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Agrochemical Characteristics of Chernozems of Mountainous Shirvan Economic Region: A Case Study of Ismayilli District

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Abstract. *This study evaluates the impact of long-term anthropogenic land-use practices on the physicochemical, particle-size, and microaggregate properties of cultivated mountain chernozems in the Ismayilli district, Azerbaijan. Soil pit No. 4 was established in a cereal field in Rushan village, while pit No. 15 was excavated under a perennial vineyard in Ivanovka village. Results indicate that continuous annual grain cropping preserves organic matter and fine particulate matter within the surface plow layer (0–29 cm), yielding higher topsoil humus (3.48% vs 4.47%) and physical clay (<0.01 mm) concentrations (80.79%). This topsoil accumulation is driven by irrigation-derived silt inputs, active root-microbial activity, and humic aggregation that mitigates leaching. Conversely, perennial vineyard management induces organic matter depletion due to deep root absorption, while promoting downward clay illuvial redistribution (fine clay <0.001 mm reaching 26.04% at 135–241 cm depths). Profile pH transitions from slightly acidic surface horizons (5.79) to moderately alkaline subsoils (8.14). The base saturation remains exceptionally high, with exchangeable cations rising up to 65.92 mmol/100 g in deeper layers due to carbonate-rich parent rock weathering. Under N.A.Kachinsky's classification, both profiles are categorized as medium-to-heavy clay variants. Overall, persistent agricultural regimes—specifically perennial viticulture versus seasonal cereal cropping—profoundly reshape organic carbon sequestration, moisture partitioning, and textural differentiation in mountain chernozems*

Keywords: *agrochemical characteristics, chernozems, Mountainous Shirvan, humus, physicochemical characteristics, granulometric composition*

Introduction

Agricultural land utilization levels and shifts in crop patterns are critical factors. These drivers directly impact the soil's agrochemical dynamics (Mammadova, 2026a). Specifically, converting areas long occupied by perennial crops, such as vineyards, into grain cultivation alters the soil's nutrient regime and organic matter balance (Mammadov & Aliyev, 2023). During such agrotechnical transitions, the soil undergoes regular tillage. As a result, nutrients are redistributed across the genetic horizons (Ismayilova et al., 2025). Hence, investigating how anthropogenic pressures affect soil fertility remains a vital research focus in modern agricultural science.

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The Mountainous Shirvan region, particularly the Ismayilli district, boasts a highly diverse soil cover. Chernozems widespread in this area are distinguished by their high fertility potential. Additionally, these soils feature a thick humus horizon along with favorable physicochemical properties. Historically, both rainfed grain farming and intensive viticulture flourished in these areas. However, over recent decades, unilateral shifts in agricultural priorities have significantly impacted the agrochemical profile of these soils (Jafarov, 2012).

The research subjects selected were the chernozems of Ivanovka and Rushan villages within the Ismayilli district. These two sites possess distinct agrotechnical histories. The experimental plot in Ivanovka was long utilized for intensive viticulture, whereas in recent years it has been converted to cereal crop cultivation. In contrast, the soils of Rushan village, chosen for comparative analysis, have traditionally served solely as grain agroecosystems over an extended period. Analyzing these two sites—which belong to the same soil classification yet possess differing agricultural legacies—clearly demonstrates how historical land-use variations directly govern nutrient dynamics (Babayev & Gurbanov, 2018).

The topography of the area transitions smoothly from plains to mountainous terrain (Mirzezadeh & Mammadova, 2026). The geomorphological structure of the region primarily consists of valleys and steep slopes. Clay shales, limestone, and alluvial deposits form the foundation of the parent rocks (Mammadova, 2026b). The hydrography of the region is well-developed, encompassing high-discharge mountain rivers and freshwater springs. The territory is dominated by humid temperate and cold climates with dry winters, featuring evenly distributed precipitation (Shukurov et al., 2025). The natural vegetation primarily consists of broad-leaved mountain forests; however, the lowland areas are currently dominated by various agricultural crops (Khudaverdi et al., 2026). The soil cover of the district comprises mountain forest cinnamonic, mountain gray-cinnamonic, and chernozem soils (Ismayilov et al., 2022).

The objective of this study is to conduct a comparative assessment of the contemporary agrochemical properties of chernozems in Ivanovka (former vineyard) and Rushan (traditional grainland) villages of the Ismayilli district. Within this framework, key parameters—including organic matter content, pH levels, exchangeable bases, carbonate levels, and physical properties—were analyzed to formulate science-based recommendations aimed at enhancing the efficiency of regional rainfed cereal production.

Materials and Methods

The study was conducted within the mountain chernozem zones of the Ismayilli district. During the fieldwork, soil pits were excavated at both locations within the same soil type to determine the agrochemical status of the soil layers in Ivanovka and Rushan villages. The morphological structure of these profiles was described, and soil samples were collected across individual genetic horizons.

Laboratory soil analyses were carried out in accordance with standard methods generally accepted in agricultural science. The study involved establishing soil cuts for field observations. Their morphological features were described based on international standards (FAO, 2006). Soil samples were collected from each genetic horizon. These samples were analyzed in the laboratory to determine their main physicochemical properties. The analysis included total humus, gross nitrogen, and the C:N ratio. Additionally, soil reaction (pH), cation exchange capacity, particle size distribution, and complete water extract composition were measured. All laboratory tests were performed using standard analytical methods (Arinushkina, 1970; Mineev, 1989).

Results and Discussion

The mountain chernozem soil type comprises four distinct subtypes: typical, leached, calcareous, and compacted (Maharram et al., 2024). Soil studies conducted in Azerbaijan reveal that mountain chernozems occur locally across relatively limited areas. In the Ismayilli district, the majority of mountain chernozems are dedicated to cereal crop production. Due to long-term agricultural use, these soils have become cultivated. Soil pit No. 4, representing cultivated mountain chernozems under grain cultivation, was established in Rushan village of the Ismayilli district at coordinates 40°47'89.3" N, 47°59'14.6" E, at an elevation of 737 m above sea level. The relief is predominantly flat. The morphological description of profile No. 4 is presented below:

Ap 0–29	Plow layer, brownish-black, medium loamy, granular-nutty, soft, presence of roots and rootlets, insect burrows, non-effervescent under 10% hydrochloric acid (HCl), gradual transition;
A/B 29–64	Brownish-black, light clay, granular-subangular blocky, slightly soft, presence of roots and fine rootlets, earthworm channels, slightly moist, non-effervescent, gradual transition;
B/Cdk 64–118	Brownish-cinnamonic, light clay, subangular blocky, slightly compact, white eyes (pseudomycelia), mycelial carbonates, moist, strongly effervescent, clear transition;
Cdk 118–182	Light yellowish, very weakly structured, compact, mycelial carbonates, strongly effervescent, clear transition.

The morphological description of the profile indicates that the soil color transitions downward from brownish-black to light yellowish. The upper horizons do not exhibit effervescence upon treatment with 10% hydrochloric acid (HCl), whereas effervescence is strongly observed in the subsoil horizons. This downward translocation demonstrates the leaching of carbonates through the profile. Based on fieldwork observations, this soil pit is classified as the leached subtype of the mountain chernozem soil type. The thickness of the humus-accumulative layer within the profile measures 64 cm.

Another noteworthy soil pit, No. 15, representing cultivated mountain chernozems, was established in Ivanovka village of the Ismayilli district at coordinates 40°44'03.2" N, 48°01'37.4" E, at an elevation of 837 m above sea level. The area was utilized under vineyards for an extended period, spanning more than half a century. Currently, the vineyards have been removed and replaced with grain crops. The relief is flat. The morphological description of soil profile No. 15 is presented below:

Ap 0–36	Dark grayish-black, light clay, granular-subangular blocky, soft, porous, presence of roots and fine rootlets, insect burrows, moist, non-effervescent, gradual transition;
A/Bg 36–106	Grayish-black, light clay, granular-subangular blocky, presence of roots and fine rootlets, insect burrows, slightly moist, occasional rust spots (gleying features), non-effervescent, gradual transition;
Bg 106–135	Lighter in color relative to the upper horizon, medium loamy, subangular blocky, abundant rust spots, very moist, non-effervescent, black humus tongues (illuvial streaks), fine gravels, clear transition;
B/Ck 135–182	Yellowish-whitish, medium loamy, nutty (subangular blocky), carbonate mycelia, fine gravels, moderately effervescent, gradual transition;
Ck 182–241	Light clay, structureless, compact, carbonate concretions, rust spots, slightly moist, moderately effervescent, gradual transition.

The morphological description reveals a remarkably dark color profile with well-developed granular-subangular blocky structure. Rust spots observed in the middle horizons are attributed to excessive moisture and the oxidation of iron compounds. Effervescence upon treatment with 10% hydrochloric acid (HCl) occurs below a depth of 135 cm, whereas the upper horizons display no effervescence. The presence of fewer carbonates in the upper horizons and their accumulation at greater depth indicate downward translocation, which has led to the formation of an illuvial Bk horizon. Consequently, this soil is classified as the leached subtype of mountain chernozems. The particle-size distribution across almost all horizons is dominated by light clay. A distinct variation in the morphological profiles of the cultivated leached mountain chernozems is clearly evident under both crop covers. This differentiation is directly attributed to the specific ecological and biological characteristics of the cultivated plants.

According to the physicochemical laboratory analysis results of soil pit No. 4, established in a grain field in Rushan village of the Ismayilli district (Table 1), hygroscopic moisture decreases down the profile from the top horizon to the bottom (9.27–7.51%); however, it peaks at 12.25% within the 29–64 cm layer during the transition from the humus layer to the illuvial horizon. The pH values (Table 1) exhibit an increasing trend from the upper layers to the lower depths, ranging between 6.28 and 8.42, which indicates a shift in soil reaction from slightly acidic to slightly alkaline conditions. The analytical data reveal that humus content (4.47–0.64%), total nitrogen (0.31–0.08%), and the C:N ratio (7.6–4.2) consistently decline downward along the profile. This distribution pattern is considered one of the primary pedogenic regularities in the profile of cultivated mountain chernozems. Based on R. H. Mammadov's humus gradation scale, these soils are classified as moderately humic according to the humus content in the surface horizon (Mammadov, 1970).

Table 1
Main physicochemical characteristics of cultivated mountain chernozems

Pit No.	Depth, cm	Hygroscopic moisture, %	pH	Humus, %	N, %	C:N	CO_2, %	$CaCO_3$, %	Exchangeable bases, mmol/100g	
									Ca^{+2}	Mg^{2+}
No. 4 Rushan village, Ismayilli district (cereal field)	Ap 0–29	9,27	6,28	4,47	0,31	7,6	---	---	24,40	1,88
	A/B 29–64	12,25	7,46	0,91	0,09	5,3	---	---	25,28	4,32
	B/Cdk64–118	8,20	7,98	0,89	0,09	5,2	12,32	28,00	27,41	4,86
	Cdk 118–182	7,51	8,42	0,64	0,08	4,2	10,08	22,91	23,81	6,46
No. 15 Ivanovka village, Ismayilli district (vineyard)	Ap 0–36	8,95	5,79	3,48	0,25	7,3	---	---	17,57	8,56
	A/Bg 36–106	10,48	6,78	2,93	0,22	7,0	---	---	33,10	19,33
	Bg 106–135	9,21	7,70	1,69	0,14	6,3	---	---	37,69	14,65
	B/Ck 135–182	6,35	8,06	0,96	0,10	5,0	7,79	17,71	28,77	37,15
	Ck 182–241	6,87	8,14	0,64	0,07	4,8	8,78	19,96	30,00	24,25

Soil carbon dioxide emissions and carbonate content (Table 1) were not detected in the 0–29 cm and 29–64 cm layers. However, carbonates are clearly pronounced in the 64–118 cm and 118–182 cm horizons, measuring 28.00% and 22.91%, respectively. According to R. H. Mammadov's carbonate classification scale (Mammadov, 1970), cultivated mountain chernozems are categorized as moderately calcareous soils. This distribution pattern is attributed to the leaching of carbonates from the upper horizons and their subsequent accumulation in the subsoil layers. The content of exchangeable bases (Table 1) ranges between 26.28 and 32.27 mmol/100 g, displaying an uneven distribution along the profile. Based on R. H. Mammadov's base saturation scale (Mammadov, 1970), this soil type is evaluated as satisfactory to moderate. The content of exchangeable Ca^{2+} (23.81–27.41 mmol/100 g) significantly predominates over Mg^{2+} (1.88–6.46 mmol/100 g).

Physicochemical evaluation of soil pit No. 15 (vineyard, Ivanovka village) indicates a general downward reduction in hygroscopic moisture levels, ranging from 6.35% to 10.48% across the profile. However, a peak moisture value of 10.48% is observed in the 36–106 cm horizon, which aligns directly with the morphological description of the soil pit. The pH values (5.79–8.14) display a downward increasing trend, indicating a transition in soil reaction from slightly acidic to moderately alkaline conditions. This shift represents a characteristic feature of cultivated mountain chernozems. The concentrations of humus (3.48–0.64%), total nitrogen (0.25–0.07%), and the C:N ratio (7.3–4.8) vary consistently across the horizons (Table 1). As the humus content declines along the profile, both total nitrogen levels and the C:N ratio decrease accordingly. Based on R. H. Mammadov's humus classification scale, this soil type is categorized as moderately humic according to the organic matter content in the surface horizon (Mammadov, 1970).

The lower humus content in this profile is attributed to the deep root system of the grapevine, which consumes soil organic matter and nutrients more intensively compared to cereal crops. As organic matter declines down the profile, total N and C:N values decrease in accordance with natural soil formation dynamics. Carbonate content and soil-released carbon dioxide are absent to a depth of 0–135 cm. In the deeper horizons, carbonate levels increase significantly, ranging from 17.71% to 19.96%, accompanied by a corresponding rise in emitted CO_2 levels (7.79–8.78%). According to R. H. Mammadov's carbonate gradation scale, these subsoils are classified as calcareous soils (Mammadov, 1970). The concentration of exchangeable bases increases from 26.13 to 65.92 mmol/100 g. This high capacity is driven by the development of these soils over parent materials rich in carbonates, predominantly composed of Ca^{2+} and Mg^{2+} cations (Gahramanova et al., 2026). The spatial distribution of Ca^{2+} and Mg^{2+} ions are uneven throughout the profile, with exchangeable Ca^{2+} ranging from 17.57 to 37.69 mmol/100 g and Mg^{2+} from 8.56 to 37.15 mmol/100 g. Based on R. H. Mammadov's base capacity evaluation scale, these soils are defined as having a very high cation exchange capacity (Mammadov, 1970).

Table 2
Granulometric composition of mountain chernozems, %

Pit No.	Depth, cm	Particle size, mm, %						
		1–0,25	0,25–0,05	0,05–0,01	0,01–0,005	0,005–0,001	<0,001	<0,01
No. 4	Ap 0–29	---	3,27	15,94	13.18	24,66	42,95	80,79
Rushan village,	A/B 29–64	---	26,58	11,85	11,83	32,11	17,63	61,57
Ismayilli district	B/Cdk 64–118	0,19	16,94	22,43	11,85	30,30	18,29	60,44
(cereal field)	Cdk 118–182	---	11,84	18,63	21,86	16,23	31,44	69,53
No. 15	Ap 0–36	---	9,56	17,64	27,89	23,44	21,47	72,80
Ivanovka	A/Bg 36–106	0,22	21,05	11, 75	25,78	23,23	18,19	67,20
village,	Bg 106–135	---	11,93	9,24	30,42	26,10	22,31	78,83
Ismayilli district	B/Ck 135–182	2,27	11,17	12,96	19,14	30,69	26,04	75,87
(vineyard)	Ck 182–241	2,12	21,58	16,57	18,45	17,38	26,02	61,85

Laboratory examination of the particle-size distribution in soil pit No. 4 (grain field, Rushan village) reveals that clay particles smaller than 0.001 mm are predominantly concentrated within the plow layer (0–29 cm) (Table 2). This topsoil accumulation is driven by silt deposition via irrigation water, combined with microbial activity and root residue decomposition. Furthermore, humic substances play a crucial role by binding fine clay particles into stable soil aggregates (Hasanova & Mammadova, 2023), thereby mitigating downward leaching. Physical clay (<0.01 mm) quantitatively dominates over all other fractions (Table 2), reaching 80.79% in the surface horizon, which categorizes the soil as medium clay based on N. A. Kachinsky's classification scale (Mammadov, 1970). In lower depths, however, the physical clay content decreases slightly to 60.44–69.53%, shifting these subsoil horizons into the light clay category (Mammadov, 1970).

Microaggregate data from soil pit No. 15, excavated under a vineyard in Ivanovka village, demonstrate a relatively low proportion of fine clay (<0.001 mm). The upper profile exhibits moderate values, measuring 21.47% in the 0–36 cm horizon, 18.19% in the 36–106 cm layer, and 22.31% at depths of 106–135 cm. Conversely, deeper layers show an increased and uniform fine clay distribution, holding at 26.04% and 26.02% in the 135–182 cm and 182–241 cm horizons, respectively. The physical clay (<0.01 mm) fraction displays an uneven vertical distribution (61.85–78.83%), classifying these cultivated mountain chernozems as medium to light clay soils under N.A.Kachinsky's scheme (Mammadov, 1970).

Conclusion

A comparative evaluation of the physicochemical parameters of soil pit No. 4 (grain field, Rushan village) and soil pit No. 15 (former vineyard, Ivanovka village) reveals distinct anthropogenic and agronomic influences on profile differentiation. Soil pit No. 4 exhibits a higher organic matter content in the topsoil (4.47% humus) compared to pit No. 15 (3.48% humus). This disparity is primarily driven by the contrasting physiological mechanisms of the root systems: the extensive, deeply penetrating root structure of grapevines induces a more intensive consumption and depletion of soil organic matter and nutrients than annual cereal crops. Both profiles demonstrate a characteristic downward leaching of carbonates, resulting in a pH shift from slightly acidic surface horizons to alkaline conditions in the subsoil. However, pit No. 15 displays a significantly higher cation exchange capacity, with exchangeable bases reaching up to 65.92 mmol/100 g in the lower horizons due to the influence of carbonate-rich parent rock materials dominated by Ca^{2+} and Mg^{2+} cations. In summary, the results demonstrate that persistent agricultural regimes—specifically perennial viticulture versus annual grain farming—profoundly reshape organic matter sequestration, hydrological profiles, and the exchangeable cation status in cultivated mountain chernozems.

Overall, the findings demonstrate that long-term agricultural regime profoundly reshapes the vertical distribution of microaggregates and soil texture in mountain chernozems. Annual cereal farming (Pit No. 4) preserves fine clay (<0.001 mm) within the upper plow horizon (0–29 cm) through humic binding and irrigation inputs, resulting in a pronounced surface accumulation of physical clay (80.79%). In contrast, perennial vineyard management (Pit No. 15) leads to topsoil clay depletion while encouraging downward particle percolation, giving rise to higher, stabilized subsoil clay contents (up to 26.04%). Despite these anthropogenic divergences, physical clay (<0.01 mm) remains the dominant fraction throughout both profiles (60.44–80.79%), defining these soils as heavy-textured variants under N. A. Kachinsky's particle-size classification.

Declaration of Competing Interests

The author declares that they have no conflict of interest.

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