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ANALYSIS OF THE EROSION PROCESS İN UNDEVELOPED MOUNTAIN GRAY-CINNAMON (CHESTNUT) SOILS IN THE SHAMKIRCHAY WATER RESERVOIR BASIN

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SUMMARY

In Azerbaijan, the Shamkir District is one of the oldest agricultural regions on the northeastern slope of the Lesser Caucasus Mountains. The presented investigations mainly assessed the current state, dynamics, and comparative parameters of erosion, emphasizing its repercussions on fertility indicators of agricultural soils. Simultaneously, the study employed state-of-the-art methodologies to scrutinize soil sections strategically positioned in key areas of the research domain. The advanced chemical analyses helped acquire results that underwent meticulous refinement through mathematical and statistical methodologies. The study also determined the nitrogen, activated phosphorus, and exchangeable potassium levels beneath the grape plants, aimed at strengthening measures for soil erosion protection in the target region. Expanding the research was imperative to highlight the correlation between soil erosion and its consequences on the local ecosystem. Beyond the immediate impact on soil fertility, erosion can lead to enhanced sedimentation in water bodies, affecting water quality and aquatic habitats.

Keywords: Mountain gray-cinnamon (chestnut), soil types and subtypes, erosion process, soil sections, arable soils, diagnostic index, fertility parameters

Key findings: Mountain gray-cinnamon (chestnut) (42759.79 ha) is one of the widespread soil types on the northeastern slope of the Lesser Caucasus mountains in Azerbaijan. The vital factors of that soil are fertility parameters like humus, nitrogen, $CaCO_3$, and the sum of absorbed bases (SUB, mg-ekv), which can sustain plant growth and optimize crop yields in that specified soil. The soil granulometric composition's expression was as a percentage of the weight of purely dry soil.

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INTRODUCTION

A considerable geological era has unfolded within the borders of the Republic of Azerbaijan, giving rise to the formation of underdeveloped mountain-gray-cinnamon soil, particularly underneath the grape plants, in the Mountain-gray brown (chestnut) soil type. Azerbaijan has a wealthy, natural condition, and cultivated land for various crop plants. The Shamkir Region sits west of the country on the northeastern slope of the Lesser Caucasus. The territory of the Shamkir District is 1656.8 km² (331 meters above sea level [masl], 40°49′57″ North latitude, 46°01′35″ East longitude) (Mammadov, 2007; Mammadov *et al.,* 2020) (Figure 1). Mountain gray-cinnamon soils' distribution mainly comprised the low mountainous and foothill zones at 150–900 masl (Sadigov, 2018a, b; Babaev *et al.,* 2017; Moitzi *et al.,* 2020; Aliev, 2021; Dai *et al.,* 2021).

Table 1 lists the Shamkir Region mountain gray-cinnamon areas by type and subtype in hectares. From the table, the region also depicts seven subtypes of mountain gray-cinnamon (chestnut) soil, i.e., 1) fully undeveloped, 2) ancient watered common mountain, 3) watered mountain light, 4) irrigated salinity mountain ordinary gray-cinnamon, 5) irrigated clayey mountain ordinary gray-cinnamon, 6) watered mountain ordinary gray-cinnamon, and 7) anciently watered saline mountain common gray-cinnamon (chestnut).

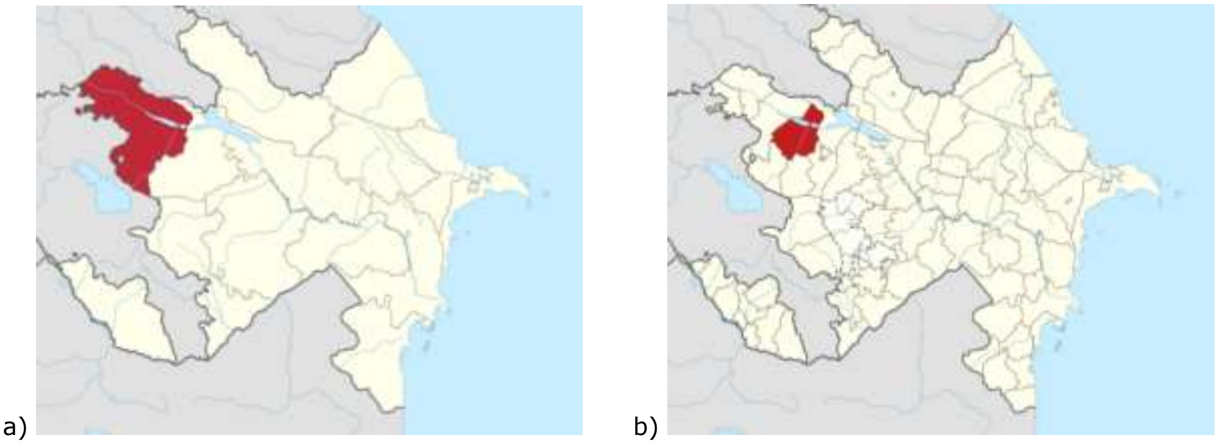
a) b)

Figure 1. Map-scheme of the research area. a) Administrative territory of Gazakh-Tovuz economic district; b) Administrative territory of Shamkir district.

Table 1. Areas of mountain gray-cinnamon soils by type and subtype (ha) in the Shamkir region.

No.	Name of the soil	Fields (ha-la)	
		By types	By subtypes
	Mountain gray-cinnamon (chestnut) type	42759.79	
1	Not fully developed mountain gray-cinnamon (chestnut)		4485.11
2	Since anciently irrigated shorakatvari mountain ordinary gray-cinnamon (chestnut)		1062.14
3	Watered mountain light gray-cinnamon (chestnut)		6543.42
4	Irrigated salinity mountain ordinary gray-cinnamon (chestnut)		9682.10
5	Irrigated clayey mountain ordinary gray-cinnamon (chestnut)		5042.91
6	Watered mountain ordinary gray-cinnamon (chestnut)		6220.10
7	Since anciently irrigated saline mountain ordinary gray-cinnamon (chestnut)		9724.01
Total		42759.79	42759.79

Looking at the complex soil-erosion research conducted in the same study area, it can be evident that soil types and subtypes existed years ago. H.A. Aliyev conducted extensive research on the northeastern slopes of the Lesser Caucasus and drew a map of the area's vegetation. V.V. Dokhuchayev, with research scientists, conducted large-scale examinations in the area to compile the first soil maps of the Caucasus Mountains. M.P. Babayev carried out large-scale analyses to study diagnostic indicators of the area soil cover and the organization of the WRB system. V.H. Hasanov led an extensive assessment of the alluvial-meadow soils formed in the existing river network in the area (Babaev *et al*., 2011; Reinhard, 2020).

Underdeveloped mountain gray-cinnamon (chestnut) soils have reached formations under dry steppe vegetation in the region’s low mountain and foothill zones (Kulhánek *et al.,* 2019). These lands also became deforested lands. Remains and scraps (1.5–2 meters deep) in the soil proved that these lands were under a dense forest before. However, the climate of these soils is dry and hot, accelerating mineralization and resulting in low humus formation in the soil. Hence, humus almost does not pass below 40–45 cm in these soils.

In the study area, 54,248 hectares have gained improvement, with 17,147 hectares newly irrigated due to the commissioning of the Shamkirchay reservoir. Built in 2008-2013 on the territory of the Shamkir region, the reservoir comprised the central canal with the right-bank and left-bank canals and feeder canals for the machine channel. Its establishment occupied a hectare of land, where these lands are already part of the crop rotation. This process, in turn, created conditions for increasing fertility and increasing organic and mineral particle contents in poorly developed mountain gray-cinnamon (chestnut) soils formed in the low-mountain and foothill zones (Sadigov, 2018b).

On the base genetic soil layers, the tillage has become active and the internal erosion process has intensified. Therefore, the granulometric composition of mountain gray-cinnamon soils is heavily granular and clayey. The basic agriculture, horticulture, viticulture, and animal husbandry have also prospered in these lands. However, at present, grain crop cultivation dominates these lands. In the soils of the agricultural zone formed under grapes of the Shamkir Region, it is better to grow cereal crops in the fields. These lands are also distinct by their slightly sloping areas. Thus, the slope accessibility in mountain gray-brown soils is mostly up to 10 degrees (Dospekhov, 1984; FAO, 2020).

The study determined that erosion spreads in the cultivated fields during the research even though the area inclination is not high. However, the erosion was weak to moderate in the study areas (National Encyclopedia of Azerbaijan, 2018; Ministry of Agriculture of Azerbaijan State Land Management Project Institute, 2020). Therefore, the pertinent study aimed to analyze the erosion process in the underdeveloped mountain gray-cinnamon soils in Shamkir District, Azerbaijan.

MATERIALS AND METHODS

The analysis of past studies on the long-term complex research for the classification, nomenclature, and diagnostics of soils helped guide the present research in Azerbaijan. The presently studied soil types and subtypes were compliant with the International Soil Names (in WRB systems), with a soil map also prepared based on the ArcCIS program. In the presented research, the soil horizons’ indexing submitted the genetic characteristics of the soils in correlation with the WRB system for the chief indicators of the Azerbaijani soil classification (Gargiulo *et al*., 2014; International soil classification system for naming soil and developing legends for soil maps, 2014; Sadigov, 2022).

The main goal of the presented research was to study and analyze the current situation under the cultivation of grape plants in the underdeveloped mountain gray-cinnamon (chestnut) soils formed in the territory of Shamkir Region, Azerbaijan, to determine the diagnostic indicators and their morphogenetic analysis. The investigations studied the dynamics of the soil erosion process in that area (Mtyobile *et al*., 2020; Mammadova, 2023).

Mountain gray-cinnamon soils cover a large area in Shamkir Region, Azerbaijan. The practical research placed the land cut sections as the characteristics and carried out according to predetermined routes for 2021–2022. Pre-specification of the cut sections relied on modern methods, and geographical coordinates determined the tools. Defining the used geographic coordinates of soil samples employed the Garmin GPS map 62s device (Table 2).

The latest research analyzed five soil sections by subtype, with the soil layers determined by the soil profile. The diagnostic indicators included granulometric content, soil color, structure, hardness, and several morphological signs. The collected soil samples underwent assessment at the Laboratory of the Ecological Engineering, Azerbaijan State University of Economics, for physico-chemical analysis, performing the required analyses based on the current methodologies.

During field studies, measuring the total humus in the soil engaged I.M. Tyurin's method, total nitrogen by Kjeldahl's technique, and estimating carbonates by a calcimeter. Titration determined the CaCO3, total phosphorus (P), and potassium (K) using the ICP-MS (Agilent). The granulometric content identification employed N.A. Kaczynski's procedure. Absorbed cations to determine soil absorption capacity followed D. Ivanov's approach, hygroscopic humidity by thermal method and reaction of the soil environment. Absorbed ammonia verification utilized Konyev's method with a pH meter, water-soluble ammonia by Nesler, and nitrates by the Grandal-Laju process. The statistical method proposed in past studies validated the integrity of the results (Dospekhov, 1984; Sadigov, 2019; State Standard of the Republic of Azerbaijan, Soil Quality, 2013; Ghanbarian and Daigle, 2015).

RESULTS AND DISCUSSİON

The presented research proceeded in the Shamkir Region, Azerbaijan, located on the northeastern slope of the Lesser Caucasus underdeveloped, mountain gray-cinnamon (chestnut) soils under agricultural use and crop cultivation for 100 years. For precise results, the study collected and analyzed the granulometric content of soil samples, studying the percentage of purely dry soil (Table 3). The soil sections' placement in characteristic areas bore analysis (Figures 2 and 3). The results in Table 3 also enunciated that underdeveloped mountain gray-cinnamon (chestnut) soils were mainly light and medium clay soils (Sadigov, 2018b).

In general and based on international classification, the underdeveloped mountain gray-cinnamon (chestnut) soils were part of the anthropogenically modified soil class (Kunypiyaeva *et al*., 2023; Zhapayev *et al.,* 2023a, b). The subtype covers a broad area, with the thickness of the Accumulative AUvz layer hesitating between 26–57 cm. The color was dark gray-brown, the structure was fine granular dust, and along with the profile, the humus layer ranges from 4.36% to 0.82%.

Table 2. Undeveloped mountain gray-cinnamon (chestnut) soil sections placed on geographic coordinates.

No.	Sections' Number	X coordinate (east length)	Y coordinate (north latitude)
Undeveloped mountain gray-cinnamon (chestnut)			
1	Section 11	X.46° 3′ 21,051″ E	Y.40° 42′ 42,381″N
2	Section 12	X.46° 3′ 55,971″ E	Y.40° 42′ 32,244″N
3	Section 13	X.46° 3′ 36,816″ E	Y.40° 42′ 18,738″N
4	Section 14	X.46° 3′ 32,059″ E	Y.40° 42′ 58,109″N
5	Section 19	X.46° 3′ 53,690″ E	Y.40° 43′ 28,922″N

Table 3. Granulometric composition of fully underdeveloped mountain gray-brown (chestnut) soils (percentage of absolute dry soil).

Sections	Depth (cm)	Size of particles (mm)						
		1-0-0.25	0.25-0.05	0.05-0.01	0.01-0.005	0.005-0.001	<0.01	<0.001
11	AUv0-26	1.26	21.85	17.34	11.27	22.19	26.08	59.54
	AUvzca26-32	2.09	13.95	22.05	13.05	25.33	23.52	61.90
	BTcaz32-57	0.90	15.48	21.08	13.15	24.90	24.48	62.53
	B\Cca(cs)L 57-83	1.66	13.58	24.62	12.18	25.31	22.64	60.13
	CcaL83-102	1.36	16.76	23.79	10.09	24.43	23.56	58.08
12	AUv0-19	2.35	18.02	23.70	14.57	13.57	28.00	55.92
	AUvzca19-50	1.10	14.85	27.56	12.05	17.95	26.48	56.48
	BTcaz50-73	3.08	13.96	24.13	12.32	19.54	26.96	58.82
	B\Cca(cs)L73-110	2.16	14.55	14.80	15.07	28.61	24.80	68.48
	CcaL110-155	1.20	13.69	25.42	11.34	22.74	25.60	59.68
13	AUv0-23	1.10	12.99	24.93	13.07	20.74	27.16	60.97
	AUvzca23-38	1.10	14.52	24.65	11.48	23.30	24.94	59.72
	BTcaz38-64	7.97	12.56	18.34	13.58	23.98	23.56	61.12
	B\Cca(cs)L 64-96	0.94	18.07	22.42	10.67	24.81	23.08	58.56
	CcaL96-125	1.90	12.51	24.62	15.08	20.41	25.47	60.96
14	AUv0-20	1.20	16.83	26.28	13.47	18.67	23.54	55.68
	AUvzca20-39	1.09	15.07	26.47	13.03	18.46	25.87	57.36
	BTcaz39-60	1.09	12.02	25.52	10.73	27.84	22.79	61.36
	B\Cca(cs)L 60-76	4.09	13.33	23.33	14.58	18.55	26.11	59.24
	CcaL76-98	9.66	15.48	19.75	11.07	16.37	27.66	55.10
19	AUv0-17	1.09	18.01	19.00	19.05	13.20	29.65	61.90
	AUvzca17-48	0.71	14.98	24.77	14.67	16.79	28.07	59.53
	BTcaz48-72	0.78	14.22	21.86	8.87	28.30	25.96	63.13
	B\Cca(cs)L 72-99	4.71	21.38	22.82	10.01	10.90	30.17	58.08
	CcaL99-132	1.11	20.05	22.06	12.01	16.36	26.08	59.54

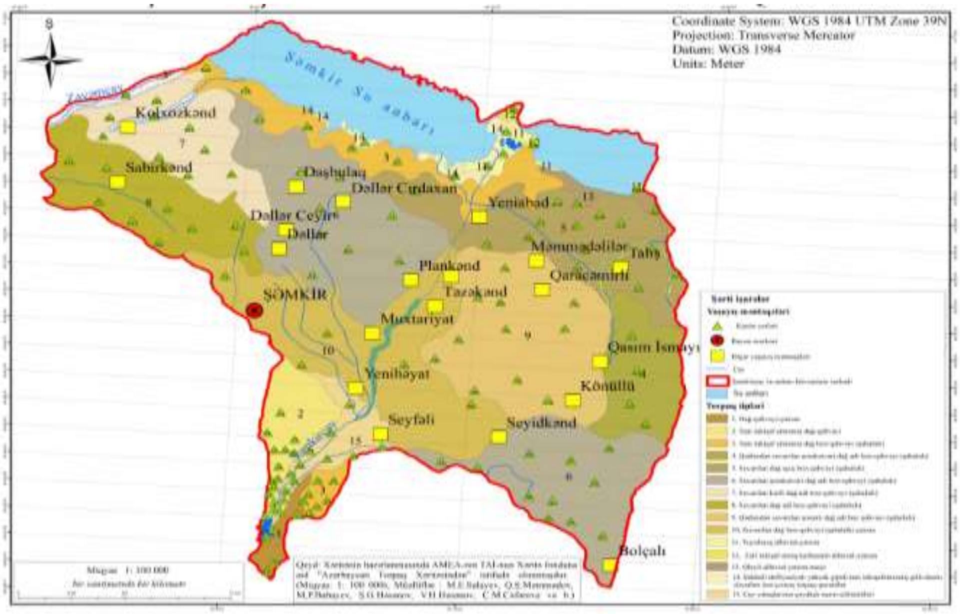

Figure 2. Description of sections placed in characteristic locations on underdeveloped mountain gray-cinnamon (chestnut) soils.

Figure 3. Mountain gray-cinnamon (chestnut) soils formed under vines in the study area.

Around 32.84–22.01 mg-eq of absorbed bases were evident in the aqueous solution with a pH of 8.1–6.6. According to the granulometric composition, particles smaller than 0.01 mm ranged from 30.17% to 22.64%, while particles smaller than 0.001 mm ranged from 55.10% to 68.48% (Tables 3 and 4).

Other scientists have also researched the subtype of undeveloped mountain gray-cinnamon (chestnut) soils spread over a wide area on the northeastern slopes of the Lesser Caucasus. It is valid from the results of the research conducted in the neighboring Dashkasan, Gadabakh, Goranboy, and Goygol regions that the thickness of the Accumulator AUvz layer fluctuates between 24–56 cm, 28–49 cm, 32–58 cm, and 27–55 cm, respectively. The color is dark gray-brown, the structure is fine granular powder, and the humus layer along with the profile was 6.48%–1.93%, 6.02%–1.67%, 4.92%–1.21%, and 5.84%, and fluctuated. The acidity environment of the areas (pH) was 8.8–7.2, 9.7–7.8, 8.5–6.4, and fluctuating between 8.9–6.2. According to the granulometric composition, particles smaller than 0.01 mm are 28.96%–21.74%, 26.12%–15.43%, 31.66%–24.28%, and 32.47%–23.53%, and particles smaller than 0.001 mm are 53.48%–64.85%, 55.33%–62.79%, 58.35%–65.49%, 54.55%–66.27%, and fluctuated (Babaev *et al*., 2011).

The comparative characteristic shown above explains that soil fertility indicators in the Shamkir Region are weak compared with other regions. The construction of a reservoir in the area and the return of land to agricultural circulation are among the leading factors in solving the problem. The field description comprised only one of the soil profile sections (Section 11). Its placement in a characteristic area distinguished the morphological properties of underdeveloped mountain gray-cinnamon (chestnut) soils. The following are various descriptions under different depths.

AUv 0–26 cm - dark gray-brown, ball-nut shaped, granular structure, light clay, rich in soft half-decayed plant remains and fringed grassroots. Low moisture, plenty of rot, roots and rhizomes, optimal biological processing, and traces of tiny insects were vividly visible with white rhizomes, and the transition was clear. It does not boil under the influence of HCL.

Table 4. Analysis of the main diagnostic indicators of soil sections placed on the soil subtype of Fully underdeveloped mountain gray-cinnamon (chestnut) soil subtype in the territory of the Shamkir region.

Sections	Depth (cm)	Humus (%)	Nitrogen (%)	Hygroscopic Moisture (%)	CaCO$_3$ content (%)	Absorbed bases (mg-equivalent)	pH	Phosphorus (kg/mg)	Potassium (kg/mg)
Weakly eroded									
11	AUv0-26	3.86	0.276	5.83	6.95	22.68	7.1	12.51	364
	AUvzca26-32	2.43	0.187	6.01	7.05	23.12	7.1	10.57	314
	BTcaz32-57	2.07	0.164	6.01	Not.an	22.72	7.0	8.19	303
	B\Cca(cs)L 57-83	1.53	0.131	5.60	8.25	25.44	7.2	7.22	267
	CcaL83-102	0.91	Not.an	5.72	8.14	29.28	7.1	7.31	289
Weakly eroded									
12	AUv0-19	4.13	0,293	6.80	3.98	30.78	6.7	13.18	332
	AUvzca19-50	2.49	0.189	7.03	3.90	31.80	6.7	10.32	302
	BTcaz50-73	2.06	0.164	6.60	2.59	29.06	6.6	8.56	298
	B\Cca(cs)L73-110	1.29	0.113	6.69	Not.an	Not.an	6.6	6.63	295
	CcaL110-155	0.94	Not.an	6.71	4.35	-----	6.7	5.03	317
Weakly eroded									
13	AUv0-23	3.97	0.283	7.87	6.97	28.19	6.8	12.05	294
	AUvzca23-38	3.12	0.230	7.08	6.57	28.26	6.8	10.98	283
	BTcaz38-64	2.21	0.173	6.83	6.95	32.84	6.9	8.21	279
	B\Cca(cs)L 64-96	1.06	0.101	7.07	7.53	Not.an	6.8	7.63	263
	CcaL96-125	0.82	Not.an	6.94	7.22	28.19	7.0	7.02	271
Not eroded									
14	AUv0-20	4.36	0.307	5.39	8.64	24.94	7.2	14.58	310
	AUvzca20-39	3.53	0.256	4.84	10.16	22.01	7.1	12.94	275
	BTcaz39-60	2.28	0.177	6.31	Not.an	Not.an	7.2	10.67	269
	B\Cca(cs)L 60-76	2.14	0.169	5.42	-----	-----	7.2	9.07	223
	CcaL76-98	1.61	0.136	5.11	11.42	24.83	7.2	6.82	282
Not eroded									
19	AUv0-17	4.09	0.291	5.83	7,82	30.39	7.2	14.04	362
	AUvzca17-48	2.53	0.193	6.01	13,41	31.13	7.2	13.57	333
	BTcaz48-72	2.01	0.161	7.45	Not.an	29.42	7.3	11.85	321
	B\Cca(cs)L 72-99	1.30	Not.an	5.66	14,02	31,24	7.1	9.72	315
	CcaL99-132	Not.an	-----	4.72	13,40	29,97	7.1	8.61	292

AUvzka 26–32 cm - grayish-brown clay, granular structure, medium clay, few plant roots and rhizomes, small tree roots, and semi-decomposed plant remains were also apparent. It was gradual and unclearly structured. However, it was also possible to come across worm tracks. The soil does not boil under the influence of HCL, with low moisture and gradual transition.

BTcaz 32–57 cm - calcareous, light-brown, indistinct structure, medium clay, hard, rust spots, carbonate molds, single tree and large plant roots, dense, low moisture, gradual transition, and boils a little with the influence of HCL.

B\Cca(cs)L 57–83 cm – light brown, with an undistinguishable structure, medium clayey, hard, dense, low moisture, gradual transition, and boils a little with the influence of HCL.

CcaL 83–102 cm - brown-like, with undistinguishable structure, light clay, hard, dense, low moisture, gradual transition, and boils a little with the influence of HCL.

Studying the morphological description of section No. 11 determined the cultivated area's soil color was gradually changing from dark gray-cinnamon to a sallow, brown-like color, with the structure broken, even in the lower layers. The structure was not visible, and the subsoil layer appeared hardened. These soils have processes that differ from each other in the separate soil genetic layers. Generally, it was evident that a poorly developed soil profile was in each soil layer. Its further characterization revealed a high humus layer and a complex granulometric composition under the half-decayed forest floor. The washed carbonates from the top layer spread to the lower layers. A humus layer manifested, which buried toward the middle and deep layers. Toward the lower soil layers, the boiling with the effect of HCl increases, and the dry residue becomes noticeable (Sadigov, 2018a, b; Sadigov, 2022, 2023).

The chief diagnostic indicators of the soil sections placed on the DBQ_v^{te} - underdeveloped mountain gray-cinnamon (chestnut) soil subtype in the Shamkir Region for five sections (humus, nitrogen, CaCO3, total absorbed bases (mg-eq), hygroscopic moisture, pH, available phosphorus [mg/kg], and exchangeable potassium [mg/kg]) gained analysis based on the determined fertility parameters (Table 4).

The analysis of the five different soil sections follows (Table 4).

Section 11: The soil section's determination used geographical coordinates. The X coordinate (East longitude) of the section was X.46°3′21,051″ E, while the Y coordinate (North latitude) was Y.40°42′42,381″N (Table 2). The thickness of the humus layer along the profile was 3.86%–0.91%. According to humus, nitrogen was 0.276%–0.131%, hygroscopic moisture (6.01%–5.72%), CaCO3 (CO2 8.25%–6.95%), total absorbed bases (29.28–22.68 mg-eq), phosphorus (12.51–7.22 mg/kg), exchangeable potassium (364–267 mg/kg), and the fluctuated pH was between 7.2–7.0 (Table 4) (Sadigov, 2022, 2023). As a result, one will find that the thickness of the humus layer along the profile has changed significantly in different areas. It was 5.48%–2.01%, 5.22%–1.37%, 4.94%–0.99%, and 3.78%–0.89% depending on the land sections. According to humus, nitrogen was 0.392%–0.287%, 0.361%–0.121%, 0.344%–0.041%, 0.271%–0.039%. The identified hygroscopic humidity of the soil ranged from 6.79%–5.44%, 6.41%–5.33%, 6.56%–5.78%, and 6.04%–5.49%, respectively.

Section 12: The soil section sits in the territory of the Shamkir Region, also determined according to geographical coordinates. The X coordinate (East longitude) of the section was X.46° 3′ 55,971″ E, and the Y coordinate (North latitude) was Y.40° 42′ 32,244″ N (Table 2). Along the soil profile, the thickness of the humus layer was 4.13%–0.94%, and the humus contained 0.293%–0.113% of nitrogen, respectively. Hygroscopic moisture ranges from 7.03% to 6.60%, CaCO3 (3.98% to 2.59%), total absorbed bases (31.80 to 29.06 mg-eq), phosphorus (13.18–5.03 mg/kg), exchangeable potassium (332–295 mg/kg), and the pH ranged from 6.7 to 6.6 (Table 4) (Sadigov, 2018a; Sadigov, 2023).

When comparing the results of soil analysis conducted on similar soils in the Gadabay Region, one will find that the thickness of the humus layer along the profile has changed significantly in different areas. It was 6.74%–1.87%, 6.24%–1.95%, 5.26%–1.59%, and 5.62%–1.84%, depending on the land sections. According to humus, nitrogen was 0.402%–0.238%, 0.394%–0.159%, 0.393%–0.127%, and 0.358%–0.146%. The hygroscopic moisture of the soil resulted in 7.85%–6.15%, 7.06%–5.96%, 6.98%–5.78%, and 6.54%–5.91%, respectively. CaCO3 ranged from 4.25%–2.78%, 4.74%–3.04%, 5.48%–2.69%, and 5.46%–2.29%, total absorbed bases scored 32.45–29.25 mg-eq, 35.14–24.63 mg-eq, 28.39–25.61 mg-eq, and 34.22–29.67 mg-eq, and the pH ranged from 7.2–6.8, 7.4–7.0, 7.8–7.2, and oath 7.1–6.7.

Section 13: The X coordinate (East longitude) of the soil section was X.46° 3′ 36,816″ E, and the Y coordinate (North latitude) was Y.40° 42′ 18,738″N (Table 2). The thickness of the humus layer along the profile was 3.97%–0.82%, and the humus contained 0.283%–0.101% of the nitrogen.

Hygroscopic moisture ranges from 7.87%–6.83%, CaCO3 (CO2 7.53%–6.57%), total absorbed bases (32.84–28.19 mg-eq), active phosphorus (12.05–7.02 mg/kg), exchangeable potassium (294–263 mg/kg), and pH fluctuated between 7.0–6.8 (Table 4) (Sadigov, 2018 b).

Underdeveloped mountain gray-cinnamon (chestnut) soils in the Goranboy Region had the humus layer thickness along the profile changed significantly in different areas. It was 6.47%–1.96%, 6.51%–1.98%, 4.58%–0.83%, and 5.26%–1.12%, depending on the land sections. According to humus, nitrogen was 0.412%–0.244%, 0.399%–0.172%, 0.326%–0.069%, and 0.324%–0.107%. The hygroscopic moisture of the soil's determination occurred as 6.18%–5.49%, 6.72%–5.46%, 6.43%–5.60%, and 6.38%–5.19%, respectively. CaCO3 gave 3.47%–2.43%, 3.79%–2.42%, 3.93%–2.76%, and 3.69%–2.72%, total absorbed bases were 31.78–27.82 mg-eq, 31.43–19.76 mg-eq, 29.21–23.93 mg-eq, and 30.04–24.32 mg-eq, and the pH ranged from 7.8–7.2, 7.7–7.3, 7.6–7.0, and oath 7.3–6.9.

Section 14: Determining soil section 14 placement in the territory of the Shamkir Region also engaged geographical coordinates. The X coordinate (East longitude) of the soil section was X.46° 3′ 32,059″ E, and the Y coordinate (North latitude) was Y.40° 42′ 58,109″N (Table 2). The humus layer thickness along the profile was 4.36%–1.61%, which also contained 0.307%–0.136% of the nitrogen. Hygroscopic moisture ranged from 6.31%–4.84%, CaCO3 CO2 (150.16%–8.64%), total absorbed bases (24.94–22.01 mg-eq), phosphorus fluctuates (14.58–9.07 mg/kg), exchangeable potassium (310–223 mg/kg), and the pH fluctuated between 7.2–7.0 (Table 4) (Sadigov, 2018a; Sadigov, 2023).

Results of the underdeveloped mountain gray-cinnamon (chestnut) soil in the Goygol region provided the humus layer thickness is 5.19%–1.34%, 5.68%–1.28%, 4.93%– 0.95%, and 5.58%–1.06%. According to humus, nitrogen was 0.387%–0.196%, 0.396%–0.174%, 0.315%–0.074%, and 0.332%–0.118%. The obtained hygroscopic moisture of the soil emerged as 6.34%–5.07%, 6.14%–4.99%, 6.49%–5.24%, and 6.73%–5.58%, respectively. CaCO3 ranged from 4.23%–2.96%, 3.16%–2.33%, 3.68%–2.25%, and 3.42%–2.86%, total absorbed bases scored 30.17–26.32, 29.39–22.68, 28.43–24.12, and 26.63–22.832mg-eq, and the pH ranged from 8.0–7.6, 7.8–7.5, 7.6–7.2, and oath 7.4–7.0.

Section 19: The section's placement came from geographic coordinates. The X coordinate (East longitude) of the section was X.46° 3′ 53,690″ E, and the Y coordinate (North latitude) was Y.40° 43′ 28,922″N (Table 2). The humus layer thickness was 4.09%–1.30%, along with nitrogen content (0.291%–0.161%). Hygroscopic moisture varied from 7.45% to 4.72%, CaCO3 (11.03% to 8.26%), total absorbed bases (30.22 to 29.64 mg-eq), phosphorus (14.04–8.61 mg/kg), exchangeable potassium (362–292 mg/kg), and the soil pH ranged from 7.3 to 7.1 (Table 4). However, the dry solids obtained no analysis (Sadigov, 2022; Sadigov, 2023).

Soil analysis results of underdeveloped mountain gray-cinnamon (chestnut) soil in the Shamkir Region about 20 years ago indicate that the humus layer thickness was 3.58%–1.02%, along with nitrogen content of 0.247%–0.152 %. Hygroscopic moisture varied from 6.73% to 4.22%, CaCO3 (12.73% to 6.86%), total absorbed bases (32.26 to 28.39 mg-eq), phosphorus (9.75 to 5.82 mg/kg), exchangeable potassium (268 to 234 mg /kg), and the soil pH ranged from 7.8 to 7.4. It was also apparent from the comparative analysis that the scientific and experimental work carried out in the research area over the years has yielded results.

The analysis of the chief diagnostic indicators of the soil sections under grape cultivation on the not-so-well-developed mountain gray-cinnamon (chestnut) soil subtype in the territory of the Shamkir Region showed Section 14 and Section 19 with minimal soil erosion observed. The low inclination (0–2 degrees) in the areas where the sections appeared did not develop such conditions for the erosion process. However, a weak level of soil erosion was evident in the other three soil sections.

Determining the amounts of nitrogen, activated phosphorus, and exchangeable potassium in the soil under the grape plants transpired to improve the soil protection measures from erosion in the specified area. Thus, grape plants are one of the soil's most productive plants in mountainous and foothill areas, absorbing humus, nitrogen, active phosphorus, and exchangeable potassium compounds from available nutrients in the soil during vegetation and development stages.

As the area is a historical vineyard, soil enrichment with mineral and organic substances is necessary. Organic and mineral fertilizers enhance the amount of nutrients in the soil and ensure the normal development of crop plants. The plant's healthy development, in turn, promotes abundant productivity and economic efficiency. The nitrogen supply to the soil from mineral fertilizers was mainly ammonium, which almost meets the plant's needs. About half of the nitrogen given to the soil was by ammonium salt within 30 days, and after two months, most of the nitrogen converts into nitrate form.

In the study area during 2021 and 2022, the first evaluation of the amount of phosphorus fertilizers ranged from 14–17 mg. After applying phosphorus fertilizers in the same portion, the available phosphorus reached 18–22 mg. However, a decrease in the phosphorus compounds in the soil also became evident. The main reason for the decline is the long-term use of ammonium sulfate fertilizer in the cultivated area, changing the soil environment from alkaline to acidic and, later, acidifying the soil. The said process prevents phosphorus from reacting with iron and aluminum oxides in the soil and eventually being absorbed by grape roots. However, when such situations occur, applying carbamide and ammonium nitrate fertilizers ensures phosphorus uptake and will lead to reduced fertility. In applied potassium fertilizers, the most part integrates into the exchangeable potassium form (Sadigov, 2022; Sadigov, 2023).

Knowing the amount of fertilizers used during periods of vegetation (flowering), fruiting, and full maturity contributes to the correct sowing times, which are more critical for the justification of food systems. With the considerable effects of phosphorus and potassium fertilizers, enhanced soil fertility positively impacts productivity. However, during the growing season, the amount of phosphorus and potassium fertilizers absorbed from the soil by the plant's root systems decreased, with the remaining parts converted into phosphate forms that are difficult to absorb.

The analysis results of the experimental lands in the vineyard plots around Yeni Hayat Village, Shamkir Region, are available in Table 5. Studying the dynamics of nutrients showed mainly the differences between the flowering and maturity stages of the compared vegetation. The research considered the vineyard areas' irrigation through the right bank canal separated from Shamkirchay (Sadigov, 2023). In the local area, the experimental section covers an area of approximately 100 ha, the distance between rows was 2.5 meters, and the distance between plants was 1.5 meters. Table 5 also shows the comparative characteristics of vegetation (flowering) and maturity development stages in the underdeveloped mountain gray-cinnamon (chestnut) soils and analyzed absorbed ammonia, nitrate, available phosphorus, and exchangeable potassium.

Based on the chemical analysis of the collected soil samples, modern methods analyzed the soil's main physico-chemical and nutritional elements. Complex features of granulometric composition in genetic profiles and the morphogenetic indicators of the underdeveloped mountain gray-cinnamon (chestnut) soils also gained assessment. In Table 4, the analyses of the diagnostic indicators of the fertility parameters of five soil sections placed in characteristics interpreted the morphological analysis of the soil sections. The presented soil sections appear in Figure 2. Incorporating mineral fertilizers into the soil separately and together with manure increased soil fertility during all stages of productivity and positively affected productivity (Table 5). In the soil, the variations and dynamics in the nutrients at each stage were also evident when applying mineral and organic fertilizers to the fields individually and combined.

Table 5. Amount of nitrogen, phosphorus, and assimilable potassium in underdeveloped mountain gray-brown (chestnut) soils under grape plants in the Shamkir region.

Variants	Depth (cm)	Vegetation (flowering) period				The period after full maturity					
		N/NH_3	N/NO_3	P_2O_5	K_2O	N/NH_3	N/NO_3	N/NH_3	N/NO_3	P_2O_5	K_2O
Control without fertilizer	0-20	14.11	5.66	16.32	134.5	12.69	4.45	10.61	3.23	11.54	115.8
	20-50	11.27	4.02	11.54	105.8	9.88	3.05	8.52	2.64	9.25	90.6
	50-100	7.82	2.04	9.62	84.6	7.06	2.07	6.41	1.82	8.29	79.4
Manure (10 t/ha per 3 years)	0-20	21.05	8.44	20.07	169.4	17.68	7.27	13.47	5.86	16.89	141.5
	20-50	16.11	6.96	16.35	114.5	13.41	5.46	11.32	4.65	11.58	106.5
	50-100	9.74	4.55	10.02	90.7	8.47	3.68	7.84	2.83	8.53	86.4
$N_{30}P_{60}K_{60}$	0-20	17.89	6.78	20.88	170.8	14.11	5.08	11.34	3.44	16.35	153.7
	20-50	14.94	5.89	16.94	123.5	12.42	4.25	10.03	2.84	10.93	115.2
	50-100	9.15	4.52	10.96	96.8	7.84	2.67	7.32	2.03	8.08	91.5
$N_{60}P_{90}K_{120}$	0-20	25.17	7.86	24.78	189.4	22.04	6.46	16.23	4.85	19.88	163.7
	20-50	18.93	6.51	17.45	135.6	15.96	4.85	12.71	3.84	11.96	121.5
	50-100	10.24	5.93	10.78	96.4	9.78	2.88	8.47	2.22	8.93	90.6
$N_{90}P_{120}K_{120}$	0-20	26.42	8.92	30.15	204.2	23.67	7.11	18.35	5.28	24.63	189.4
	20-50	22.37	7.06	20.59	142.0	17.68	5.12	13.42	4.26	16.92	129.4
	50-100	12.61	4.66	11.58	105.7	9.95	3.49	9.18	2.44	9.33	96.8
$N_{30}P_{60}K_{60}$+10 t/ha manure (Once per 3 years)	0-20	26.11	10.02	25.62	197.2	22.73	8.14	17.66	6.11	21.08	170.8
	20-50	22.08	8.09	17.99	139.2	17.06	6.72	14.11	4.94	13.80	127.5
	50-100	11.92	6.52	10.84	98.8	9.68	4.25	8.49	3.26	9.86	91.4
$N_{60}P_{90}K_{120}$+10 t/ha manure (Once per 3 years)	0-20	29.14	11.35	29.48	216.4	25.94	9.16	21.05	7.15	24.82	198.2
	20-50	25.61	9.07	20.64	149.8	20.02	7.11	17.32	5.348	17.39	115.6
	50-100	13.49	7.29	11.19	98.7	11.34	4.48	9.68	3.26	9.66	90.3
$N_{90}P_{120}K_{120}$+10 t/ha manure (Once per 3 years)	0-20	32.86	11.94	34.93	241.6	26.83	9.77	22.59	7.69	26.82	216.4
	20-50	28.34	10.37	26.51	162.8	24.72	8.12	21.42	6.22	19.48	142.9
	50-100	14.74	8.16	13.52	109.7	12.31	4.69	10.28	4.08	10.09	105.7

CONCLUSIONS

The results revealed the gradual decrease of soil fertility from the upper layers to the lower layers during erosion, which may be due to the increased grape productivity. As the best erosion control measures, cropland cultivation should be across the slope. Carrying out plowing, planting, sowing, and other field operations across the slope reduces the surface water flow caused by rains, weakens erosion, prevents the loss of soil, humus, and nutrient contents, and develops favorable conditions for increased productivity.

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