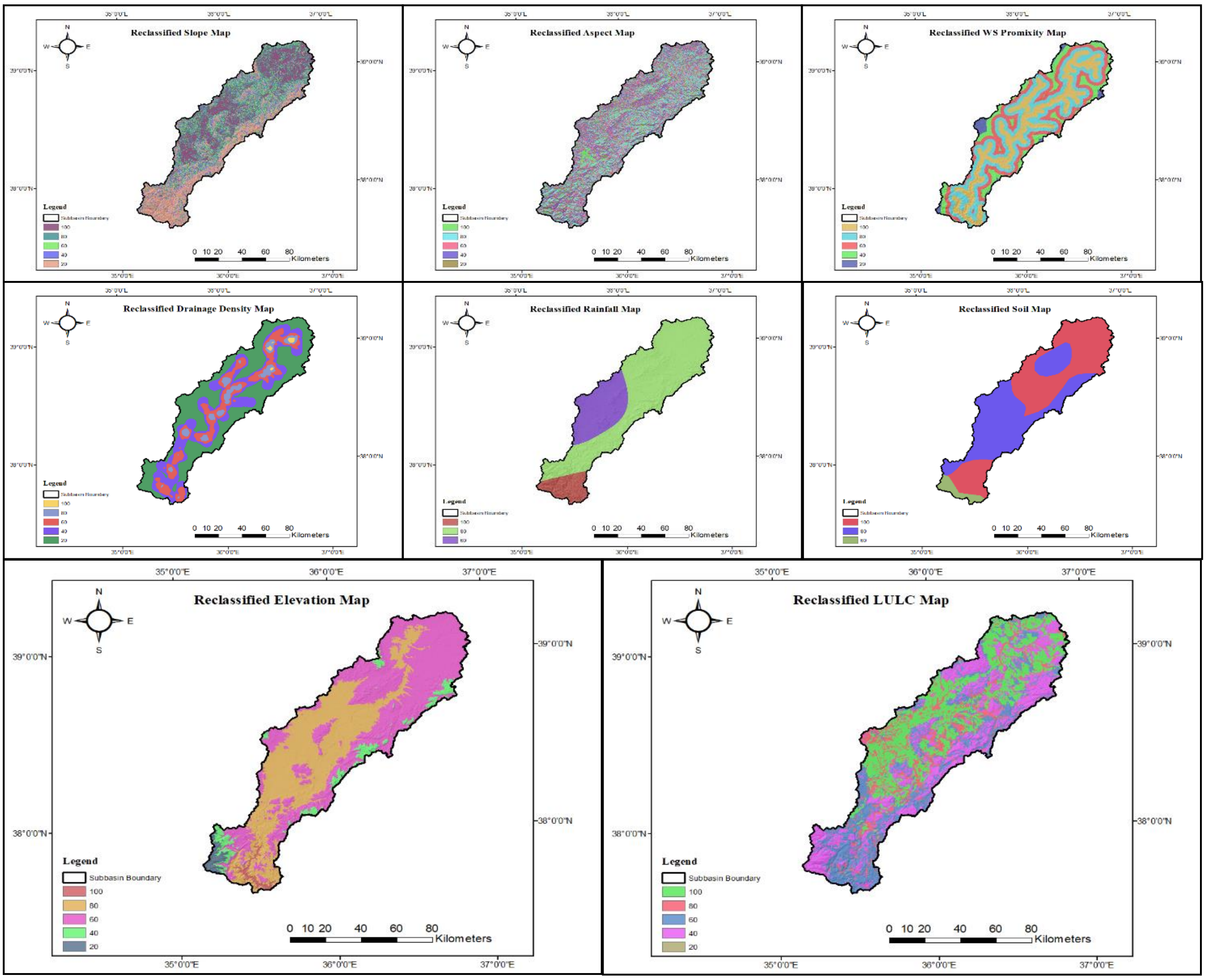

Fig. 5: The maps of the eight criteria after reclassification and weighting according to the AHP method.

Table 7: Weights assigned to the eight criteria used for the suitability analysis of agricultural land in the Zamantı Watershed based on the AHP method.

No	Parameter Name	Weights
1	Soil	0.31
2	Water Source Proximity	0.22
3	Slope	0.13
4	Rainfall	0.13
5	LULC	0.09
6	Elevation	0.06
7	Drainage Density	0.04
8	Aspect	0.03

Table 8: The five levels of suitability for agricultural land in the Zamantı Watershed based on the MCDA scores.

No	Suitability	Classification
1	Highly Suitable	> 85
2	Moderately Suitable	85 - 75
3	Suitable	75 - 65
4	Not Suitable	65 – 50
5	Permanent unsuitable	< 50

Table 9: Agricultural Suitability classification

No	Suitability	Area (km2)	Percentage
1	Highly Suitable	1,289	14.72%
2	Moderately Suitable	3,010	34.38%
3	Suitable	2,578	29.44%
4	Not Suitable	1,570	17.93%
5	Permanent unsuitable	309	3.53%

Approximately 34.38% of the land, equivalent to 3,010 square kilometers, is moderately suitable for agricultural purposes. Approximately 29.44% of the land, or 2,578 square kilometers, is deemed to be normally suitable. According to established criteria, more than 78% of the basin area is suitable for agricultural use. In contrast, 17.93% of the basin area was considered unsuitable for agricultural purposes, based on our established criteria. The results for these areas fell between 50 and 65, indicating that they have potential for improvement and could potentially be made suitable for agricultural use.

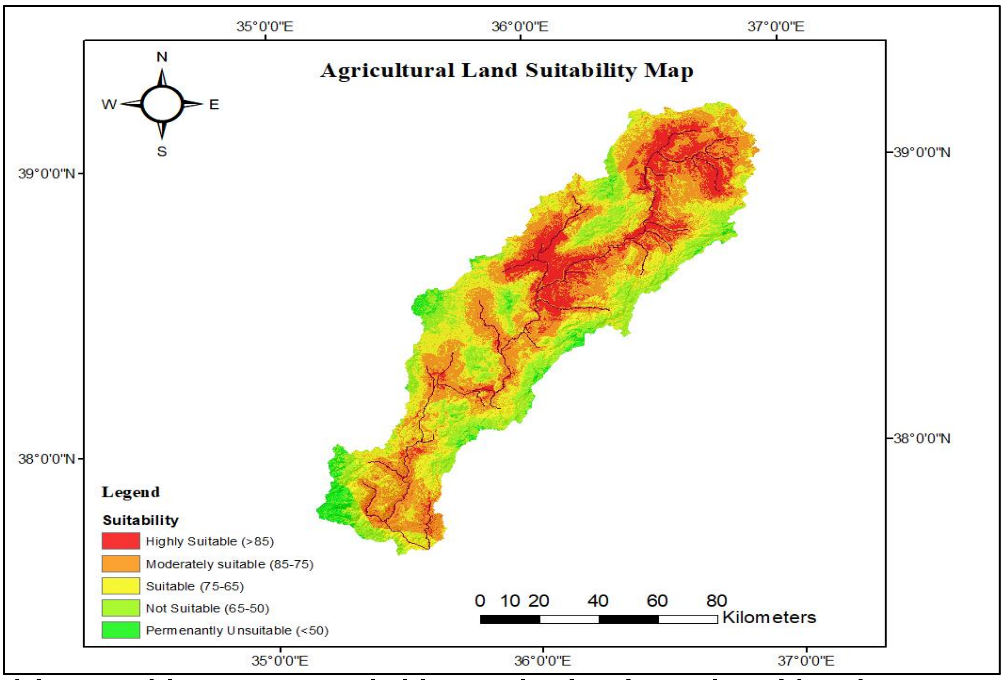

Fig. 6: The suitability map of the Zamantı Watershed for agricultural production derived from the MCDA method.

Based on the established criteria and classification, it was determined that 3.53% of the basin region is permanently unsuitable for agricultural production. These areas, which are primarily composed of hilly terrain and are distant from water sources, are inaccessible and are not conducive to cultivation and agriculture. This information is highlighted in Table 9, which presents the suitability ratio and the percentage of the area. The above map illustrates the suitability of the Zamantı Basin, with different colors indicating varying levels of suitability. The red areas are highly suitable for agricultural development, whereas the orange areas are moderately suitable. Yellow areas typically signify suitable lands, whereas light-green and green areas denote lands that are not suitable or permanently unsuitable for agricultural development. The color code on the map represents the suitability of the land in the basin.

Conclusion

The objective of this study is to use GIS and AHP methodologies to identify locations in the Zamantı sub-basin that are suitable for agriculture. The analysis was conducted using eight factors that reflect the area's topography, land use, weather conditions, and soil structure. According to the evaluation findings, 78% of the study area is suitable for agricultural production. This high suitability rate is primarily due to two major factors. The soil of the area is primarily composed of clay and clay loam, which are considered favorable for cultivation and production. Additionally, the average elevation of the basin ranges from 1,000 m to 2,000 m, resulting in slopes that are suitable for agricultural activities. Furthermore, the shape of the basin boundary allows for easy irrigation of farm areas, because the most remote areas of the basin are located less than 25,000 km away. These factors contribute to the suitability of the agricultural production areas.

Data Access Statement:

Research data supporting this publication is available upon request.

Conflict of Interest declaration:

The authors (s) declare that they have no affiliations with or involvement in any organization or entity with any financial interest in the subject of matter or materials discussed in this manuscript.

References

Aburas, M. M., Abullah, S. H., Ramli, M. F., Ash'aari, Z. H. (2016). A Review of Land Suitability Analysis for Urban Growth by using the GIS-Based Analytic Hierarchy Process. *Asian Journal of Applied Sciences*, *3*.

Akıncı, H., Özalp, A. Y., Turgut, B. (2013). Agricultural land use suitability analysis using GIS and AHP technique. *Computers and Electronics in Agriculture*, *97*, 71–82.

Atik, M. E., Safi, O. (2024). Investigation of GIS-based Analytical Hierarchy Process for Multi-Criteria Earthquake Risk Assessment: The Case Study of Kahramanmaras Province. *International Journal of Environment and Geoinformatics*, 11(3), 156-165.

Aykut, T. (2021). Determination of groundwater potential zones using Geographical Information Systems (GIS) and Analytic Hierarchy Process (AHP) between Edirne-Kalkansogut (northwestern Türkiye). *Groundwater for Sustainable Development*, *12*, 100545.

Bellitürk, K. (2018). Vermicomposting in Türkiye: Challenges and opportunities in future. *Eurasian Journal of Forest Science*, *6*(4), 32–41.

Bonham-Carter, G. (1994). *Geographic Information Systems for Geoscientists: Modelling with GIS*.

Bozdağ, A., Yavuz, F., Günay, A. S. (2016). AHP and GIS based land suitability analysis for Cihanbeyli (Türkiye) County. *Environmental Earth Sciences*, *75*(9), 813.

Brans, J. P., Vincke, Ph. (1985). A preference ranking organisation method (the PROMETHEE method for multiple criteria decision-making). *Management Science*, *31*(6), 647–656.

Everest, T., Sungur, A., Özcan, H. (2021). Determination of agricultural land suitability with a multiple-criteria decision-making method in Northwestern Türkiye. *International Journal of Environmental Science and Technology*, *18*(5), 1073–1088.

FAO. (1976). *A framework for land evaluation*. Food and Agriculture Organization of the United Nations.

Ghosh, A., Kar, S. K. (2018). Application of analytical hierarchy process (AHP) for flood risk assessment: a case study in Malda district of West Bengal, India. *Natural Hazards*, *94*(1), 349–368.

Hekimoğlu, M., Savun-Hekimoğlu, B., Erbay, B., Gazioğlu, C. (2022). Multi-Criteria Decision-Making analysis for the selection of desalination technologies. *International Journal of Environment and Geoinformatics*, *9*(4), 207-216.

Hopkins, L. D. (1977). Methods for Generating Land Suitability Maps: A Comparative Evaluation. *Journal of the American Institute of Planners*, *43*(4), 386–400.

Hwang, C.-L., Yoon, K. (1981). Multiple Attribute Decision Making: Methods and Applications - A State-of-the-Art Survey. *Lecture Notes in Economics and Mathematical Systems*.

Kalogirou, S. (2002). Expert systems and GIS: an application of land suitability evaluation. *Computers, Environment and Urban Systems*, *26*(2), 89–112.

Liu, R., Zhang, K., Zhang, Z., Borthwick, A. G. L. (2014). Land-use suitability analysis for urban development in Beijing. *Journal of Environmental Management*, *145*, 170–179.

Mahdi, A., Esztergár-Kiss, D. (2021). Modelling the Accommodation Preferences of Tourists by Combining Fuzzy-AHP and GIS Methods. *Journal of Advanced Transportation*, *2021*, 9913513.

Malczewski, J. (2004). GIS-based land-use suitability analysis: a critical overview. *Progress in Planning*, *62*(1), 3–65.

Miller, W., Collins, M. G., Steiner, F. R., Cook, E. (1998). An approach for greenway suitability analysis. *Landscape and Urban Planning*, *42*(2), 91–105.

Opricovic, S., Tzeng, G.-H. (2004). Compromise solution by MCDM methods: A comparative analysis of VIKOR and TOPSIS. *European Journal of Operational Research*, *156*(2), 445–455.

Petersen, J. F., Sack, D., Gabler, R. E. (2013). *Physical Geography* 672p.

Purnamasari, R. A., Ahamed, T., Noguchi, R. (2019). Land suitability assessment for cassava production in Indonesia using GIS, remote sensing and multi-criteria analysis. *Asia-Pacific Journal of Regional Science*, *3*(1), 1–32.

Razvanchy, H. A. S., Fayyadh, M. A. (2022). GIS and AHP Based Techniques for Agricultural Land Suitability Assessment in Erbil Province, Kurdistan region, Iraq. *Basrah Journal of Agricultural Sciences*, *35*(1), 140–157.

Roy, B. (1968). *Classement et choix en présence de points de vue multiples (la méthode ELECTRE)*.

Saaty, T. L. (1977). A scaling method for priorities in hierarchical structures. *Journal of Mathematical Psychology*, *15*(3), 234–281.

Saaty, T. L. (1980). *The analytic hierarchy process: planning, priority setting, resource allocation*.

Saini, S. S.., S.P. (2012). Risk and vulnerability assessment of flood hazard in part of Ghaggar Basin : A case study of Guhla block, Kaithal , Haryana , India. *International Journal of Geomatics and Geosciences*, *3*(1), 42–54.

Savun-Hekimoğlu, B., Erbay, B., Burak, Z. S., Gazioğlu, C. (2021). A comparative MCDM analysis of potential short-term measures for dealing with mucilage problem in the Sea of Marmara. *International Journal of Environment and Geoinformatics*, *8*(4), 572-580.

Seyedmohammadi, J., Sarmadian, F., Jafarzadeh, A. A., McDowell, R. W. (2019). Development of a model using matter element, AHP and GIS techniques to assess the suitability of land for agriculture. *Geoderma*, *352*(February 2018), 80–95.

Store, R., Kangas, J. (2001). Integrating spatial multi-criteria evaluation and expert knowledge for GIS-based habitat suitability modelling. *Landscape and Urban Planning*, *55*(2), 79–93.

Taneja, S., Ozen, E. (2023). Impact of the European Green Deal (EDG) on the Agricultural Carbon (CO2)

Emission in Türkiye. *International Journal of Sustainable Development and Planning*, *18*(3), 715–727.

Thakuriah, G. (2023). Geographic information system and analytical hierarchical process approach for groundwater potential zone of lower Kulsi basin, India. *Sustainable Water Resources Management*, *9*(3), 85

Tolche, A. D., Gurara, M. A., Pham, Q. B., Ditthakit, P., Anh, D. T. (2022). Agricultural land use suitability analysis using AHP and GIS techniques at basin scale. *Arabian Journal of Geosciences*, *15*(18), 1522.

Ustaoglu, E., Sisman, S., Aydınoglu, A. C. (2021). Determining agricultural suitable land in peri-urban geography using GIS and Multi Criteria Decision Analysis (MCDA) techniques. *Ecological Modelling*, *455*.

World Bank. (2020). *World Development Report 2020: Trading for Development in the Age of Global Value Chains*. Washington, DC: World Bank.

Wu, Q., Liu, Y., Liu, D., Zhou, W. (2011). Prediction of Floor Water Inrush: The Application of GIS-Based AHP Vulnerable Index Method to Donghuantuo Coal Mine, China. *Rock Mechanics and Rock Engineering*, *44*(5), 591–600. https://doi.org/10.1007/s00603-011-0146-5

Wulder, M. A., Franklin, S. E. (2006). *Understanding Forest Disturbance and Spatial Pattern : Remote Sensing and GIS Approaches*.

Yanmaz, A. M. (2018). *Applied Water Resources Engineering*.

Yazici, H., Hilmi ŞAHİN, S., Kocatepe Üniversitesi Eğitim Fak Sos Bil Öğrt Afyonkarahisar, A., Fevzi Çakmak Ortaokulu Afyonkarahisar, M. (2013). Teknolojik Araştirmalar CBS Yardımıyla Zamantı Çayı Havzası Ekoturizm Çekiciliklerinin Sunulması. *Electronic Journal of Map Technologies*, *5*(3), 33–43. www.teknolojikarastirmalar.com

Ying, X., Zeng, G.-M., Chen, G.-Q., Tang, L., Wang, K.-L., Huang, D.-Y. (2007). Combining AHP with GIS in synthetic evaluation of eco-environment quality—A case study of Hunan Province, China. *Ecological Modelling*, *209*(2), 97–109.

Yohannes, H., Soromessa, T. (2018). Land suitability assessment for major crops by using GIS-based multi-criteria approach in Andit Tid watershed, Ethiopia. *Cogent Food Agriculture*, *4*(1), 1470481.