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ASSESSMENT OF VINEYARDS' SOIL PROPERTIES IN THE MOUNTAIN SHIRVAN REGION OF AZERBAIJAN

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SUMMARY

The conducted research studied the soil samples from a depth of 0–90 cm from vineyards and determined the soil characteristics and the corresponding classification of soil quality located in the territories of Shamakhi and Ismailli Districts, Mountainous Shirvan Region, Azerbaijan. The results revealed the soil quality index (SQI) varied with a range of 0.52–0.88. According to the SQI values, 62 out of 100 soil samples received a very suitable classification, with 25 as suitable, 11 as partially suitable, and two as unsuitable classifications. The SQI values of the analyzed samples had a significant positive correlation with the soil organic matter, nitrogen, phosphorus, potassium, calcium, magnesium, zinc, iron, manganese, molybdenum, and boron (N, P, K, Ca, Mg, Zn, Fe, Mn, Mo, and B, respectively). Meanwhile, other values enunciated significant negative correlation with the soil pH, chloride (Cl), sulfate (SO_4), and calcium carbonate ($CaCO_3$). The results further showed the majority of soil samples at a depth of 0 cm had a fine-grained structure. At a depth of 20 cm, it was sandy-clayey; at the depth of 40–80 cm, it was fine-grained; and at the depth of 90 cm, it was sandy-clayey.

Keywords: Viticulture, soil analysis, soil composition, soil elements, soil quality index, Mountainous Shirvan

Key findings: Considering that the territory of the Upper Shirvan Region experienced soil erosion, it received proposals to apply protective tillage methods to improve the soil quality in the existing vineyards. Similarly, recommendations to apply green manure, manure, and compost manure will improve the physical structure of the soil and enhance the soil organic matter.

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INTRODUCTION

Azerbaijan is the birthplace of grapes (*Vitis* spp.), which have become one of the most important agricultural products in the world. Azerbaijan has the naturally favorable climatic conditions for viticulture, and historically, it occupies a unique position in the world of viticulture. The country has the most favorable climate zone for viticulture, which became the first center of grape domestication based on geographical location at the intersection of gene centers. Azerbaijan has a rich genetic potential for grapes (De-Lorenzis *et al*., 2015; Salimov *et al.,* 2025; Salimov and Huseynov, 2025).

According to statistics from 2023, in Azerbaijan, the area under vineyards was 15,020 hectares, and grape production was 224,517.1 tons, which was 5.6% more than in the previous year. The varietal composition of the vineyards comprised the local and introduced table, technical, and raisin grape cultivars (AZ-Stat, 2025). Grapes are a valuable product with an influential place in the agricultural sector of Azerbaijan due to their wide range of applications, a domestic market, and an export product with high added value. Thus, the grape represents a large space for activity in the agricultural sector.

Soil fertility means the soil that is sufficient for cultivation, growth, and development of crop plants, with a balanced amount of nutrients and active biological properties. For healthy plant development, knowledge of the physical and biochemical properties of the soil is crucial in developing a soil fertilization program for cultivated plants. According to past studies, by producing one ton of grapes in the form of a crop and vegetative mass from the soil during the growing season, this consumes 5–8 kg of nitrogen, 1.5–2.5 kg of phosphorus, and 5–7 kg of potassium (Salimov *et al*., 2024; Asadullayev *et al.,* 2024).

Effective and balanced soil fertilization improves the soil's physical, chemical, and biological structure and returns nutrients to the soil consumed by vines throughout the year. However, excessive use of chemicals leads to soil degradation, groundwater pollution, and loss of biodiversity. Recommended organic and sustainable farming practices emerged as key strategies to reduce the environmental damage and ensure sustainability in agriculture. In ensuring sustainable soil productivity, applying fertilizers should continue in a balanced manner and must have calculations as the soil needs (Sabir *et al*., 2020; Huseynov and Aghayev, 2024).

In agricultural production, the deficiency and excess of macro- and micro-elements necessary for plants in the soil limit plants' use of nutrients from the soil. Such a situation negatively affects the development, productivity, and quality of cultivated crop plants (Boyaci *et al*., 2021). In viticulture, the fruit yield and its quality depend on the variety, rootstock, soil type, nutrient composition in soil, and agrotechnical measures, such as soil cultivation, fertilization, irrigation, plant protection, and spring and winter pruning (Makarova, 2019; Gumbatov *et al.,* 2024). Grapes are a non-selective crop plant in terms of genetic structure and can easily grow in soil where many crop plants cannot. However, the areas with very heavy, impermeable, toxic, and saline soil structure are unsuitable for planting vineyards.

Soils with medium and light loamy as well as sandy structure are more suitable for growing high-quality table, raisin, and technical grape cultivars (Salimov *et al*., 2022). In this direction, Mammadov (2015), Mammadov and Heydarova (2016), and Sadigov and Mustafayev (2024) conducted studies to determine the soil characteristics and the fertility status of arable lands in various regions of Azerbaijan and put forward the proposals to solve the challenging issues. Soil quality and health is a concept that indicates whether the soil is suitable for the purpose for which it is used. If the soil can perform various functions, it authenticates the good quality and health of the soil.

From a viticulture perspective, soil quality can be its ability to support production for vine development, yield, and quality without causing soil degradation and environmental harm. Soil quality measurement cannot also occur directly; therefore, it is necessary to assess some soil-determining parameters. These variables should include the physical and chemical properties of the soil and easy-to-assess and measure plant traits. Along with identifying the soil parameters under consideration, it is essential to propose some solutions to improve soil functions. Soil quality assessment should include the analysis of physical, chemical, and biological properties of the soil and crop plants (Salimov *et al*., 2022; Shukurova *et al.,* 2026).

The characteristics selected as determinant parameters can entail assessment for quantity and quality. Knowledge about the soil quality can result from analyzing the distribution of measurements of the examined properties and by comparing measurements taken in different years and areas. The Mountainous Shirvan economic region ranks first among the 14 regions of Azerbaijan, providing more than 20% of the total vineyard area and accounting for more than 15% of the grape production. According to statistics from 2023, the Upper Shirvan had 3159.3 hectares of vineyards and produced 34591.2 tons of fresh grapes (AZ-Stat, 2025).

In general, the following grape cultivars appeared predominant in the region: Agadai, Marandi, Prima, Cardinal, Moldova, Ag Kishmish, Gara Kishmish, Sultani, Red Globe, Madrasa, Shirvanshahi, Khindogni, Saperavi, Carignan, Mourvedre, Cinsault, Grenache Noir, Marselan, Bayanshira, Arna-Grna, Rkasiteli, Roussanne, Marsanne, Kakhuri Mtsvane, Clairette, Grenache Blanc, and Cabernet Sauvignon. Likewise, seedless grape varieties, such as Superior and Crimson, abound. However, a comprehensive study of the qualitative characteristics of the soils under vineyards has yet to be conducted, and the available information on this issue is insufficient. In light of the above discussion, the presented study aimed to assess the physicochemical properties of the soils under the vineyards in the Shamakhi and Ismailli Districts, Mountainous Shirvan Region, Azerbaijan. The study also sought to evaluate the soil quality index under the vineyards.

MATERIALS AND METHODS

The studies conducted in 2024 occurred in the viticultural areas of the Shamakhi (40°38′07.0″N 48°36′32.7″E) and Ismailli (40°43′55.7″N 48°06′45.9″E) Districts, Mountainous Shirvan, Azerbaijan. The Shamakhi District is part of the Mountainous Shirvan economic region (Figures 1 and 2), located on the southern and southeastern slopes of the Greater Caucasus Range. Its borders include the Main Caucasus Range (north), the Agsu Pass (west), the Langebiz Range (southwest), the Kudru-Shirvan plain (south), the Gobustan plateau (southeast), and the Pirsaat River (east). Its total area was 154,691 ha. The height of the District Shamakhi region ranges from 135 to 2,500 masl. The highest point seemed to be the peak of Gulumdostu. As a geographical structure, it

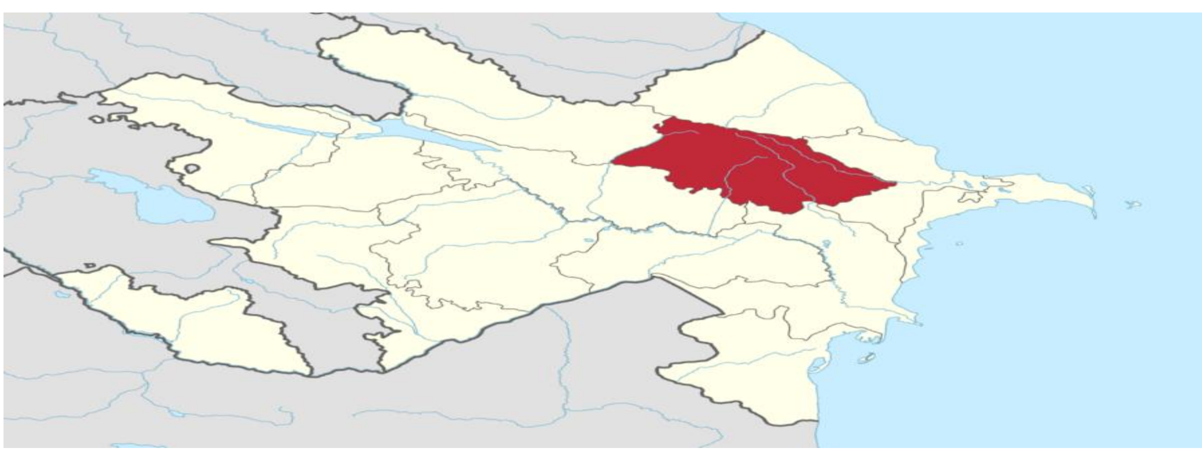

Figure 1. Map scheme of the research area: Administrative territory of Mountain Shirvan economic district.

Figure 2. Satellite image of a vineyard located in the Mountainous Shirvan during 2024.

has all the characteristic features of the Mountainous Shirvan. It has a moderately warm climate, with average temperatures of -4 °C–2 °C in January and 15 °C–25 °C in July and an annual precipitation of 300–800 mm.

The Ismailli District sits mainly on the southern slope of the Main Caucasus Range, in the belt of high and medium mountains, on the Ajinohur lowland, and in the valley of the Alazan-Haftaran River. The highest peaks of the main range are Babadag Peak (3629 m), Asaddag (3471 m), Karaburga (3345 m), Shakhnazardag (2874 m), and Mount Gamcha (2139 m). Its location is in the subtropical and partially temperate climate zone. The northern border of the subtropical belt passes through the territory of the region at an altitude of about 550–650 m. The average annual air temperature drops to 14 °C–14.5 °C on the plains, 11 °C–13 °C in the foothills and lowlands, 7 °C–9 °C in the middle mountains, and 0 °C in the highlands. On the high peaks of the Main Ridge, temperatures can even drop to minus 2 °C–5 °C. The July average temperature on the plains was 22 °C–25 °C, in the midlands was 20 °C–15 °C, and in the highlands was 10 °C–5 °C. The January average temperature was 0 °C–4 °C on the plains, 0 °C–3 °C in the foothills and lowlands, -3 °C–6 °C in the midlands, and -14 °C–15 °C in the highlands. The average annual precipitation ranges from 500 to 1000 mm. By ascending to an altitude of 2400–2800 m, the precipitation increases and reaches 1400–1500 mm. Above 2800 m, the precipitation decreases again to 900–1000 mm. On the plains, the precipitation was 400–600 mm. The area suitable for agriculture is 89,517 ha, in which 33,835 ha are mainly under dry farming.

From the existing vineyards in 22 settlements where table, raisin and technical grape cultivars are intensively cultivated in the Districts Shamakhi and Ismailli, Mountainous Shirvan region, 100 different soil samples were collected at the depth of 0-90 cm during the period of berry formation. The collected soil samples were mixed, dried in the shade, crushed with a wooden mallet and passed through a sieve with a mesh size of 2.0 mm in preparation for analysis. In the collected soil samples, the soil structure was determined according to the method presented by Ulgen and Yurtsever (1995).

Soil pH values, as determined, used the pH saturation test analysis method Mt5.4.2.T.55, according to Jackson (1967) and Kacar (1995). Water saturation determination was according to Richards (1954), while determining total soluble salts (%) was by electrical conductivity (EC) in saturated solution according to ISO 11256. Total lime detection used the Scheibler calcimeter, according to Chaglar (1958), with organic matter content in soil samples determined by the wet oxidation method. Detecting total nitrogen (N) was by the Kjeldahl method (Mertens, 2005); available phosphorus was according to Olsen and Dean (1965); exchangeable calcium, magnesium, and potassium was according to TS 8341 by extraction with 1 N ammonium acetate according to Kacar (1995); and sodium determination relied on the ISO 14870 ICP-OES

(DTPA). Iron (Fe), manganese (Mn), zinc (Zn), and copper (Cu) entailed determination by extraction with 0.05 DTPA-TEA according to Lindsay and Norvell (1978), with readings on an ICP OES according to ISO 14870. By interpreting the analytical results (Mammadov, 2018), the following geometric mean formula helped calculate the soil quality index for each vineyard.

$$\mathrm{SQI} = \sqrt[n]{a_1 . a_2 . a_3 \ldots a_n}$$

Where SQI = soil quality index, $a_1 \ldots a_n$: the position of each soil parameter listed in Table 1 between 0.2 and 1.0, and n: the number of soil parameters involved in the assessment.

For the soil quality index (SQI), the value ranges used in the classification for grape growing (Dogan and Gulser, 2019) comprised very suitable (S1 0.75–1.00), suitable (S2 0.60–0.75), limited suitability (S3 0.50–0.60), and not suitable (N < 0.50).

RESULTS AND DISCUSSION

General characteristics of the soils

For the study area, the descriptive statistics of some soil properties and soil quality index values appear in Table 1. Overall, the soil structure (saturation %) in vineyards of the Shamakhi-Ismailly Districts ranged from 39.17 to 72.44. Based on the limits determined by Ülgen and Yurtsever (1995), the soil samples had a fine structure at 0 cm and in the 40–80 cm layer and a sandy-clay-fine structure at 20 and 90 cm (Table 1). For the normal growth of grapes, medium and light loamy soils, as well as sandy soils, seemed more favorable. Such soils are usually very fertile and have a good water-air regime. Since these soils have a relatively light cultivation, they require less labor and less fuel for machinery.

The soil pH level of the study area varied within the range of 7.90–8.00. All the vineyard soils appeared to be slightly alkaline, according to the limits established (Table 1). According to Kacar (1995), all the soil samples had pH values ideal for growing grapes. However, the pH values of vineyard soils varied from 5.5 to 8.5. Salimov *et al*. (2022) also reported that for grapes, the best soils have a neutral or slightly alkaline reaction (6.5–8.5).

In the vineyard soils, the total dissolved salts' content varied within the range of 0.16%–0.29%. According to the limits established by the Soil Survey Staff, the soils of the experimental plots emerged to be categorized as salt-free (Table 1). Regarding the lime content in the vineyard soils, the lowest content was 5.00%, and the highest amount was 18.00%. According to the limits defined by Chaglar (1958), by evaluating the lime content, the results enunciated that 52% belonged to the low class, 40% to the limestone class, 5% to the high limestone class, and 3% to the very high limestone class (Table 1). The lime content in the vineyard soils was generally low and medium. By studying the organic matter content in the vineyard soils of the Upper Shirvan Region, it varied between 2.2% and 3.8% (Table 1). The results further revealed the organic matter of all vineyard soils fell into the 'good' (2.5%–3.5%) and 'ideal' (> 3.5%) classes, based on the limits defined by Walkey and Black (1934) (Table 1). Findings of Hasanov (1961) and Kurtural (2011) showed the organic matter content of soils should be 2.0%–5.0% for viticulture.

The total nitrogen content of vineyard soils ranged from 9.0 to 19.0 mg/kg (Table 1). All the soils appeared to have low nitrogen content, according to the threshold defined by Kacar (1995). Optimizing nitrogen use in plants improves productivity and reduces environmental damage (Midolo *et al.,* 2018; Chen *et al.,* 2020). However, the said process is especially necessary for agricultural sustainability (Zhang *et al.,* 2023; Huseynov *et al.,* 2026). Proper nitrogen management is important from the economic and environmental perspectives. Determining plant nitrogen (N) requirements is vital because of the crucial role of N in plant growth and development and yield. Nitrogen is generally essential for plants in large quantities, often found in soils as a limiting nutrient.

Table 1. Descriptive statistics of vineyard soil characteristics for the soil quality index.

Soil characteristics	Minimum	Maximum	Average	Standard deviation	Asymmetry (Skewness)	Density (Kurtosis)
Structure - saturation (%)	39.17	55.83	53.62	5.74	0.91	1.73
pH	7.90	8.00	7.95	0.58	-1.18	2.08
Total salt (%)	0.16	0.29	0.21	0.05	0.76	0.29
$CaCO_3$ (%)	5.00	18.00	7.00	1.30	2.88	12.21
OM (%)	2.20	3.80	2.80	0.19	2.14	8.78
N (mg/kg)	9.00	19.00	13.00	0.02	0.05	5.93
P (mg/kg)	13.00	43.00	16.00	9.85	1.96	7.98
K (mg/kg)	29.00	280.00	123.30	29.14	2.98	14.34
Mg (mg/kg)	331.00	764.00	400.00	173.12	0.92	-0.33
Ca (mg/kg)	2017.00	3922.00	2245.00	1769.49	1.13	2.65
Na (mg/kg)	189.00	401.00	279.00	32.78	2.56	12.45
Zn (mg/kg)	0.39	4.00	2.88	0.18	0.98	0.22
Mn (mg/kg)	25.00	40.00	29.00	5.06	2.07	9.23
Fe (mg/kg)	62.00	102.00	78.66	8.34	2.10	2.94
Cu (mg/kg)	0.20	2.30	0.70	0.76	1.19	5.02
Cl (mg/kg)	10.00	10.00	10.00	0.00	0.00	0.00
SO_4 (mg/kg)	67.00	125.00	92.00	7.88	2.66	11.58
B (mg/kg)	17.00	25.00	20.83	12.10	1.35	7.67
Mo (mg/kg)	0.04	0.09	0.07	0.01	0.01	0.02
Soil quality index (SQI)	0.52	0.88	0.70	0.04	0.05	-0.290

In the soils of the viticultural zones, the lowest content of available phosphorus was apparently 13 mg/kg, and the highest was 43 mg/kg. According to the limits determined by Olsen and Dean (1965), 42% of soils had very low, 32% low, 23% medium, and 3% high phosphorus content (Table 1). The potassium content in the vineyard soils was in the range of 29.00–280.00 mg/kg. According to Kacar (1995), 97% of the soils had low and 3% had higher potassium content (Table 1).

The most common cation in grape fruits at all stages of viticulture development was potassium. The effect of potassium on plant development, as well as grape and wine quality, was common knowledge; however, further research was necessary to determine its full mechanism in vine plants (Rogiers *et al.*, 2017). Barish (1983) stated that grapes need nitrogen, phosphorus, and potassium, and most of these plant nutrients affect grapes in different ways. According to past research, applying nitrogen fertilizers should be in early spring because grapes require much nitrogen from the time of bud break until the end of flowering. Barış also found that regular application of phosphorus fertilizers enhances the number of inflorescences in buds formed the previous year, with potassium found to be an important nutrient for stem growth and fruit yield. The magnesium content in vineyard soils ranged from 331.00 to 764.00 mg/kg. By assessing the magnesium content in soils using the Loué method, all the soil samples showed the highest content of magnesium. Hasanov's (1961) and Mammadov's (2018) studies showed the magnesium content in soils was generally sufficient in vineyard areas.

The Ca content in the vineyard soils ranges from 2017.00 to 3922.00 mg/kg. All soils showed the highest Ca content according to the cutoff value determined by Kacar (1995) (Table 1). One can mention that the calcium element in soils does not present any difficulty for viticulture. The available zinc (Zn) in the vineyard soils ranges from 0.39 to 4.00 mg/kg. According to the cutoff value, 6% of the soils have low zinc levels, 78% of the soils were within the normal range, and 16% of the soils were above the normal range of zinc. The zinc content in most soil samples was within the normal range. The content of available manganese in the soils of experimental sites ranged from 25.00 to 40.00 mg/kg. Based on the data presented by Lindsay and Norvell (1978), the level of manganese (Mn) proved to be above the standard in the studied vineyard soils.

The available iron content of the vineyard soils ranged from 62.00 to 102.00 mg/kg (Viets *et al.,* 1973). Considering the proposed limit, all the studied soil samples had significantly higher iron (Fe) content than the standard. Generally, the Fe element content was very high. The available copper content of the vineyard soils ranged from 0.20 to 2.30 mg/kg. Based on the data presented, 12% of the soils had low copper levels, 32% of the soils had medium levels, and 56% of the soils had the highest copper content. Overall, one can conclude most vineyard soils were close to the adequate level of copper (Cu). Nitrogen application should help stimulate vegetative growth in new orchards, while phosphorus and potassium applications should be together in productive orchards to increase yield. The three nutrients grapes required, as determined by the studies, were nitrogen and potassium, which proved to be more crucial than phosphorus, with calcium as the next needed. Brohi (1984) stated nitrogen treatment should help stimulate vegetative growth in new orchards, while phosphorus and potassium require application together in productive orchards to increase yield.

By considering the structural types of soils, the results showed most of the soils used for growing grapes have a fine-grained structure at the depth of 0 cm, sandy-clayey-fine-grained at 20 cm depth, fine-grained at 40–80 cm depth, and sandy-clayey-fine-grained at 90 cm. They were generally calcareous, neutral, and slightly alkaline. The studies further revealed the vineyard soils have a sufficient amount of organic matter and an insufficient amount of nitrogen but do not have problems with salt background. These results were greatly analogous to previous studies (Mammadov, 2018; Salimov *et al*., 2022; Huseynov *et al.,* 2025). Ates (2022) summarized the soil quality index classes and the physical and chemical properties of the soil used to determine the soil quality in terms of suitability for grape growing. The use of the geometric mean equation calculated the suitability index for assessing the quality of grapevine lands in the Shamakhi and Ismailli Districts. According to Ates (2022), by assessing soil samples for suitability classes for viticulture, 62% of the soils were recognizably very suitable (S1, 0.75–1.00), 25% of the soils were suitable (S2, 0.60–0.75), 11% were partially suitable (S3, 0.50–0.60), and 2% of the soils were unsuitable (N, <50).

The relationship between the physical and chemical properties of the soil samples taken from the vineyard sites is available in Table 2. Soil structure (saturation, %) proved to be positively correlated with the content of exchangeable potassium, iron, and ICP. Soil reaction has a positive association with exchangeable phosphorus content and total soil mineralization but shows a negative association with the total salt content and the soil-available phosphorus, zinc, iron, manganese, and ICP. In soils, the lime content was positive with phosphorus content and negative with the content of iron, UM, and ICP. Lime and Cu showed a negative relationship with OM and a positive relationship with available P, N, Zn, Fe, Mn, and ICP. The ICP showed a positive relationship with the structure (saturation, %), N, P, K, Zn, Fe, Mn, Ca, Mg, and UM, as well as a negative relationship with pH, salts, and lime. On the correlation, the obtained results showed similarity with the findings of Ates (2022) and Salimov *et al*.'s (2022) studies in viticultural areas. The results stated the widespread carbonate and brown forest soils in the area are prone to erosion. Therefore, appropriate land reclamation and soil conservation measures are necessary in the area.

CONCLUSIONS

The quality of 100 different soil samples from vineyards of the Shamakhi and Ismailli Districts, Mountainous Shirvan Region, Azerbaijan, underwent assessment based on the physical and chemical properties of the soil. The vast majority of soil samples had a fine-grained structure at the depth of 0 cm, sandy-clayey (at 20 cm depth), fine-grained (at 40–80 cm depth), and sandy-clayey (90 cm). The soils were calcareous, with low N, K, Cu, Cl, and Mo contents; normal OM, $CaCO_3$, P,

Table 2. Relationship between the vineyard soil characteristics and SQI in the study area.

Soil traits & SQI	Structure	pH	Total. Salt (%)	$CaCO_3$ (%)	P (mg/kg)	K (mg/kg)	N (%)	Zn (mg/kg)	Fe (mg/kg)	Cu (mg/kg)	Mn (mg/kg)	Mg (mg/kg)	Ca (mg/kg)	OM (%)	Cl (mg/kg)	SO_4 (mg/kg)	B (mg/kg)	Mo (mg/kg)	SQI
Structure	1	-0.159	0.161	0.201	0.199	0.633*	0.182	0.348	0.519*	0.207	0.192	0.262	0.239	0.182	0.170	0.179	0.154	0.133	0.978**
pH		1	-0.149	0.031	-0.598**	0.469*	0.176	-0.522*	-0.549*	0.168	-0.399*	0.122	0.182	-0.338	-0.342	-0.342	-0.353	-0.355	-0.470**
Total Salt (%)			1	0.186	0.544*	0.344	0.028	0.288	0.328	0.342	0.338	0.234	0.301	-0.112	-0.103	-0.111	-0.168	-0.177	-0.558*
$CaCO_3$ (%)				1	0.556*	-0.178	-0.042	-0.408	-0.579**	-0.174	-0.128	-0.136	0.755	-0.493*	-0.486	-0.484	-0.467	-0.486*	-0.599*
P (mg/kg)					1	0.298	0.112	0.311	0.342	0.336	0.312	0.218	0.279	0.491*	0.492	0.483	0.477	0.487	0.566**
K (mg/kg)						1	0.101	0.351	0.351	0.366	0.354	0.255	0.345	0.137	0.144	0.145*	0.144	0.148	0.566*
N (%)							1	0.348	0.308	0.334	0.229	0.213	0.256	0.672**	0.679	0.678	0.663	0.669	0.577**
Zn (mg/kg)								1	0.319	0.356	0.237	0.194	0.267	0.554*	0.553	0.569	0.562**	0.561	0.605**
Fe (mg/kg)									1	0.388	0.239	0.211	0.274	0.473*	0.460**	0.468	0.461	0.422	0.605**
Cu (mg/kg)										1	0.253	0.167	0.224	-0.558*	-0.568	-0.560	-0.562	-0.544	0.199
Mn (mg/kg)											1	0.168	0.254	0.466*	0.479	0.476	0.433	0.475	0.598*
Mg (mg/kg)												1	0.211	0.151	0.149	0.143	0.154	0.166	0.578**
Ca (mg/kg)													1	0.193	0.181	0.182	0.176	0.170	0.582**
OM (%)														1	0.223	0.148	0.178	0.146	0.584*
Cl (mg/kg)															1	0.181	0.178	0.187	0.148
SO_4 (mg/kg)																1	0.144	0.133	0.185
B (mg/kg)																	1	0.142	0.148
Mo (mg/kg)																		1	0.148
SQI																			1

and Zn contents; and very high Ca, Mg, Na, Mn, Fe, and SO_4 contents. The majority of vineyard areas (87%) had classifications as very suitable (S1) and suitable (S2) for viticulture, and 13% were partially suitable (S3) and unsuitable (N) classes. Considering that the said territory was subject to erosion, therefore, the study proposed to apply protective tillage methods to improve the soil quality in existing vineyards. Likewise, a recommendation states applying green manure, manure, and compost to improve the physical structure by enhancing organic matter.

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