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Evaluation of Granulometric Characteristics and Biogenic Element Diagnostic Indicators of Mountain Gray-Brown Soils in the Gazakh-Tovuz Economic Region According to the Wrb System

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Abstract. *This article presents the results of comprehensive investigations conducted between 2020 and 2025 on mountain gray-brown soils within the Gazakh-Tovuz economic region of western Azerbaijan, focusing on the Shamkir administrative district. The research covered an area of 10,522.55 ha and aimed to evaluate the morphological, physicochemical, and spatial characteristics of these soils using conventional soil survey methods integrated with modern geospatial technologies. Detailed field and laboratory analyses were carried out on representative soil profiles, particularly sections 12, 19, 25, and 98, supplemented by observations from additional target sites. Morphological assessments were supported by analyses of key diagnostic indicators, including humus content, total nitrogen, available phosphorus and potassium, granulometric composition, soil reaction (pH), and calcium carbonate ($CaCO_3$) content. Statistical methods were applied to determine the variability and relationships among soil properties. Geographic coordinates of representative soil sections were established using a Garmin GPSMAP 62s device to ensure accurate spatial referencing. A high-resolution digital elevation model (DEM) was generated through interpolation of elevation data obtained from topographic maps, and a detailed relief model of the study area was developed using ArcGIS 10.3 software. The integration of soil analytical data with GIS-based spatial modeling enabled a comprehensive characterization of mountain gray-brown soils. The findings provide a scientific basis for soil classification, land evaluation, sustainable land management, and agricultural planning aimed at improving land-use efficiency and agricultural productivity in the region. Key finding: The study revealed that mountain gray-brown soils in the Shamkir region exhibit moderate humus content, slightly alkaline pH, and variable nutrient distribution, with noticeable differences across soil profiles influenced by relief and parent material. Spatial analysis based on DEM and GIS modeling confirmed that topography plays a significant role in shaping soil properties and their distribution patterns. Overall, the integration of field data and geospatial techniques provided a reliable basis for accurate soil classification and more efficient land use planning in the Gazakh-Tovuz economic region.*

Keywords: *mountain gray-brown soils, granulometric composition, biogenic elements, WRB soil classification, soil diagnostics, Gazakh-Tovuz economic region*

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Qazax-Tovuz iqtisadi bölgəsindəki dağ boz-qəhvəyi torpaqlarının qranulometrik xüsusiyyətlərinin və biogen element diaqnostik göstəricilərinin WRB sisteminə görə qiymətləndirilməsi

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Xülasə. *Məqalədə Azərbaycanın qərb hissəsində yerləşən Qazax-Tovuz iqtisadi rayonunun Şəmkir inzibati rayonu ərazisində yayılmış dağ boz-qəhvəyi torpaqlar üzrə 2020–2025-ci illərdə aparılmış kompleks tədqiqatların nəticələri təqdim edilmişdir. Tədqiqat 10 522,55 ha ərazini əhatə etmiş və müasir geoməkan texnologiyaları ilə inteqrasiya olunmuş ənənəvi torpaq tədqiqat metodları əsasında həmin torpaqların morfoloji, fiziki-kimyəvi və məkan xüsusiyyətlərinin qiymətləndirilməsini hədəfləmişdir. Nümayəndə torpaq profillərində, xüsusilə 12, 19, 25 və 98 nömrəli kəsimlərdə ətraflı sahə və laboratoriya tədqiqatları aparılmış, əlavə müşahidələr isə seçilmiş hədəf sahələrində davam etdirilmişdir. Torpaqların morfoloji xüsusiyyətləri humusun miqdarı, ümumi azot, mütəhərrik fosfor və kalium, qranulometrik tərkib, torpaq reaksiyası (pH) və kalsium karbonatın ($CaCO_3$) miqdarı kimi əsas diaqnostik göstəricilərin təhlili ilə səciyyələndirilmişdir. Tədqiq olunan torpaq göstəricilərinin dəyişkənliyinin və qarşılıqlı əlaqələrinin müəyyən edilməsi məqsədilə statistik təhlil metodlarından istifadə olunmuşdur. Məkan məlumatlarının dəqiqliyinin təmin edilməsi üçün nümayəndə torpaq kəsimlərinin coğrafi koordinatları Garmin GPSMAP 62s cihazı vasitəsilə müəyyən edilmişdir. Topoqrafik xəritələrdən əldə edilmiş yüksəklik məlumatlarının interpolasiyası əsasında yüksək ayırdetmə qabiliyyətinə malik rəqəmsal yüksəklik modeli (DEM) yaradılmış, ArcGIS 10.3 proqram təminatında tədqiqat ərazisinin ətraflı relyef modeli hazırlanmışdır. Torpaq analizlərinin nəticələrinin CİS əsaslı məkan modelləşdirməsi ilə inteqrasiyası dağ boz-qəhvəyi torpaqların hərtərəfli xarakteristikasının müəyyən edilməsinə imkan vermişdir. Əldə olunan nəticələr torpaqların təsnifatı, qiymətləndirilməsi, davamlı torpaq idarəçiliyi və kənd təsərrüfatının elmi əsaslarla planlaşdırılması üçün mühüm elmi baza formalaşdırır, həmçinin regionda torpaqdan istifadənin səmərəliliyinin və kənd təsərrüfatı məhsuldarlığının artırılmasına xidmət edir.*

Açar sözlər: *dağ boz-qəhvəyi torpaqları, qranulometrik tərkib, biogen elementlər, WRB torpaq təsnifatı, torpaq diaqnostikası, Qazax-Tovuz iqtisadi rayonu*

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Introduction

Soil resources play a fundamental role in ensuring agricultural productivity, ecological stability, and sustainable land use, particularly in regions with diverse natural and geomorphological conditions. In mountainous and foothill areas, soil formation is strongly influenced by relief, parent material, climate, and land use practices, resulting in high spatial variability of soil properties. Comprehensive assessment of soil morphological, physicochemical, and spatial characteristics is therefore essential for accurate soil classification, land evaluation, and the development of effective management strategies (Waghorn, 2008; Shukurov et. al., 2025).

The western region of the Republic of Azerbaijan, particularly the Gazakh-Tovuz economic region, is of considerable importance for national agricultural development due to its favorable agroclimatic conditions and long-standing tradition of crop production. However, increasing anthropogenic pressure, combined with complex relief and erosion-prone landscapes, necessitates detailed soil investigations to support sustainable land use planning. Among the dominant soil types of this region, mountain gray-brown soils are widely distributed and form the basis of agricultural activity, yet their diagnostic properties and spatial variability remain insufficiently studied under modern classification frameworks (Mueller-Harvey, 2006; Huseynov et. al., 2025).

Recent advances in soil science emphasize the integration of classical field and laboratory methods with geospatial technologies, such as geographic information systems (GIS), global positioning systems (GPS), and digital elevation models (DEMs). These tools enable more precise spatial analysis of soil properties and improve the reliability of soil mapping and land resource assessments. Moreover, the application of internationally recognized soil classification systems, such as the World Reference Base for Soil Resources (WRB), allows for standardized soil characterization and facilitates comparison with soils from other regions (Mammadov et. al., 2025).

Against this background, the present study aims to provide a comprehensive evaluation of mountain gray-brown soils in the Shamkir administrative region within the Gazakh–Tovuz economic zone. The research focuses on the assessment of morphological features, physicochemical properties, and key diagnostic indicators, including humus content, nutrient status, granulometric composition, soil reaction, and carbonate content. By combining detailed field observations, laboratory analyses, and geospatial modeling techniques, this study seeks to improve the understanding of soil variability and to establish a scientific basis for soil classification, land evaluation, and sustainable agricultural planning in the region (Interstate standard, 2019; Mustafayev et. al., 2025; Sadigov et. al., 2026a).

Materials and Methods

This study analyzes and synthesizes the results of long-term soil investigations conducted in the Gazakh-Tovuz economic region Shamkir administrative district since 2020. The research was conducted using large-scale topographic maps, geographic information system (GIS) software, and biogeographic route survey methods. Soil investigations were based on the soil–geographic comparative approach and morphological diagnostics carried out in accordance with FAO guidelines. Soil profile descriptions and horizon identification were performed following the international soil classification system of the World Reference Base for Soil Resources (WRB). Laboratory analyses were conducted using generally accepted and standardized soil analysis methods. The research focused on mountain gray-brown soils, which were correlated with the World Reference Base for Soil Resources (WRB) classification system. Based on this correlation, a digital soil map was compiled using the ArcGIS software package (Jabroil et al., 2013).

During field investigations, soil horizons were identified and indexed according to genetic principles, and their characteristics were harmonized with WRB diagnostic criteria and the national land classification parameters of Azerbaijan. The main objective of the study was to assess the current condition of mountain gray-brown soils formed within the Gazakh–Tovuz economic region through field surveys, determination of diagnostic indicators, and morphogenetic evaluation (State Standard of the Republic of Azerbaijan, Soil Quality, 2013).

Mountain gray-brown soil occupies an area of 10,522.55 hectares within the Gazakh-Tovuz economic region. The present research examined soil plots located in adjacent areas along predetermined survey routes during the period 2020-2025. Soil sections were established using modern georeferencing techniques, and their geographic coordinates were determined with a Garmin GPSMAP 62s device. In total, four representative soil profiles were described and analyzed. Soil horizons were differentiated within each profile, and key morphological features-including color, structure, hardness, and horizon thickness-were recorded. Granulometric composition was also determined as a major diagnostic parameter (Sleugh et al., 2020).

Laboratory analyses were performed at the Ecology laboratory at the Azerbaijan State University of Economics using standardized methods. Soil humus content was determined by the Dry Combustion method following ISO 10694. Total nitrogen concentration was measured using the Dumas combustion technique. Available phosphorus was quantified using the Olsen or Bray extraction methods, as appropriate for the soil conditions. The granulometric composition of the soil was determined by laser diffraction particle-size analysis. Hygroscopic moisture content was assessed using automated thermogravimetric analyzers (TGA). Soil pH was measured potentiometrically in soil-water and soil-KCl suspensions using a digital pH meter in accordance with ISO 10390 (Figure 1) (Nelson and Sommers, 1996; Houba et al., 2000; Eshel et al., 2004; International Organization for Standardization, 1998; 2012; 2019; 2021).

Results and Discussion

The granulometric composition of soils is regarded as one of their principal genetic characteristics, exerting a significant influence on both physical and chemical soil properties. Along with texture, humus content and other biogenic elements constitute the basis of key morphological and diagnostic features of soils. In the present study, a comparative analysis of diagnostic indicators was conducted for all soil sections established within the study area, taking into account differences in erosion intensity. On this basis, the investigated soil profiles were evaluated accordingly (Khalilov et al., 2023; Huseynov et al., 2026).

Soil section No. 12 was established within an area occupied by mountain brown soils, with the primary objective of conducting a comparative assessment of their diagnostic indicators relative to those of mountain gray-brown soils. The results of physicochemical analyses of the non-eroded soil profile (Table 1) indicate that the soils are characterized by a heavy clay texture in the upper 0–16 cm layer, where the clay content reaches 76%. Throughout the profile, the proportion of physical clay particles (<0.01 mm) ranges from 71.60% to 72.0% in the middle and lower horizons, confirming the heavy clayey nature of the soil. The content of fine silt (<0.001 mm) varies from 32.00% in the surface horizon to 31.60-38.40% in the deeper layers. Soil bulk density averages 1.25 ± 0.12 g/cm³ (Gumbatov et. al., 2024; Sadigov et al., 2026b).

Hygroscopic moisture content within the soil profile ranges from 6.95% to 7.19%. The thickness of the cultivated layer is 40–45 cm, while the sowing layer extends to a depth of 25–30 cm. The humus horizon is dark brown in color, with a humus content of 2.71% in the surface 0–16 cm layer, which is assessed as sufficient. A pronounced decrease in humus content is observed with increasing depth. In the middle horizons (44-73 cm), humus content decreases to 1.64%, corresponding to low humus status, while in the parent material at depths of 73–91 cm, it declines further to 0.77%, which is classified as very low. This vertical distribution of humus is characteristic and reflects typical pedogenetic processes (Haynes and Naidu, 1998).

The carbon-to-nitrogen (C:N) ratio remains relatively low, ranging from 9.6 to 9.0, indicating that soil organic matter is comparatively well supplied with nitrogen. Soil reaction throughout the profile is neutral, with pH values ranging from 7.12 to 7.40. The carbonate ($CaCO_3$) content in the surface horizon (0-16 cm) is 16.06%, decreasing slightly to 15.22% in the middle horizons (44-73 cm) and further to 13.36% in the parent material. Overall, the soils are classified as carbonated (Table 2) (Ayubov et. al., 2025; Mirzezadeh et al., 2025).

The total amount of absorbed bases in the soil adsorption complex exhibited moderate variability along the soil profile. In the upper 0–16 cm horizon, the content of absorbed bases was 28.80 mmol eq·100/g soil, increasing to 31.0 mmol eq·100/g soil in the middle 39-57 cm layer, and further rising slightly to 33.7 mmol eq·100/g soil in the lower 101-137 cm horizon. Overall, the soil adsorption capacity was evaluated as moderate. Based on the composition of exchangeable cations, the studied soils were classified as calcium–magnesium type.

Calcium (Ca) was the dominant cation within the adsorption complex throughout the profile. Its content amounted to 24.1 mmol eq·100/g soil (83.68%) in the upper horizon, 26.8 mmol eq·100/g soil (86.45%) in the middle layer, and 25.9 mmol eq·100/g soil (76.85%) in the lower horizon. In contrast, magnesium (Mg) contents were considerably lower, reaching 4.7, 4.2, and 7.8 mmol eq·100/g soil in the upper, middle, and lower horizons, respectively, corresponding to 16.32%, 13.55%, and 23.15% of the total absorbed bases (Table 2).

Consistent with the vertical distribution of humus, total nitrogen content showed a distinct decreasing trend with increasing depth. The highest total nitrogen concentration (0.21 %) was recorded in the upper 0–16 cm layer, declining to 0.168% in the middle part of the profile and to 0.048% in the parent material. Overall, the distribution pattern of nutrients in mountain gray-brown soils indicates a gradual reduction in nutrient availability with depth.

In non-eroded soils of this type, ammonium nitrogen (NH_4^+- N) content was relatively high in the surface horizon (0–16 cm), reaching 121.16 mg/kg, and decreased to 86.45 mg/kg in the middle 39–57 cm layer and 64.37 mg/kg in the lower 101-137 cm horizon. In comparison, the content of mobile phosphorus (P_2O_5) was markedly lower, amounting to 24.44 m/kg in the upper layer, 15.55 mg/kg in the middle layer, and 7.77 mg/kg in the parent material. Exchangeable potassium (K_2O), however, was present in relatively high concentrations, with values of 398.44 mg/kg in the upper horizon, 241.18 mg/kg in the middle horizon, and 126.52 mg/kg in the lower horizon (Table 2).

The diagnostic indicators of soil section No. 19, established on mountain gray-brown soils not subjected to erosion, were analyzed along the soil profile (Tables 1 and 2). The granulometric composition indicates that the upper 0-11 cm horizon is medium-textured clay soil, with a clay fraction of 69.0%. The proportion of physical clay (<0.01 mm) gradually increases toward the middle and lower horizons, reaching 75.40% in the 28-56 cm layer and 85.20% in the lower 82-105 cm layer, classifying these horizons as heavy clayey soils. The physical silt fraction (<0.001 mm) varies from 30.20% in the surface layer to 34.00-40.40% in the deeper layers. Soil bulk density averages 1.25±0.12 g/cm^3, and hygroscopic moisture content ranges between 5.45% and 6.69%. The cultivated layer has a thickness of 30-35 cm, while the sowing layer extends to 25-30 cm.

The humus layer exhibits a gray-brown color, with humus content of 1.86% in the upper horizon, assessed as low. Humus content decreases progressively with depth, reaching 1.45% in the middle horizon (28-56 cm) and 0.98% in the lower 82-105 cm layer, which is classified as very low. The C:N ratio ranges from 9.6 to 10.1. Soil reaction increases from weakly alkaline to moderately alkaline along the profile, with pH values ranging from 7.64 to 8.69. Carbonate content ($CaCO_3$) shows minimal variation along the profile, ranging from 14.16% to 17.75%, and the soils are thus classified as carbonate (Sadigov et al., 2026 c).

The total content of absorbed bases in the soil adsorption complex varies along the profile, being 25.60 mmol eq·100 g soil in the upper horizon, increasing slightly to 26.1 mmol eq·100 g in the middle horizon, and decreasing to 22.9 mmol eq·100 g in the lower horizon, corresponding to a sufficient absorption capacity. Calcium (Ca) is the dominant cation, with concentrations of 18.3 mmol eq·100 g in the surface horizon and 16.1 mmol eq·100 g in the lower horizon, representing 71.48% and 70.30% of total bases, respectively. Magnesium (Mg) contents are lower, ranging from 7.3 mmol eq·100 g in the surface layer to 6.8 mmol eq·100 g^{-1} in the lower horizon (28.52–29.70%).

The vertical distribution of total nitrogen follows the humus pattern, decreasing from 0.112% in the upper 0-11 cm layer to 0.084% in the middle horizon and 0.056% in the parent material. Ammonium nitrogen (NH_4^+–N) also declines with depth, from 51.34 mg/kg in the surface horizon to 42.09 mg/kg in the middle horizon and 26.38 mg/kg in the lower layer. Mobile phosphorus (P_2O_5) is relatively low, with values of 11.11 mg/kg in the upper layer, 7.77 mg/kg in the middle horizon, and 4.44 mg/kg in the parent rock. In contrast, exchangeable potassium (K_2O) is high compared to other nutrients, amounting to 409.16 mg/kg in the surface layer, 351.49 mg/kg in the middle horizon, and 283.45 mg/kg in the lower horizon (Table 2).

The physical and chemical characteristics of soil section No. 25, established on uneroded mountain gray-brown soils in the Seyfali village area, were analyzed along the soil profile. Based on the granulometric composition, the upper 0-16 cm horizon is heavy clayey, with a clay fraction of 72.0%. In the middle part of the profile (33-92 cm), the clay content (<0.01 mm) increases to 78.40%, while in the lower 92-108 cm horizon, it decreases to 68.80%, corresponding to a medium-textured clay soil. The silt fraction (<0.001 mm) varies from 33.20% in the surface layer to 40.80-44.00% in the lower horizons. Hygroscopic moisture in the soil profile ranges from 4.82% to 5.93% (Mammadova et al., 2025; Sadigov et al., 2025).

Humus content in the upper 0-16 cm horizon is 2.59%, classified as sufficient, and decreases progressively with depth to 1.24% in the 33-92 cm layer (low humus) and 0.87% in the 92-108 cm horizon (very low humus), a typical pattern in these soils. Soil reaction along the profile is alkaline, with pH values ranging from 8.14 to 8.69. Carbonate content ($CaCO_3$) is relatively uniform, ranging from 11.61% in the surface layer to 11.81–10.97% in the lower horizons, indicating carbonated soils.

The total amount of absorbed bases in the soil adsorption complex varies along the profile. In the upper horizon, it is 22.90 mmol eq·100 g soil (sufficient), increasing to 50.8 mmol eq·100 g in the middle layer, and 44.1 mmol eq·100 g in the lower layer, classified as high. According to the cation composition, these soils are calcium–magnesium type. Calcium predominates, with concentrations of 16.1 mmol eq·100 g in the upper layer, 40.7 mmol eq·100 g in the middle horizon, and 30.4 mmol eq·100 g in the parent rock, accounting for 70.31%, 80.11%, and 64.96% of the total absorbed bases, respectively. Magnesium contents are also relatively high, ranging from 8.3 mmol eq·100 g in the surface horizon to 17.2 mmol eq·100 g in the 92-108 cm horizon, and 16.4 mmol eq·100 g below 108 cm, corresponding to 38.42%, 39.0%, and 35.04% of the total bases. The C:N ratio ranges from 9.7 to 11.8, indicating that humus is relatively well supplied with nitrogen.

Total nitrogen follows a decreasing trend with depth, ranging from 0.154% in the surface layer to 0.070% in the middle horizon and 0.048% in the parent rock. Similarly, ammonium nitrogen (NH_4^+-N) decreases from 23.34 mg/kg in the upper horizon to 16.49 mg/kg in the middle layer and 9.50 mg/kg in the lower horizon. Mobile phosphorus (P_2O_5) is relatively low, with values of 14.44 mg/kg in the surface horizon, 12.20 mg/kg in the middle horizon, and 8.90 mg/kg in the parent rock. Exchangeable potassium (K_2O) is relatively high compared to other nutrients, with concentrations of 410.15 mg/kg in the upper layer, 325.29 mg/kg in the middle layer, and 187.23 mg/kg in the lower horizon (Table 2).

The diagnostic indicators of soil section No. 98, established on uneroded mountain gray-brown soils, were analyzed along the soil profile. Based on granulometric composition, the upper 0–18 cm horizon is heavy clayey, with 74.0% clay content (<0.01 mm). In the middle 41–63 cm layer, clay content increases to 78.80%, and in the lower 87–110 cm horizon it reaches 83.60%, confirming the heavy clayey texture of these soils. The silt fraction (<0.001 mm) varies from 34.00% in the surface layer to 37.20% in the middle horizon and 38.80% in the parent rock. Hygroscopic moisture content in the upper horizon is 5.23%, and varies between 5.03% and 6.72% in the deeper layers.

The humus layer is gray-brown, with 2.64% humus in the upper 0–18 cm horizon, assessed as sufficient. Humus content decreases sharply with depth, reaching 0.67% in the middle 41–63 cm horizon (very low) and 0.41% in the 87–110 cm horizon (almost negligible). Soil reaction is moderately alkaline, with pH values ranging from 8.25 to 8.63 along the profile. The C:N ratio varies from 8.1 to 17.4 in the middle and lower horizons, indicating relatively high nitrogen availability in the organic matter. Carbonate content ($CaCO_3$) is relatively uniform, ranging from 15.41% to 16.68%, classifying these soils as carbonated.

The total amount of absorbed bases in the soil adsorption complex is 27.40 mmol eq·100 g in the upper horizon (sufficient), decreases to 18.4 mmol eq·100 g in the middle horizon, and rises again to 21.6 mmol eq·100 g in the lower horizon, assessed overall as sufficient. Calcium predominates, with values of 16.9 mmol eq·100 g in the upper horizon, decreasing slightly to 13.7 mmol eq·100 g in the parent rock, accounting for 61.67% and 63.42% of the total absorbed bases, respectively. Magnesium shows higher values in the upper horizon (10.5 mmol eq·100 g), decreases to 3.7 mmol eq·100 g in the middle layer, and increases to 7.9 mmol eq·100 g in the parent rock, corresponding to 38.33% and 36.58% of the total bases.

Total nitrogen decreases along the profile from 0.164% in the surface layer to 0.048% in the middle horizon and 0.014% in the parent rock, consistent with the distribution of humus. Ammonium nitrogen (NH_4^+-N) decreases from 19.37 mg/kg in the upper horizon to 14.52 mg/kg in the middle horizon and 6.21 mg/kg in the lower horizon. Mobile phosphorus (P_2O_5) is low, ranging from 10.00 mg/kg in the upper layer to 7.77 mg/kg in the middle horizon and 5.60 mg/kg in the parent rock. Exchangeable potassium (K_2O) is relatively high compared to other nutrients, with concentrations of 241.56 mg/kg in the surface horizon, 165.12 mg/kg in the middle layer, and 106.42 mg/kg in the lower horizon (Tables 2 and 3).

The morphogenetic characteristics of mountain gray-brown soils in the Shamkir region were assessed considering natural climatic conditions and anthropogenic influences, with classification harmonized according to the international WRB system. Four representative uneroded and anthropogenically influenced soil sections (Soil sections: 12, 19, 25, and 98) were analyzed.

Section 12 - Shamkir, Tazakend village
Classified as Someric Calcic Kastanozems (Clayic, Humic), this soil exhibits a mollic layer (<20 cm) with high humus content in the upper 0-6 cm (3.52%) and 6-39 cm (3.31%). The humus layer is dark brown, granular, or nut-grained. Carbonate content ($CaCO_3$) ranges between 14.36-17.52%. The granulometric composition is silty clay, with particle-size fractions of <0.001 mm (28.00-42.00%), <0.01 mm (72.00-86.00%), and 0.005-0.001 mm (26.80-36.40%). The upper layers are rich in humic substances, reflecting a well-developed mollic horizon.

Section 19 - Shamkir, Sabirkand village
This section corresponds to Calcic Kastanozems (Clayic). The carbonate content varies between 14.16-17.75%. The granulometric composition is silty clay, with <0.001 mm fraction ranging from 33.20-40.40%, <0.01 mm from 74.80-88.40%, and 0.005-0.001 mm from 29.60-36.80%. The soil demonstrates typical characteristics of uneroded mountain gray-brown soils, with a moderately developed humus layer.

Section 25 - Shamkir, Seyfali village
Classified as Calcic Kastanozems (Clayic, Humic), this soil has a carbonate content of 10.97-11.81%. The granulometric composition is silty clay loam, with <0.001 mm fraction of 33.20-44.00%, <0.01 mm fraction of 68.80-76.40%, and 0.005-0.001 mm fraction of 22.00-27.20%. Humus content is high in the upper layers, reflecting good soil fertility and a well-preserved mollic horizon.

Section 98 - Shamkir, Seyidkand village
This section represents Terric Calcic Kastanozems (Anthric, Clayic, Humic). The carbonate content ranges from 15.41-16.68%. The soil exhibits Anthric properties due to long-term anthropogenic influence, including viticulture and grazing, which has impacted vegetation cover. The granulometric composition is silty clay, with <0.001 mm fraction of 28.80-39.60%, <0.01 mm fraction of 73.20-84.00%, and 0.005-0.001 mm fraction of 30.80-36.40%. The humic layer is relatively thick and nutrient-rich in the upper horizon, supported by anthropogenically improved forest strips.

Conclusion

The comprehensive study of mountain gray-brown soils in the Shamkir administrative region of the Gazakh-Tovuz economic region provides a detailed understanding of their morphogenetic, physical, and chemical characteristics. Field and laboratory analyses of four representative soil sections (Soil sections: 12, 19, 25, and 98) revealed that these soils are predominantly heavy clayey to medium-textured clay soil, with a significant proportion of fine clay and silt particles, which strongly influence their physical and chemical properties.

The morphogenetic diagnostics indicate that the studied mountain gray-brown soils are predominantly clayic and humus-rich in the upper horizons, with variation in carbonate content and anthropogenic influence reflecting local land use practices. These observations provide a robust framework for soil classification, land evaluation, and sustainable management in the Gazakh-Tovuz economic region.

Integration of granulometric, chemical, and morphogenetic analyses, together with geospatial mapping, provides a solid foundation for soil classification, land evaluation, and sustainable agricultural planning in the Gazakh–Tovuz region. The results highlight the potential of mountain gray-brown soils for productive agriculture while emphasizing the need for careful management of nutrients and erosion control to preserve soil fertility.

Table 1
Granulometric composition of uneroded mountain gray-brown soils, in %

№ of soil sections	Location	Genetic layers and depth, Cm		Particle diameter, mm						
				1-0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	<0,01
1	2	3		4	5	6	7	8	9	10
12	Shamkir Tazakend village	AUvz	0-16	1.19	6.81	16.00	13.40	30.60	32.00	76.00
		AYvz	16-39	3.19	8.41	16.20	15.00	27.20	30.00	72.20
		Bvp	39-57	3.91	6.69	17.80	14.00	26.00	31.60	71.60
		B/Cca	57-101	3.00	4.80	19.20	13.60	31.40	28.00	73.00
		Cca	101-137	4.79	2.81	20.40	6.80	26.80	38.40	72.00
19	Shamkir Sabirkand village	AYvaz	0-11	3.30	9.70	18.00	13.00	25.80	30.20	69.00
		AYaz	11-28	2.60	7.40	17.20	12.20	28.40	32.20	72.80
		Bca	28-56	2.50	7.50	14.30	13.80	27.60	34.00	75.40
		B/Ccap	56-82	0.61	2.59	11.60	10.80	34.40	40.00	85.20
		Cca	82-105	0.37	0.43	10.80	11.20	36.80	40.40	88.40
25	Shamkir Seyfali village	Ayvz	0-16	0.08	3.12	24.80	11.60	27.20	33.20	72.00
		A/Bv	16-33	0.14	1.86	26.00	10.80	25.20	36.00	72.00
		Bvca	33-92	0.77	0.43	20.40	10.40	27.20	40.80	78.40
		B/Ccap	92-108	2.05	3.55	25.60	2.40	22.80	43.60	68.80
		Cca	below 108	0.38	1.62	21.60	10.40	22.00	44.00	76.40
98	Shamkir Seyidkand village	AYvz	0-18	0.16	2.64	23.20	13.60	26.40	34.00	74.00
		A/Bcs	18-41	0.26	3.74	22.80	11.20	33.20	28.80	73.20
		Bca	41-63	0.27	1.73	19.20	9.20	32.40	37.20	78.80
		B/Cca	63-87	0.26	0.94	20.00	8.40	30.80	39.60	78.80
		Cca	87-110	0.17	1.03	15.20	11.60	33.20	38.80	83.60

Table 2
Indicators of humus and basic biogenic elements of uneroded mountain gray-brown soils

№ of soil sections	Location	Genetic layers and depth, cm		Hygroscopic moisture %	Humus %	C:N	$CaCO_3$ %	pH	Absorbed bases (in 100 g. soil), mmol.eq. Ca	Mg	Total absorbed bases, mmol.eq. per 100g soil
1	2	3		4	5	6	7	8	9	10	11
12	Shamkir Tazakend village	AUvz	0-16	6.35	3.52	9.7	17.11	7.10	24.1	4.7	28.8
		AYvz	16-39	6.14	3.31	9.8	16.68	7.35	24.6	7.3	31.9
		Bvp	39-57	6.57	2.74	9.4	17.32	7.40	26.8	4.2	31.0
		B/Cca	57-101	4.60	1.14	9.4	17.52	7.73	22.8	9.1	31.9
		Cca	101-137	6.67	0.77	9.3	14.36	8.20	25.9	7.8	33.7
19	Shamkir Sabirkand village	AYvaz	0-11	5.45	1.86	9.6	14.16	7.60	18.3	7.3	25.6
		AYaz	11-28	5.88	1.71	10.1	14.56	7.80	20.1	3.7	23.8
		Bca	28-56	6.47	1.45	10.0	14.16	8.10	18.7	7.4	26.1
		B/Ccap	56-82	6.09	1.08	8.9	17.75	8.64	15.5	9.7	25.2
		Cca	82-105	6.69	0.98	10.1	16.27	8.69	16.1	6.8	22.9
25	Shamkir Seyfali village	Ayvz	0-16	5.44	2.59	9.7	11.61	8.14	13.3	8.3	21.6
		A/Bv	16-33	5.04	1.71	10.1	10.97	8.26	25.1	10	36.2
		Bvca	33-92	5.71	1.24	10.3	11.61	8.65	40.7	10.1	50.8
		B/Ccap	92-108	4.82	1.14	11.8	11.81	8.69	26.9	17.2	44.1
		Cca	below	5.93	0.87	10.5	11.18	8.63	30.4	16.4	46.8
98	Shamkir Seyidkand village	AYvz	0-18	5.23	2.64	9.9	16.27	8.25	16.9	10.5	27.4
		A/Bcs	18-41	5.44	1.81	9.4	16.27	8.38	17.3	2.0	19.3
		Bca	41-63	5.03	0.67	8.1	15.41	8.57	14.7	3.7	18.4
		B/Cca	63-87	6.26	0.62	12.8	15.84	8.63	17.4	6.9	24.3
		Cca	87-110	6.72	0.41	17.4	16.68	8.47	13.7	7.9	21.6

Table 3
Assessment of mountain gray-brown soils according to diagnostic indicators (0-25 cm) (according to R.H. Mammadov)

Indicators	Assessment: Uneroded	Weakly eroded	Moderately eroded
Granulometric composition, <0.01mm, %	74.00 heavy clay	67.60 Medium-textured clay	60.40 Medium-textured clay
Carbonate CaCO3, %	16.27 carbonated	15.21 carbonated	13.95 carbonated
Humus, %	2.64 Enough	1.94 Low humus	1.66 Low humus
pH (in water solution)	8.25 Medium alkaline	8.15 Medium alkaline	7.45 Low alkaline
Total absorbed bases, mmol.eq.	27.4 Enough	24.3 Enough	24.6 Enough
Total Ca	16.9 Medium calcium	16.0 Medium calcium	17.3 Medium calcium
Mg	10.5 Low magnesium	8.3 Low magnesium	7.9 Low magnesium

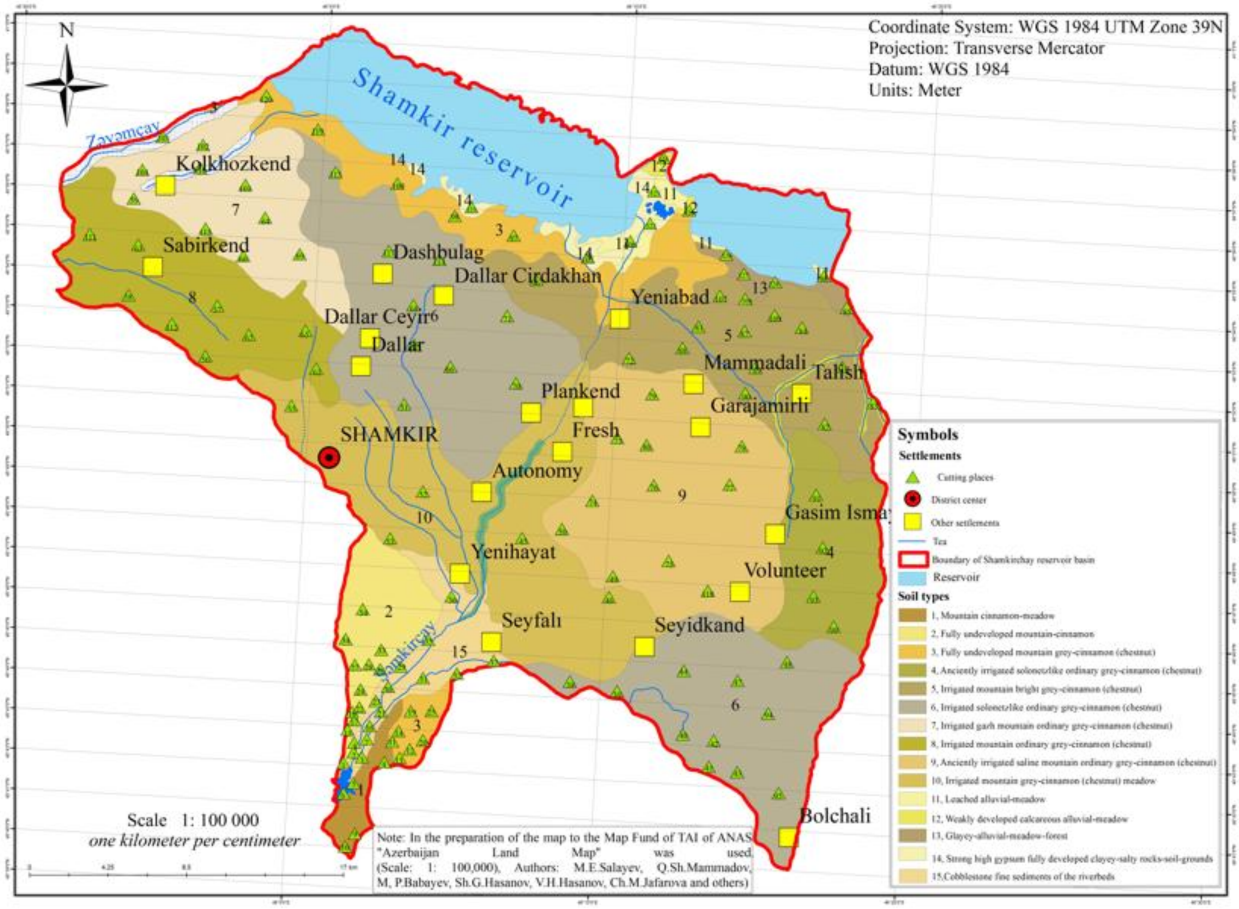

Figure 1
Land map of Shamkir district

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