

ASSESSMENT OF THE MORPHOGENETIC CHARACTERISTICS OF MOUNTAIN FOREST BROWN SOILS IN THE LANKARAN–ASTARA REGION

ОЦЕНКА МОРФОГЕНЕТИЧЕСКИХ ХАРАКТЕРИСТИК ГОРНО-ЛЕСНЫХ ПОЧВ В ЛЕНКОРАНЬ-АСТАРСКОЙ ОБЛАСТИ

AHADOV TURAL (ORCID.ORG/0009-0001-6277-7136)

Institute of Geography of the Ministry of Science and Education of the Republic of Azerbaijan,
Baku, Azerbaijan

(Поступила в редакцию 15.06.2026)

This study investigates the morphogenetic characteristics of mountain forest brown soils in the Lankaran–Astara region of Azerbaijan. Soil samples were collected from 12 soil profiles established at three representative sites in the Lerik District, located at elevations ranging from 880 to 1,650 m above sea level. The primary objective of the research was to evaluate the morphological, physical, and chemical properties of mountain forest brown soils and to assess their fertility potential. Detailed field investigations included morphological descriptions of soil profiles, comprising horizon thickness, color, structure, texture, root abundance, pedogenic features, and the characteristics of horizon boundaries. Laboratory analyses were performed to determine particle-size distribution, humus content, total nitrogen, soil reaction (pH), and exchangeable calcium (Ca^{2+}) and magnesium (Mg^{2+}). The particle-size distribution was determined using the pipette method, humus content by the Tyurin method, total nitrogen by the Kjeldahl method, soil pH by the potentiometric method, and exchangeable bases by the Kappen method. The results demonstrated considerable spatial variability in the physicochemical properties of the investigated soils. The Vizamin site exhibited the highest humus content (4.06 %) and the greatest sum of exchangeable bases (41.4 mmol(eq)/100 g), indicating a relatively high nutrient retention capacity and fertility status. In contrast, the soils of the Çayrud site contained the lowest humus content (2.82 %) and were characterized by a moderate fertility level. The Siyov site was distinguished by a relatively high humus content (4.12 %) and the highest C ratio (8.2), reflecting favorable conditions for organic matter accumulation and transformation. Particle-size analysis revealed clear differences in soil texture among the study sites. The soils were classified as heavy clay at Vizamin, clay at Çayrud, and sandy clay loam at Siyov, indicating the influence of local environmental conditions and parent materials on soil formation processes. The soil quality (bonitation) assessment indicated that the Vizamin soils possess a high fertility potential, whereas the Çayrud soils exhibit moderate fertility and the Siyov soils comparatively lower fertility. Overall, the findings provide valuable information on the morphogenetic properties and fertility status of mountain forest brown soils in the Lankaran–Astara region and contribute to a better understanding of their ecological condition. The results may serve as a scientific basis for the sustainable management, conservation, and rational utilization of these soils under changing environmental conditions.

Key words: mountain forest brown soils; Lankaran–Astara region; morphogenetic characteristics; soil morphology.

В данном исследовании изучаются морфогенетические характеристики горных лесных бурых почв в Ленкорань-Астарской области Азербайджана. Образцы почвы были отобраны из 12 почвенных профилей, заложенных на трех репрезентативных участках в Лерикском районе, расположенных на высотах от 880 до 1650 м над уровнем моря. Основная цель исследования заключалась в оценке морфологических, физических и химических свойств горных лесных бурых почв и оценке их плодородного потенциала. Детальные полевые исследования включали морфологическое описание почвенных профилей, в том числе толщину горизонтов, цвет, структуру, текстуру, количество корней, педогенные особенности и характеристики границ горизонтов. В лабораторных условиях были проведены анализы для определения гранулометрического состава, содержания гумуса, общего азота, реакции почвы (pH), а также обменного кальция (Ca^{2+}) и магния (Mg^{2+}). Гранулометрический состав определяли пипеточным методом, содержание гумуса – методом Тюринга, общее содержание азота – методом Кельдаля, pH почвы – потенциометрическим методом, а обменные основания – методом Каппена. Результаты показали значительную пространственную изменчивость физико-химических свойств исследованных почв. На участке Визамин было отмечено самое высокое содержание гумуса (4,06 %) и наибольшая сумма обменных оснований (41,4 ммоль(экв)/100 г), что указывает на относительно высокую способность к удержанию питательных веществ и плодородию. В отличие от этого, почвы участка Чайруд содержали самое низкое содержание гумуса (2,82 %) и характеризовались умеренным уровнем плодородия. Участок Сийов отличался относительно высоким содержанием гумуса (4,12 %) и самым высоким коэффициентом C (8,2), что отражает благоприятные условия для накопления и трансформации органического вещества. Гранулометрический анализ выявил явные различия в текстуре почвы между исследуемыми участками. Почвы были классифицированы как тяжелая глина в Визамине, глина в Чайруде и песчано-глинистый суглинок в Сийове, что указывает на влияние местных условий окружающей среды и материнских пород на процессы почвообразования. Оценка качества почвы (бонитизация) показала, что почвы Визамина обладают высоким потенциалом плодородия, тогда как почвы Чайруда демонстрируют умеренное плодородие, а почвы Сийова – сравнительно более низкое. В целом, полученные результаты предоставляют ценную информацию о морфогенетических свойствах и состоянии плодородия бурых почв горных лесов в регионе Ленкорань-Астара и способствуют лучшему пониманию их экологического состояния. Результаты могут служить научной основой для устойчивого управления, сохранения и рационального использования этих почв в условиях меняющейся окружающей среды.

Ключевые слова: бурые почвы горных лесов; Ленкорань-Астарский регион; морфогенетические характеристики.

Introduction

The Lankaran–Astara region, located in the southeastern part of Azerbaijan, is distinguished by its unique natural environment, humid subtropical climate, rich vegetation cover, and diverse soil resources. One of the most widespread soil types in the region is mountain forest brown soil, which has developed under the relict Hyrcanian forests dominated by endemic and relict tree species such as Persian ironwood (*Parrotia persica*),

chestnut-leaved oak (*Quercus castaneifolia*), Caucasian alder (*Alnus subcordata*), European hornbeam (*Carpinus betulus*), and other characteristic forest species [2, 10].

Mountain forest brown soils are predominantly distributed within the foothill and middle mountain zones of the region, at elevations ranging from approximately 200 to 1,200 m above sea level. These soils have formed under humid climatic conditions on both calcareous and non-calcareous parent materials beneath forest litter. Their morphological profiles are characterized by the accumulation of humus, the development of moderately expressed eluviation–illuviation processes, and the formation of a distinctive brown-colored diagnostic horizon [4, 13].

During recent decades, increasing anthropogenic pressures—including deforestation, fuelwood collection, livestock grazing, tourism infrastructure development, and illegal logging—have significantly accelerated soil degradation processes throughout the region. These disturbances have intensified soil erosion, reduced soil fertility, and negatively affected the ecological stability of forest ecosystems [1, 5]. In particular, enhanced surface runoff on sloping terrain promotes the removal of fertile topsoil, decreases humus reserves, and alters the natural structure of soil profiles. Consequently, these processes pose a substantial threat to regional biodiversity and ecosystem sustainability.

Soil morphological characteristics are widely recognized as reliable indicators of soil genesis, pedogenic evolution, ecological status, and fertility potential. Morphogenetic investigations are based on the analysis of soil profile architecture, horizon morphology, pedogenic features, horizon boundaries, and other field characteristics that collectively reflect soil-forming processes. Such investigations are particularly valuable in mountainous environments, where comprehensive laboratory analyses may be difficult to perform, providing an efficient basis for rapid soil assessment and classification [8].

Despite the ecological importance of the Lankaran–Astara region, comprehensive investigations of the morphogenetic characteristics of its mountain forest brown soils remain limited. Although the soils of the region have been described in general pedological studies, relatively few studies have focused on integrated soil quality (bonitation) assessment based on morphogenetic criteria [2, 10, 12].

The objective of the present study was to characterize the morphogenetic properties of mountain forest brown soils in the Lankaran–Astara region, to analyze their principal morphological features, and to evaluate their soil quality and fertility potential based on morphological indicators.

Materials and Methods

Mountain forest brown soils are widely distributed within the middle-mountain (880–1,150 m a.s.l.) and upper-mountain (1,250–1,650 m a.s.l.) altitudinal belts of the Lerik District, located in the Lankaran–Astara economic region of Azerbaijan. In the present study, these soils were investigated using samples collected from 12 soil profiles established at three representative sites: **Vizazamin**, **Çayrud**, and **Siyov**.

A large-scale soil survey (1:20,000) was conducted using the relief plasticity method. To characterize the spatial variability of the soil cover, complete soil profiles with a depth of up to 1.5 m were excavated on slopes with different aspects. Soil samples were collected from each genetic horizon, while detailed field descriptions were recorded, including horizon thickness, color (according to the Munsell Soil Color Charts), particle-size composition, pedogenic features, soil structure, field consistency, soil moisture status, and the intensity of effervescence with 10 % HCl. The geographical coordinates of all sampling sites were recorded using a Global Positioning System (GPS).

The geographical coordinates of the investigated soil profiles were as follows:

- **K-4:** 48°31'32" E, 38°46'33" N
- **K-8:** 48°36'43.3" E, 38°40'40.8" N
- **K-9:** 48°29'22.1" E, 38°42'44.2" N

Morphological descriptions of the soil profiles were carried out following the classical methodology of V. V. Dokuchaev, subsequently refined by B. G. Rozanov [3, 13]. For each profile, the thickness, color, structure, texture, root abundance, pedogenic features, characteristics of horizon boundaries, degree of erosion, and properties of the parent material were systematically documented. Schematic drawings of each soil profile were prepared, and photographic documentation was obtained to support the field descriptions.

Following the field survey, soil samples (1.0–1.5 kg) were collected from each genetic horizon. The samples were placed in polyethylene bags, labeled according to profile number, horizon designation, and sampling depth, and transported to the laboratory. Prior to analysis, the samples were air-dried at room temperature and sieved through a 2-mm mesh.

Comprehensive physicochemical analyses were performed on the collected soil samples. Particle-size distribution was determined using the pipette method. Soil organic matter (humus) content was determined by the Tyurin wet oxidation method using potassium dichromate. Total nitrogen was measured by the Kjeldahl method [7]. Soil pH was determined potentiometrically in a soil-to-water suspension (1:2.5) using a calibrated pH meter. Exchangeable calcium (Ca^{2+}) and magnesium (Mg^{2+}) were determined using the Kappen method

with NH_4Cl extraction [6]. Calcium was quantified by complexometric titration using murexide as the indicator, whereas magnesium was determined by complexometric titration with Eriochrome Black T. The concentrations of exchangeable cations were expressed as **cmol(+)/kg** (equivalent to **meq/100 g soil**).

Conclusion

Mountain forest brown soils are formed under two distinct climatic belts: the moderately warm and humid middle-mountain zone and the cold, relatively dry upper-mountain zone. These soils develop predominantly under beech (*Fagus orientalis*) forests and are regarded as one of the most naturally fertile soil groups in the region. Within the study area, the mean annual air temperature ranges from 6 to 12 °C, while annual precipitation varies between 1,200 and 1,800 mm. With increasing elevation, air temperature decreases at an average lapse rate of approximately 0.5–0.6 °C per 100 m. In contrast, precipitation reaches its maximum (1,600–1,800 mm) within the middle-mountain belt before declining to approximately 1,200–1,400 mm in the upper-mountain zone.

The assessment of the morphological and physicochemical properties of soils plays a fundamental role in determining their ecological condition. The formation of mountain forest brown soils is governed by the complex interactions among climate, topography, parent material, and vegetation, resulting in characteristic pedogenic processes and distinct ecological patterns. Understanding these relationships provides a scientific basis for evaluating soil fertility potential, promoting sustainable land use, and developing effective soil conservation and management strategies.

Physicochemical Properties of the Studied Mountain Forest Brown Soil Profiles in the Lankaran–Astara Region

Genetic horizon and depth (cm)	Hygroscopic moisture	Humus, %	Total nitrogen (%)	C:N	pH (H_2O)	Bulk density (g cm^{-3})	Exchangeable Ca^{2+} (cmol(+)/kg)	Exchangeable Mg^{2+} (cmol(+)/kg)
Profile No. 4 – Vizazamin: Weakly Developed Mountain Forest Brown Soil								
0-25	4,38	4,06	0,33	7,7	6,17	1,13	26,3	11,2
125-48	5,69	3,45	0,19	7,5	5,86	1,27	23,5	12,2
48-62	5,48	1,38	0,12	6,6	5,83	1,32	27,8	13,1
62-85	5,32	1,02	0,10	5,9	6,04	1,34	28,9	12,5
85-104	4,18	0,88	0,09	5,7	6,12	1,41	25,3	11,5
Profile No. 9 – Çayrud: Meadowized Mountain Forest Brown Soil								
0-24	4,36	2,82	0,21	7,8	6,35	1,20	16,8	9,81
24-53	4,45	2,36	0,18	7,6	6,33	1,28	17,87	8,32
53-90	4,22	1,16	0,11	6,1	6,37	1,33	18,3	9,64
90-145	4,18	0,72	0,08	5,3	6,73	1,38	19,9	6,57
145-172	4,23	0,52	0,07	4,3	6,68	1,42	19,8	6,21
Profile No. 8 – Siyov: Loessified Mountain Forest Brown Soil								
0-17	4,84	4,12	0,29	8,2	6,22	1,18	23,32	10,07
17-29	4,57	2,21	0,27	7,5	6,51	1,28	19,62	9,50
29-79	4,47	1,92	0,19	5,9	6,70	1,36	17,12	15,23
79-100	3,05	1,31	0,07	7,7	6,27	1,48	–	–

The Vizazamin soil profile was distinguished as one of the profiles with the highest humus content within the study area. The soil profile was divided into several genetic horizons according to depth. In the 0–25 cm horizon, the humus content was 4.06 %, which is considered a high value for forest soils. The total nitrogen content was 0.33 %, and the C ratio was 7.7. This ratio indicates moderate mineralization of organic matter and the presence of nitrogen in forms available for plant uptake. The soil pH was 6.17, reflecting a slightly acidic reaction. Such a pH level is considered optimal for most forest vegetation because it provides favorable conditions for nutrient availability and plant absorption. The bulk density was 1.13 g cm^{-3} , indicating a loose, well-aerated surface horizon favorable for root development. The sum of exchangeable bases was 37.5 cmol(+)/kg, including 26.3 cmol(+)/kg Ca^{2+} and 11.2 cmol(+)/kg Mg^{2+} . The higher proportion of calcium compared with magnesium indicates that the soil exchange complex is rich in base cations and possesses relatively high fertility potential. Hygroscopic moisture content was 4.38 %, indicating a normal soil water retention capacity.

In the 25–48 cm horizon, the humus content decreased to 3.45 %. This reduction is associated with the gradual decline of organic matter accumulation with increasing depth. The total nitrogen content was 0.19 %, while the C ratio was 7.5. The pH value decreased to 5.86, indicating a slightly acidic soil reaction. The lower pH value may be related to the influence of organic acids formed during the decomposition of organic matter. The bulk density increased to 1.27 g cm^{-3} , while the sum of exchangeable bases reached 35.7 cmol (+)/kg (Ca^{2+} – 23.5 cmol(+)/kg; Mg^{2+} – 12.2 cmol(+)/kg). The increase in bulk density reflects gradual soil compaction in deeper horizons as a result of natural pedogenic processes. Hygroscopic moisture was 5.69 %.

In the 48–62 cm horizon, the humus content significantly decreased to 1.38 %, indicating weaker accumulation of organic matter in this layer. The total nitrogen content was 0.12 %, and the C ratio was 6.6. The soil pH was 5.83, while bulk density reached 1.32 g cm^{-3} . The sum of exchangeable bases increased to 40.9 cmol(+)/kg, due to increases

in both Ca^{2+} (27.8 cmol(+)/kg) and Mg^{2+} (13.1 cmol(+)/kg). The higher content of exchangeable bases in this horizon indicates its important role in nutrient retention and accumulation processes. Hygroscopic moisture was 5.48 %.

In the 62–85 cm horizon, the humus content decreased further to 1.02 %, and total nitrogen declined to 0.10 %. The C ratio was 5.9, soil pH was 6.04, and bulk density reached 1.34 g cm^{-3} . The sum of exchangeable bases showed the highest value within the entire profile (41.4 cmol(+)/kg), including 28.9 cmol(+)/kg Ca^{2+} and 12.5 cmol(+)/kg Mg^{2+} . The high concentration of exchangeable bases indicates enrichment of this horizon with base cations and a relatively high fertility potential. Hygroscopic moisture content was 5.32 %.

In the deepest 85–104 cm horizon, the humus content was 0.88 %, total nitrogen 0.09 %, and C ratio 5.7. The soil pH was 6.12, while bulk density increased to 1.41 g cm^{-3} . The sum of exchangeable bases was 36.8 cmol(+)/kg, including 25.3 cmol(+)/kg Ca^{2+} and 11.5 cmol(+)/kg Mg^{2+} . The increase in bulk density indicates stronger compaction of this horizon and a potential reduction in water permeability. Hygroscopic moisture was 4.18 %.

The Cayrud soil profile represents a comparatively lower humus-containing soil profile compared with the Vizazamin profile. The soil profile was divided into five genetic horizons according to depth.

In the 0–24 cm horizon, the humus content was 2.82 %, total nitrogen was 0.21 %, and the C ratio was 7.8. The soil pH was 6.35, indicating a slightly acidic reaction. The bulk density was 1.20 g cm^{-3} . The sum of exchangeable bases was 26.61 cmol(+)/kg, including 16.8 cmol(+)/kg Ca^{2+} and 9.81 cmol(+)/kg Mg^{2+} . Hygroscopic moisture content was 4.36 %. The lower humus content in this horizon compared with the Vizazamin profile may be related to differences in vegetation composition, relief conditions, and possible anthropogenic influences. The pH value of 6.35 represents a favorable soil reaction for the growth of most plant species.

In the 24–53 cm horizon, the humus content decreased to 2.36 %, total nitrogen was 0.18 %, and the C ratio was 7.6. The pH value was 6.33, while bulk density increased to 1.28 g cm^{-3} . The sum of exchangeable bases was 26.19 cmol(+)/kg, including 17.87 cmol(+)/kg Ca^{2+} and 8.32 cmol(+)/kg Mg^{2+} . Hygroscopic moisture content was 4.45 %. The reduction in humus content compared with the upper horizon reflects the gradual decline of organic matter with depth, while the relatively stable pH value indicates a stable soil chemical environment.

In the 53–90 cm horizon, humus content decreased to 1.16 %, total nitrogen to 0.11 %, and the C ratio was 6.1. The soil pH was 6.37, and bulk density reached 1.33 g cm^{-3} . The sum of exchangeable bases increased slightly to 27.94 cmol(+)/kg, including 18.3 cmol(+)/kg Ca^{2+} and 9.64 cmol(+)/kg Mg^{2+} . Hygroscopic moisture content was 4.22 %. The slight increase in exchangeable bases in this horizon indicates the accumulation of nutrient elements in this layer.

In the 90–145 cm horizon, the humus content was 0.72 %, total nitrogen was 0.08 %, and the C ratio decreased to 5.3. The pH value increased to 6.73, indicating a nearly neutral soil reaction, which may be associated with the influence of carbonate-containing materials. Bulk density reached 1.38 g cm^{-3} . The sum of exchangeable bases was 26.47 cmol(+)/kg, including 19.9 cmol(+)/kg Ca^{2+} and 6.57 cmol(+)/kg Mg^{2+} . Hygroscopic moisture content was 4.18 %. The decrease in magnesium content in this horizon represents one of the notable characteristics of the profile.

In the deepest 145–172 cm horizon, the humus content decreased to 0.52 %, total nitrogen to 0.07 %, and the C ratio to 4.3. The soil pH was 6.68, and bulk density reached 1.42 g cm^{-3} . The sum of exchangeable bases was 26.01 cmol(+)/kg, including 19.8 cmol(+)/kg Ca^{2+} and 6.21 cmol(+)/kg Mg^{2+} . Hygroscopic moisture content was 4.23%. The reduction of humus content to 0.52 % and the increase in bulk density to 1.42 g cm^{-3} indicate progressive soil compaction toward the parent material.

The Siyov soil profile represents one of the profiles with a high humus content among the studied mountain forest brown soils. Particularly, the surface horizon is characterized by a high accumulation of organic matter, with a humus content of 4.12 %. The soil profile was divided into four genetic horizons according to depth.

In the 0–17 cm horizon, the humus content was 4.12 %, total nitrogen was 0.29 %, and the C ratio reached 8.2. The soil pH was 6.22, indicating a slightly acidic reaction. Bulk density was 1.18 g cm^{-3} , reflecting a loose and well-aerated upper horizon favorable for root development. The sum of exchangeable bases was 33.39 cmol(+)/kg, including 23.32 cmol(+)/kg Ca^{2+} and 10.07 cmol(+)/kg Mg^{2+} . Hygroscopic moisture content was 4.84 %. The C ratio of 8.2 was the highest value recorded among all studied profiles, indicating relatively slower decomposition of organic matter and a relatively fresh forest litter layer. The high humus content can be associated with dense forest vegetation and the continuous input of organic residues.

In the 17–29 cm horizon, the humus content decreased to 2.21 %, total nitrogen was 0.27 %, and the C ratio was 7.5. The soil pH increased to 6.51, while bulk density reached 1.28 g cm^{-3} . The sum of exchangeable bases was 29.12 cmol(+)/kg, including 19.62 cmol(+)/kg Ca^{2+} and 9.50 cmol(+)/kg Mg^{2+} . Hygroscopic moisture content was 4.57 %. The sharp decrease in humus content compared with the surface horizon indicates a reduction in organic matter accumulation with increasing depth.

In the 29–79 cm horizon, the humus content was 1.92 %, total nitrogen was 0.19 %, and the C ratio decreased to 5.9. The soil pH reached 6.70, approaching a neutral reaction. Bulk density increased to 1.36 g cm^{-3} . The sum of exchangeable bases was 32.35 cmol(+)/kg, consisting of 17.12 cmol(+)/kg Ca^{2+} and 15.23 cmol(+)/kg Mg^{2+} . Hygroscopic moisture content was 4.47%. A notable feature of this horizon is the

increased magnesium content (15.23 cmol(+)/kg), representing the highest Mg^{2+} value among all studied profiles. This feature may be associated with the magnesium-rich composition of the parent material.

In the deepest 79–100 cm horizon, the humus content was 1.31 %, total nitrogen was 0.07 %, and the C ratio was 7.7. The soil pH was 6.27, while bulk density increased to 1.48 g cm⁻³. Hygroscopic moisture content decreased to 3.05 %. Data on exchangeable Ca^{2+} and Mg^{2+} were not available for this horizon. The increase in bulk density to 1.48 g cm⁻³ indicates strong compaction of this layer and reduced water permeability.

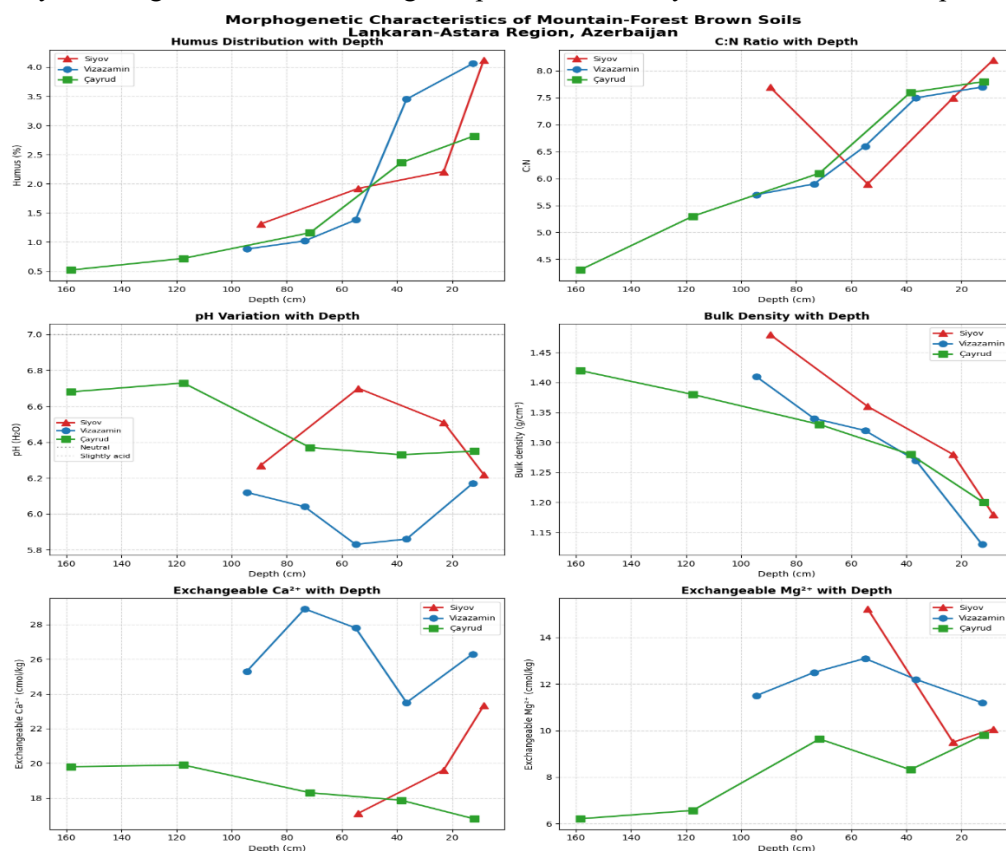


Figure 1. Morphogenetic characteristics of Mountain-forest brown soils

REFERENCES

- Ahmadova, L. A. (2025). Assessment of anthropogenic degradation processes in mountain-forest brown soils in Ajinohur low mountainous (Ganikh-Turyanchay break). *Science, Education and Innovations in the Context of Modern Problems*, 8(10), 164–169. <https://doi.org/10.56332/sei/8.10.17>
- Babayev, M. P., Hasanov, V. H., & Jafarova, Ch. M. (2011). *Morphological Diagnostics, Nomenclature and Classification of Soils of Azerbaijan*. Baku: Elm Publishing House. 448 p.
- Dokuchaev, V. V. (1954). *Selected Works*. Vol. 3. Moscow: Selkhozgiz. 348 p.
- Fridland, V. M. (1972). *Morphogenetic Classification of Forest Soils*. Moscow. 198 p.
- Huseynov, A. Sh. (2018). *Ecological Problems of the Lankaran–Astara Region*. Baku. 240 p.
- Kappen, G. (1930). *Method for the Determination of Exchangeable Bases in Soils*. Moscow: Nauka.
- Kjeldahl, J. (1965). *Determination of Nitrogen in Organic Compounds*. Moscow: Khimiya.
- Kovda, V. A. (1973). *Fundamentals of Soil Science*. Books 1–2. Moscow: Nauka. 468 p.
- Mammadzade, V. T., Aliyeva, M. M., Rzaeva, A. L., Nasirova, A. I., & Mammadova, R. N. (2025). Soil bioactivity study through innovative approaches in Lankaran–Astara Region, Azerbaijan. *SABRAO Journal of Breeding and Genetics*, 57(3), 1180–1191. <https://doi.org/10.54910/sabrao2025.57.3.29>
- Mammadov, Q. Sh., & Khalilov, M. Y. (2016). *Soil Resources of Azerbaijan*. Baku: Elm Publishing House. 410 p.
- Mammadova, S. Z. (2019). *Agrochemical Properties of Yellow Mountain Forest Soils*. Baku.
- Guliyev, I. A. (2013). *Soil Resources of Mountainous Areas and Their Conservation*. Baku.
- Rozanov, B. G. (1983). *Morphological Diagnosis of Soils*. Moscow: Moscow State University Press. 320 p.
- Rzaeva, A. L. (2023). Microbiological studies of mountain forest brown and mountain forest greyish-brown soils. *Bulletin of Science and Practice*, 9(4), 109–112.
- Rzaeva, A. L. (2024). Indicators of mountain-forest brown soils in Azerbaijan. *InterConf*, (43)193, 263–268. <https://doi.org/10.51582/interconf.19-20.03.2024.027>
- Sadigov, R. A., & Mustafayev, M. G. (2024). Analysis of mountain-forest cinnamon soil types in the basin of the New Shamkirchay Reservoir. *SABRAO Journal of Breeding and Genetics*, 56(1), 266–279. <https://doi.org/10.54910/sabrao2024.56.1.24>
- Samadov, P. A., Mammadov, Z. R., Aliyeva, M. M., Rzaeva, A. L., Nasirova, A. I., Mammadova, R. N., Mammadzade, V. T., Aliyeva, B. B., & Sadikhova, M. E. (2026). Eco-biological indicators of mountain forest soils in the Lankaran Region, Azerbaijan. *SABRAO Journal of Breeding and Genetics*, 58(1), 442–452. <https://doi.org/10.54910/sabrao2026.58.1.41>