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RESEARCH PAPER

Assessment of soil quality of the southwestern region of Ezine district, (Çanakkale, NW-Türkiye)

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Abstract

This study was conducted to determine the soil quality of the soils located in the SW part of Ezine District in Çanakkale, NW Türkiye, on a total area of 15,345 ha. In the assessment of soil quality, ten different parameters were evaluated. Soil depth, slope, texture, pH, electrical conductivity (EC), calcium carbonate ($CaCO_3$%), organic matter, nitrogen (N), phosphorus (P), and potassium (K) parameters were considered. To determine the weights of characteristics, the Analytic Hierarchy Process (AHP), a multi-criteria decision-making (MCDM) method, was employed. Based on the calculations and evaluations, it was determined that 23.01% of the soils in the SW part of the Ezine district have very high quality, 69.26% have high quality, 5.82% have moderate quality, 1.93% have low soil quality. The soil quality map produced with this study reveals that the very high and high-quality soils should be managed carefully to ensure agricultural sustainability, and that these favorable conditions should be preserved over time. In areas classified as moderate and low soil quality, appropriate conservation measures should be implemented to prevent further degradation and enhance soil conditions. Furthermore, it is recommended that the model proposed in this study be applied to other regions with similar climatic conditions.

Introduction

Soil is the uppermost layer of the Earth's crust, a thin, unconsolidated layer that forms a dynamic interrelationship with the lithosphere, atmosphere, hydrosphere, and biosphere. The rapidly growing global population negatively impacts the quality of this non-renewable natural resource. Industrialization, housing demands, and tourism activities exert increasing pressure on already limited soil resources. This growing pressure on soil has become a significant concern at the global scale. Soils provide essential ecosystem functions such as food and fiber production, raw material supply, carbon sequestration, water filtration and storage, and serve as a habitat for living organisms. Given these vital functions, the concept of soil quality has been introduced by various researchers as an indicator of the soil's ability and capacity to perform these functions (Singer and Ewing, 2000; Karlen et al., 2003). Soil quality is a concept that refers to the capacity of soils, while in use, to sustain biological productivity within ecosystem boundaries, maintain environmental quality, and promote plant and animal health (Karlen et.al., 1997; Hermans et al., 2021). With high soil quality conditions, soils exhibit high fertility and productivity, as well as increased resistance to erosion. In other words, soil quality is the capacity of soils to resist natural or anthropogenic factors (Lal, 2017). The relationship between soil and humans is interrelated; management practices that improve soil health increase both short-term and long-term productivity and profitability. Therefore, preserving and maximizing soil quality is one of the fundamental requirements for sustainability. Otherwise, poor management and improper use significantly reduce the soil's production capacity and lead to irreversible degradation. Soil quality cannot be directly measured but is estimated through the evaluation of its biological, physical, and chemical properties, as suggested by various methods (Garrigues et al. 2012). In recent decades, researchers have conducted various studies to determine and evaluate soil quality. The concept of soil quality has also been discussed in Türkiye, and several valuable studies have been carried out in this field (Şeker et al. 2017; Koca et al. 2019; Alaboz et al. 2023; Bayraklı et al. 2023; Pacci and Dengiz 2023; Alebachew and Dengiz 2025; Everest et al. 2025). The existing literature highlights the importance of soil quality through studies conducted in different regions, while also indicating the need for new applications at the regional level. According to the literature review conducted in the SW part of the Ezine district, no studies have been found focusing on the determination of soil quality in this area. In this context, the main objective of this study is to assess the soil quality of the study area located in the SW part of the Ezine district. Furthermore, the Analytic Hierarchy Process (AHP), a multi-criteria decision-making method, was employed to determine the weight values of the parameters used in soil quality evaluation.

Material and Methods

Material

The study area is located between 39°43′30″–39°51′18″ N latitudes and 26°08′25″–26°17′25″ E longitudes, covering a total area of 15,345 hectares. It is bordered by the Aegean Sea to the west, Ayvacık district to the south, and Bayramiç district to the east (Figure 1). The area receives an average annual precipitation of 624 mm (MGM, 2025). The climate is characterized by hot and dry summers and cool and rainy winters, representing a transitional type between the Mediterranean and Marmara climates. Elevation ranges from sea level (0 m) along the coastal parts to 335 m at the highest point.

Various geological units are found within the study area, including young alluvial and conglomerate deposits, as well as sedimentary rocks such as limestone, sandstone, mudstone, and schist. Additionally, magmatic rocks such as granite, trachyandesite, and rhyolite, and metamorphic rocks such as serpentinite are also present (Ilgar et al. 2008). The main economic activity in the region is agricultural production. Dry farming, olive cultivation, vegetable growing in irrigated areas, and field crops under irrigation are the major agricultural practices in the area.

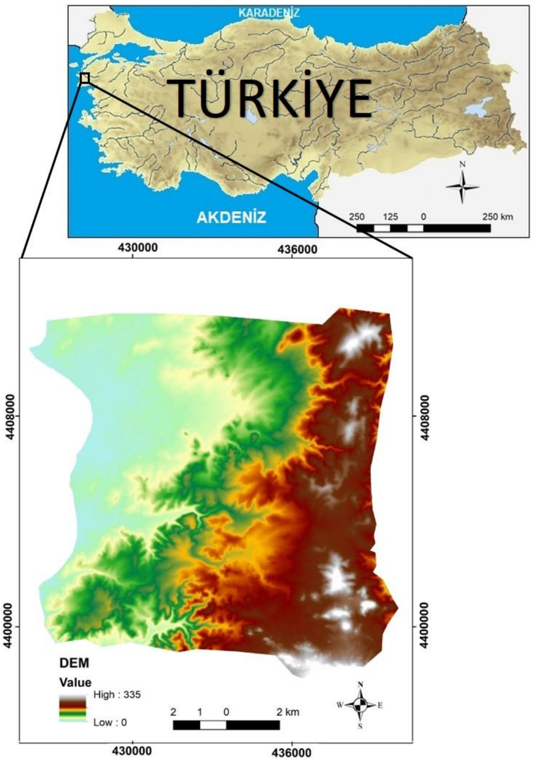

Figure 1. Study area

Methods

Within the scope of this study, 10 parameters were evaluated: soil depth, slope, texture, pH, EC, $CaCO_3$%, organic matter, N, P, and K. Common soil physical and chemical quality indicators were used in the present study. These parameters are also evaluated by other researchers (Wang and Gong, 1998; Karaca et al. 2021; Çakır and Dengiz, 2021). A total of 25 soil samples were collected from a depth of 0–30 cm. The physicochemical analyses conducted on soil samples and the procedures followed are presented in Table 1. Soil depth data were obtained from the General Directorate of Rural Services (KHGM, 1999), while slope was derived from a 10 × 10 m resolution Digital Elevation Model (DEM).

To score the sub-parameters, the classification scheme presented in Table 2 was followed. In addition, several previous studies were consulted to assign weight scores to the parameter classes (Wang and Gong, 1998; Çakır and Dengiz, 2021; Everest et al., 2021). For parameter evaluation, a 9-point fundamental scale was used for pairwise comparisons. The pairwise comparison matrix is presented in Table 2.

Table 1. Analyzing methods and their procedure

Parameter	Method / Measurement	Reference
Texture	Hydrometer method	Gee and Or (2002)
pH	In 1:2.5 (sample: water ratio, w/v) suspension with pH meter	Grewelling and Peech (1960)
EC	Potentiometrically in a 1:2.5 ratio in H_2O	Rhoades (1982)
$CaCO_3$	"Scheibler Calcimeter"	Nelson (1982)
Organic matter	Smith–Weldon method	Nelson and Sommers (1982)
Total nitrogen	Micro-Kjeldahl method	Bremner and Mulvaney (1982)
Available phosphorus	Olsen method	Olsen and Sommers (1982)
Available potassium	Ammonium acetate extraction method	Knudsen et al. (1982)

Table 2. Indicators and classes for the evaluation of soil quality (Wang and Gong, 1998; Çakır and Dengiz, 2021; Everest et al., 2021)

Characteristics	I	II	III	IV
Soil depth (cm)	> 100	80 - 100	50 - 80	< 50
Texture	L, CL	SCL, SiCL, SL, Si, SiL	SC, SiC, < C % 50	S, LS, C > % 50
Slope (%)	0 - 5	5 - 10	10 - 20	> 20
Organic matter (%)	> 3	2 - 3	1 - 2	< 1
Total N (%)	> 0.25	0.15 - 0.25	0.05 - 0.15	< 0.05
Available P (mg / kg)	> 25	10 - 25	5 - 10	< 5
Available K (mg / kg)	> 60	30 - 60	10 - 30	< 10
pH	6.5 - 7.5	7.5 - 8.2	5.5 - 6.5	> 8.2- 5.5 <
EC (dS m^{-1})	0 - 2	2 - 4	4 - 8	> 8
$CaCO_3$ (%)	5 - 10	10 - 20	0 - 5	> 20

Saaty (1980) MCDM methodology (AHP) was used for determining the weighted values. The main steps of the AHP are summarized below.

An (n x n) matrix is constructed (Table 3). Here, it is proposed that aij = factor (factor i to factor j). Then, the reciprocal relationship is considered as aij = 1/aij.

The matrix values were normalized. Here, the sum of each column was obtained. The pairwise comparison matrix element was divided by the total values of the column (Table 4)

Arithmetic mean values were obtained. The obtained values were employed in determining the relative priorities (Table 5).

Then the consistency ratio (CR) is checked. For this calculation, the max eigenvalues for each matrix are obtained. The formula of the consistency index (CI) is used for this.

$$CI = \frac{\lambda max - n}{n-1} \qquad (1)$$

λmax: The eigenvalue of the pairwise comparison matrix.

Then the consistency is checked. For this, the RI value used (Table 6).

CR was determined with the formula;

$$CR = \frac{CI}{RI} \qquad (2)$$

RI: The random consistency index. RI values are provided in Table (6). If the CR value calculated is below 10%, the evaluation is considered consistent; if the value is above 10%, it is considered inconsistent, and the analysis must be reviewed by returning to the first step. In this study, the CR value was calculated to be 6%, indicating consistency.

Microsoft Excel was used in matrix calculations. The evaluated parameters were classified according to Table 7. The data were processed using ArcMAP 10.4, and the final soil quality map was produced.

Results and Discussion

Basic descriptive statistics of the soils in the study area are presented in (Table 8). The pH values of the soils vary between very strongly acid (4.9) and slightly alkaline (7.80). EC values range between 0.21 and 2.11 dS m^{-1}. $CaCO_3$ varies from 0.40 to 41.87%, and organic matter varies between 0.23 and 3.46%. The clay content of the soil ranges from 12.38% to 39.14%, the silt content from 12.13% to 35.92%, and the sand content from 36.12% to 74.32%.

Table 3. Pairwise comparison matrix

	Slope	Texture	Depth	pH	EC	$CaCO_3$	Org Mat.	N	P	K
Slope	1	2	2	3	4	5	5	5	5	5
Texture	1/2	1	2	3	3	3	3	5	5	5
Depth	1/2	1/2	1	2	3	3	3	4	5	5
pH	1/3	1/3	1/2	1	2	3	3	4	4	4
EC	1/4	1/3	1/3	1/2	1	2	3	3	3	3
$CaCO_3$%	1/5	1/3	1/3	1/3	1/3	1	3	3	3	3
Org Mat.	1/5	1/5	1/3	1/3	1/3	1/3	1	2	2	2
N	1/5	1/5	1/4	1/4	1/4	1/3	1/2	1	2	2
P	1/5	1/5	1/5	1/4	1/4	1/3	1/2	1/2	1	2
K	1/5	1/5	1/5	1/4	1/4	1/3	1/2	1/2	1/2	1
Colum total	3,58	5,43	7,15	10,91	15	18,33	22,5	28	30,5	32

Table 4. Normalized Pairwise comparison matrix

	Slope	Texture	Depth	pH	EC	$CaCO_3$	Org Mat.	N	P	K
Slope	0,28	0,36	0,28	0,28	0,27	0,27	0,22	0,17	0,17	0,15
Texture	0,14	0,18	0,28	0,28	0,2	0,16	0,13	0,17	0,17	0,15
Depth	0,14	0,09	0,13	0,18	0,2	0,16	0,13	0,14	0,17	0,15
pH	0,09	0,06	0,06	0,09	0,13	0,16	0,13	0,14	0,13	0,12
EC	0,06	0,06	0,04	0,04	0,06	0,11	0,13	0,1	0,09	0,09
$CaCO_3$%	0,05	0,06	0,04	0,03	0,03	0,05	0,13	0,1	0,09	0,09
Org Mat.	0,05	0,06	0,04	0,03	0,02	0,01	0,04	0,07	0,06	0,06
N	0,05	0,03	0,03	0,02	0,02	0,01	0,02	0,03	0,06	0,06
P	0,05	0,03	0,02	0,02	0,02	0,01	0,02	0,01	0,03	0,06
K	0,05	0,03	0,02	0,02	0,02	0,01	0,02	0,01	0,01	0,03

Table 5. Eigenvector values

	Normalized Sums of Rows	Normalized Average Rows	Eigenvector
Slope	2,45	2.45 / 10	0,245
Texture	1,86	1.86 / 10	0,186
Depth	1,49	1.49 / 10	0,149
pH	1,11	1.11 / 10	0,110
EC	0,78	0.78 / 10	0,078
$CaCO_3$%	0,68	0.68 / 10	0,068
Org Mat.	0,44	0.44 / 10	0,044
N	0,33	0.33 / 10	0,033
P	0,27	0.27 / 10	0,027
K	0,22	0.22 / 10	0,022

λ = 10.76, n = 10, CI (Consistency index) = 0.08, RI (Random index) = 1.49, CI/RI = 0.05

Table 6. RI values

n	1	2	3	4	5	6	7	9	**10***
	0,00	0,00	0,58	0,90	1,12	1,24	1,32	1,45	**1,49**

* The RI value for 10 criteria is 1.49

Table 7. Soil quality classes

Description	Value	Class
Very high	3.50-4.00	S1
High	2.50-3.50	S2
Moderate	2.00-2.50	S3
Low	0-2.00	N

To determine the soil quality levels, criterion weights were assigned based on their relative importance or influence, using the data in Table 3, which was constructed according to the methodology proposed by Saaty (1980). The AHP technique was employed for this purpose. Within this framework, the pairwise comparison process was carried out by comparing each criterion with the others, thereby deriving the weight values for each parameter.

The obtained weight values, which are based on pairwise comparisons of the physicochemical parameters selected to assess soil quality (soil depth, slope, texture, pH, EC, $CaCO_3$%, organic matter, N, P, and K), are presented in Table 2. According to the data in Table 5, the physical parameters generally exhibited higher weight values among the land characteristics considered for assessing soil quality. This is mainly because soil quality indicators are classified under two main categories: inherent and dynamic indicators. Parameters such as slope, texture, and depth, which received higher weights, belong to the inherent group that represents the fundamental and relatively permanent characteristics of the soil. In contrast, inherent factors cannot be altered, while dynamic factors can be modified through soil management practices (Çakır and Dengiz, 2021; Karaca et al., 2021). Based on the AHP results, slope was identified as the most effective parameter in determining soil quality.

Table 8. Descriptive statistics for physicochemical properties

Parameter	Unit	Min.	Max.	Mean	Std. Dev.	Variance
Clay	%	12.38	39.14	25.80	8.01	64.22
Silt	%	12.13	35.92	23.23	6.73	45.30
Sand	%	36.12	74.32	51.58	11.36	128.95
EC	dS m^{-1}	0.21	2.11	0.75	0.43	0.19
pH	-	4.92	7.80	7.36	0.66	0.44
$CaCO_3$	%	0.40	41.87	11.11	9.19	84.48
Org. Matter	%	0.23	3.46	2.10	0.67	0.45
N	%	0,12	0,45	0,29	0.10	0.01
P_2O_5	mg kg^{-1}	2.87	53.24	17.33	14.36	206.24
K_2O	mg kg^{-1}	33.37	541.4	223.22	108.89	11857.08

Increasing slope not only restricts the mechanization and efficiency of agricultural activities such as tillage, seeding, and harvesting but also enhances soil erosion (Sauer et al., 2010; Sengupta et al., 2022). The second most effective factor was found to be soil texture, followed by soil depth. These characteristics are directly related to key quality attributes such as water and nutrient retention, structural development, root growth, and microbial activity, making them essential indicators for understanding soil quality potential (Şenol et al., 2020; Choudhary et al., 2023). Then the chemical parameters, pH and EC, followed. Soil pH strongly influences nutrient availability and plant development (Anusha et al., 2023). Likewise, soil salinity is a crucial factor affecting plant growth, as many cultivated plants have low tolerance to salt, and excessive salinity limits vegetation and overall development (Everest et al., 2022). Soil organic matter (SOM) is another key component of soil quality, as it influences physical, chemical, and biological properties. It contributes to soil aggregation, nutrient cycling, water retention, and pH regulation (Celestina et al., 2019). Finally, the macronutrients nitrogen (N), phosphorus (P), and potassium (K) were identified as the least effective parameters. This is mainly because these factors can be relatively easily improved through soil management practices such as fertilization.

Table 9. Soil quality evaluation results

Class	Area (ha)	(Area %)
Very high	3531	23,01
High	10627,9	69,26
Moderate	893,09	5,82
Low	293,01	1,91
Total	15345	100

According to the analysis, it was determined that 23.01% of the soils located in the western part of the Ezine district fall into the very high-quality category, while 69.26% are high, 5.82% are moderate, and 1.93% are low in quality (Figure 2 and Table 9). The areas with the highest soil quality are characterized by flat or nearly flat topography, deep and medium-textured soils, and optimal levels of pH and plant nutrient content. The gradual decline in soil quality across the study area is primarily attributed to increasing slope, reduced soil depth, variations in soil texture, and changes in specific chemical properties. The findings of this study are generally consistent with previous research in the literature, further supporting the reliability of the results (Çakır and Dengiz, 2021; Karaca et al., 2021; Alaboz et al., 2023; Bayraklı et al., 2023; Everest et al., 2025). Comprehensive evaluation and monitoring of soil quality form the foundation of sustainable agricultural practices, serving as a crucial guarantee for food security, ecosystem continuity, and the well-being of future generations.

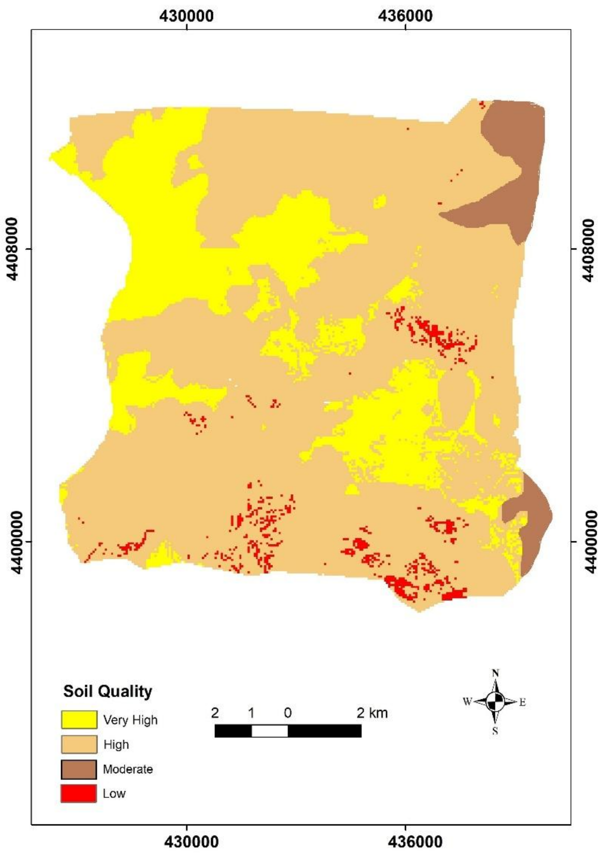

Figure 2. Soil quality map

Conclusions

This study was conducted to assess the soil quality of lands located in the SW part of the Ezine district, providing valuable data to support sustainable agricultural practices. AHP was used to determine the weighted coefficients of the parameters. According to the results, soil quality in the study area was classified as very high in 3,531 ha, high in 10,627.90 ha, moderate in 893.09 ha, and low in 293.01 ha. The fact that 92.27% of the soils in the area were classified as high and very high quality indicates that the region possesses highly favorable conditions for agricultural productivity and sustainability. These soils should be carefully managed to maintain their superior characteristics. On the other hand, areas with moderate and low soil quality, particularly those located on sloping terrain, highlight the urgent need for improved soil management practices. Implementing cultural measures such as terracing would help mitigate slope-induced degradation. Overall, these findings provide a scientific basis for the development of sustainable land management strategies in the region. In addition, integrating the AHP with GIS techniques provided a practical approach for soil quality assessment. It can serve as a decision-support tool for land-use planning and the sustainable utilization of soil resources in similar agricultural regions. The main limitation of the study is that the evaluation model primarily focuses on basic physical and chemical soil parameters. For a more detailed evaluation of soil quality, integrating biological and chemical indicators (heavy metal concentrations) into the model in future studies would significantly enhance the power and sensitivity of the evaluation.

Conflict of Interest

The authors declare that they have no known competing financial or non-financial, professional, or personal conflicts that might appear to influence the work reported in this paper.

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Authorship Contribution

TE: Writing – original draft, Visualization, Investigation, Formal analysis, Data curation, Conceptualization. **AS:** Resources, Investigation Conceptualization. **HÖ:** Writing – review & editing, Supervision.

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