









## Eco-Biological Features of Mountain Gray-Brown Soils Development in the Karabakh Steppe (Republic of Azerbaijan)

Pirverdi Samadov Ahmad <sup>1</sup>, Afaq Rzayeva Latifaga <sup>1</sup>, Matanat Aliyeva Mirismayil <sup>1</sup>, Roza Mammadova Nazim<sup>2\*</sup>, Anara Nasirova Ikhtiyar<sup>1</sup>, Vafa Mammadzade Telman <sup>1</sup>, Tarana Safar Aghayeva <sup>3</sup> and Gulnar Fagan Shirinova <sup>3</sup>

<sup>1</sup>Institute of Geography Public Legal Entity, Ministry of Science and Education, Baku, Azerbaijan

<sup>2</sup>Baku State University, Baku, Azerbaijan

<sup>3</sup>Department of Technology of Organic Substances and High-Molecular Compounds, Faculty of Chemical Technology, Azerbaijan State Oil and Industry University, Azerbaijan

\*Corresponding author: [roza.mammadova.nazim@bsu.edu.az](mailto:roza.mammadova.nazim@bsu.edu.az)

### ABSTRACT

The soils discussed in this article are widespread in the dry subtropical steppe and semi-desert zones. The primary objective of our research is a comprehensive study of the key, dominant biological indicators (phytomass, invertebrate composition, microbial abundance, total humus content), as well as some physicochemical soil properties. The comprehensive study covered both natural (virgin soil) and cultivated (alfalfa agrocenoses) biotopes. The results were systematically analyzed to clarify possible differentially developing cenotic relationships between individual biotope indicators. This approach allows us to approach the development of mountain gray-brown soils not only from the perspective of classical soil genetics, but also from the perspective of developing ecosystems in the dry subtropical steppe zone where these soils are found. For the first time for Karabakh steppe (Republic of Azerbaijan) where studied relationships between plant diversity and soil (Topsoil, Subsoil and Deepsoil) properties like qCO<sub>2</sub>, carbon use efficiency, SOC, soil carbonate, Electrical Conductivity, Soil pH, enzyme activities, Vegetation length. A new result of the study was the relationship between plant diversity depending on the carbonate content and organic matter of the soil. The current unsatisfactory state of the natural environment in many regions of the Karabakh necessitates the organization of ecological and biological research, which should be based on an assessment of the state of the environment and a forecast of the development of natural ecosystems during their further economic development.

**Keywords:** Agriculture, Invertebrates, Microflora, SOM, Biogeocenoses, Plant diversity.

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### INTRODUCTION

International experience in the development of countries with transition economies shows that in the context of globalization, it is important to prevent the consolidation of raw materials specialization and to find a rational balance between innovation and the traditional way of life of the population. Mountain soils are unique in their formation, morphology, composition, and dynamics. Among the morphological features most characteristic of mountain soils are: relatively weak differentiation into horizons, shallow profile thickness, high skeletal structure, and enrichment in large fractions and primary, weakly

weathered minerals. In mountainous regions, the influence of each soil-forming factor will be different; even with the naked eye, one can see, for example, the influence of relief located on the northern, western, eastern, and southern slopes, within a few degrees (Bakshaliyeva et al., 2020; Abdurahmanov, 2023; Bunyatova et al., 2025). Geological processes intervene in soil formation here, complicating it with erosion, aggradation, scree, and landslides. Extensive denudation processes lead to the predominance of relatively young soils in the mountains; these soils are constantly developing and renewing, and the soil cover they form is not continuously distributed. The gray-brown soils and ecosystems of arid steppes represent a unique

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transition zone between temperate steppes and true deserts. These are vital yet fragile landscapes that play a key role in the global carbon cycle and food security in many countries. Mountainous topography is the main reason for the wide diversity of soil cover. The vertical zonal change in soil formation types reflects the corresponding change in all soil factors with altitude, primarily climate and vegetation (Hasanova et al., 2021; Cotrufo & Lavallee, 2022; Hasanova & Mammadova, 2023). Unsustainable management practices are destroying fragile natural landscapes (forests, meadows, pastures), leading to widespread irrigation degradation, secondary salinization, and other adverse effects, leading to the loss of hundreds of thousands of hectares of fertile land from agricultural use. This, in turn, has prompted the global community to embark on a path toward building a future in harmony with nature. In the regional context, these soils develop in dry, moisture-deficient subtropical steppe conditions common in Azerbaijan (Kura-Araz Lowland, Karabakh steppe), Central Asia, and other arid regions. These ecosystems are characterized by low humus content (1-2%), high salinity, are susceptible to degradation due to grazing, and require salinity management (Ikhtiyar & Bahram, 2023; Huseynova et al., 2025; Ismayilova et al., 2025a; Ismayilova et al., 2025b). The mountain gray-brown (dark) soils we studied are quite widespread at altitudes of 200-600 meters, where they interact with brown steppe soils. These soils occupy the elevated foothill zone of the Karabakh steppe (Fig. 1). This zone is characterized by a pronounced arid climate and mountainous gray-brown soils, which develop under natural wormwood-cereal-forb and mountain-xerophilous vegetation adapted to the conditions of the dry-steppe subtropical climate. Studied soils develop under plant formations typical of dry subtropical steppe and semi-desert climates on a carbonate weathering crust (Mamedzade, 2021; Ismayil et al., 2025; Madnee et al., 2025). The conditions in which these mountain soils are found are characterized by their own specific ecological and climatic parameters. The climate of this zone is subtropical, with mild winters and dry summers. Average annual temperatures range from 12-13.2°C, with January, the coldest month, reaching

above-zero temperatures of 3.9-5.2°C. Precipitation ranges from 250-440 mm. The moisture content (MC) is relatively low, ranging from 0.3-0.6. Mountain gray-brown soils are completely non-saline, with solid residue averaging 0.04-0.05%. The distribution of these soils in foothill and slope positions facilitates surface runoff, resulting in varying degrees of erosion (Manu et al., 2022; Mammadzade, 2025; Mammadova et al., 2025a; Mammadova et al., 2025b). As a result, their overall surface takes on the appearance of rolling, dissected landforms. Low precipitation and high temperatures over long periods promote vigorous subsurface weathering and the accumulation of poorly soluble products of their transformation and soil formation within the soil profile (Mammadzade, 2025). Therefore, these soils are characterized by their pronounced clay content. The arid climate results in active mineralization of organic matter and a slow rate of humus formation (Mirzazadeh et al., 2025; Mir et al., 2025). Mountainous regions are susceptible to erosion due to human activity, which is carried out without regard for natural soil-forming conditions and topography. In some places, natural biogeocenoses completely disappear, resulting in the erosion of the soil surface, which leads to changes in the water and air regimes and the mechanical composition of the soil. The relevance and importance of solving this problem place it among the problems that limit the environmental, economic and food security of the country, creating tension in its regions, since agriculture and regulation of the ecological balance are defined as a strategic priority (after the oil industry) direction of the socio-economic development of Azerbaijan. Scientific and technological progress must be aimed at radically improving the use of natural resources, raw materials, fuel, and energy at all stages from extraction and integrated processing of raw materials to the production and use of final products. Rational intensification of agricultural production, capable of ensuring soil fertility and stable crop yields, is a global challenge of our time (Mammadova et al., 2024; Mirismayil, 2025; Macnunlu et al., 2025). The task of increasing agricultural productivity and enhancing soil fertility is addressed primarily through improved agricultural practices, plant breeding, land reclamation,



Fig. 1: Research are Karabakh steppe.

irrigation, fertilizer application, land development, and planned land use. Significant progress has been made in this area. There is an ecobiotic relationship between vegetation and soil. Vegetation, being one of the most important factors in soil formation and playing a significant role in regulating the microclimate and water regime of soils, also determines the biogeochemical cycle of substances in nature (Nasirova et al., 2022; Nazim & Oqtay, 2024). The area under study is unique and distinct from others. Because the area was under occupation for many years, the research is considered innovative, and the data will be useful for future forecasts. The slope of the terrain plays a significant role in the development of mountain soils (Nasirova et al., 2026). Moisture distribution, sunlight exposure, vegetation cover, soil density, and rock content, especially on slopes, directly influence the thickness of the soil profile. This results in soil types with different compositions and properties. The reduction or complete disappearance of vegetation, in turn, leads to the complete destruction of the soil cover, resulting in the emergence of bedrock on mountain slopes, leading to the extinction of rare medicinal plant species. Therefore, it is recommended that the use of mountainous areas for livestock farming be strictly planned, and limited to flat areas with gentle slopes (Rzayeva & Mamedzade, 2024; Nasirova et al., 2025).

## MATERIALS & METHODS

Classical methods of genetic soil science allow us to classify and diagnose soils developing in today's diverse geographic and eco-climatic conditions. In this context, it's also worth noting the research conducted on the main soil types of the republic's dry-steppe subtropical zone, which has distinct ecological characteristics and biological indicators (Mammadova et al., 2025a; Mammadova et al., 2025b). Given the considerable complexity of biogeocenoses' formation in such contrasting environmental conditions, the authors of this article conducted comprehensive soil-biological studies using gray-brown (dark) soils in the Karabakh steppe (Agdere district, Talysh village) as an example. A natural ceneses under natural vegetation and an alfalfa agroceneses were chosen as experimental biotopes (Mammadzada et al., 2025; Mirzadeh et al., 2025). The Karabakh region is located in southwestern Azerbaijan, approximately between 39°00'-40°30' north latitude and 46°00'-47°30' east longitude. This territory, stretching from the plains of the Kura and Araz rivers to the mountainous regions of the Karabakh range, covers an area of over 7.330 square kilometers (Fig. 1).

Since mountain gray-brown (dark) soils are a subtype of gray-brown soils, we thought it appropriate to first discuss some common elements of their development. As is well known, various plant formations are important factors in the soil-forming process, synthesizing organic matter as a solar energy accumulator, which is of great importance for soil fertility (Rowell, 1999; Rzayeva, 2023). A study of the vegetation cover revealed that these soils develop under natural forb and wormwood-grass-herbaceous plant communities. These soils have a

shortened soil profile and are represented by clayey and heavy clay varieties. These soils show no signs of salinization properties. They possess physicochemical properties quite satisfactory for rainfed agriculture, with well-aggregated topsoil and subsoil, and are classified as high-quality soils (Shukurov et al., 2025a).

Thickness and density of the sod layer: depth 0-20 cm; loose;

Root system penetration depth (mass): 50-65 cm;

Humus layer color: brownish-brown; brown;

Humus layer thickness: 50-60 cm deep, AU-AY horizon

Particle size distribution: <0.001 mm, 25-45%; <0.01 mm, 50-75%

Al' horizon texture: granular, finely nutty

Al'' horizon texture: nutty-lumpy

Carbonate layer depth and expression: AVz horizon, weak, BTcaz horizon, strong

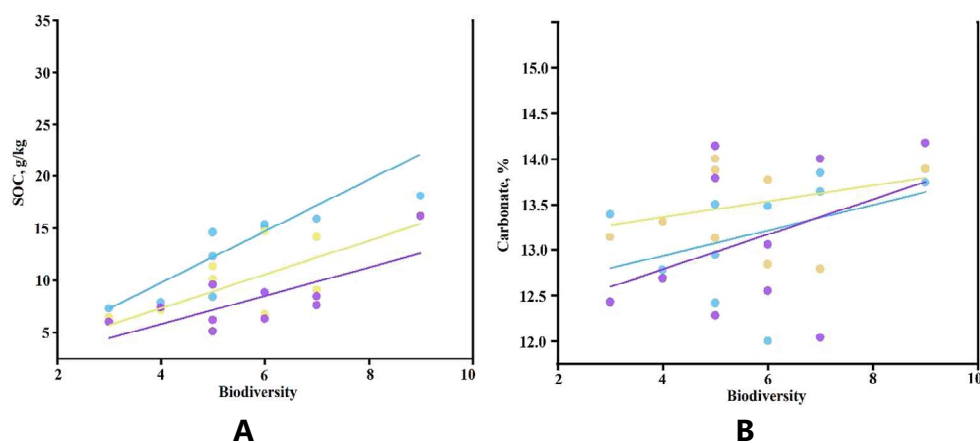
Carbonate form: predominantly mycelial or soft-mealy, depth: 60-70 cm, BCA horizon

The profile of these soils is characterized by the following system of genetic horizons: AUv-AYzvca-NTcfz-BCA(p)-B/Cca(cs)L-CcaL.

Biomass determination in virgin and cultivated communities was conducted using the following method: Aboveground biomass was cut from a 1 m<sup>2</sup> area in five replicates, and then their wet and air-dried masses were weighed (Rowell, 1999; Samadov, 2023). Invertebrate complexes (mesofauna) were studied using soil-zoological methodology, which served as the basis for P.A. Samadov's continued research on soils of the dry steppe zone, which have distinct ecological and biological indicators of soil formation. The discovered invertebrate representatives were grouped based on their ecological characteristics and adaptation to the specific conditions of their habitats. CO<sub>2</sub> carbonates were determined using Golubev's calcimetric. Microbiological analyses of the collected soil samples were conducted using D.G. Zvyagintsev's method, under the required aseptic conditions (Rzayeva, 2023; Samadov, 2024). Hydrothermal parameters and pH values were measured using Orion 3-star Benchtop, pH Meters (Thermo Scientific, USA). Absorbed cations were determined using a KFK-2-UKHL 4.2 device with light-sensitive filters with spectral lengths from 354 to 980 λ mm. To determine the total humus content and the degree of condensation of its aromatic ring in the soil samples, the electron paramagnetic resonance (EPR) method was used, which allows one to determine the paramagnetic centers of humic substances.

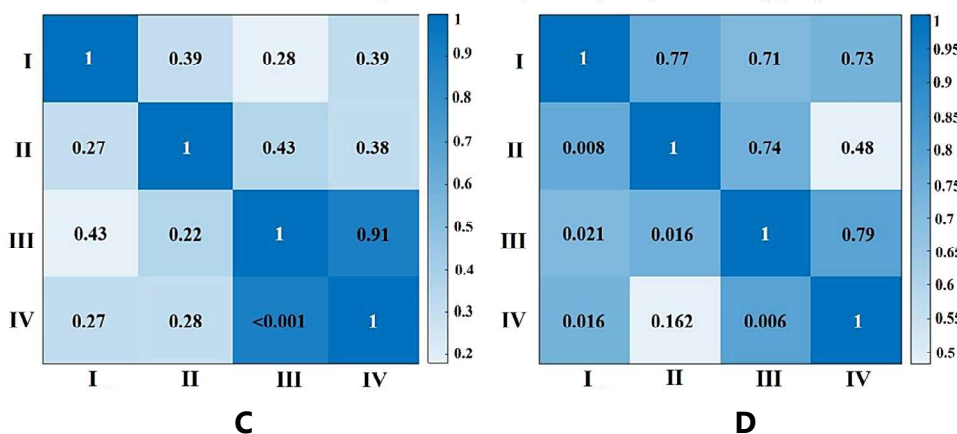
## RESULTS

Knowledge of the floristic composition of natural pastures and hayfields demonstrates the richness and diversity of the country's forage flora, while valuable leguminous grass species, which supply plant proteins and enrich the soil with nitrogen, are comparatively scarce. When determining the distribution patterns of plant communities occupying low-lying areas, groundwater levels, surface and underground runoff patterns, and the presence of isolated permafrost soils should be taken into account (Fig. 2 A-D). A comparative study of the distribution of invertebrates in natural and cultivated



**Fig. 2:** Relationships between plant diversity and soil properties. A - Regression of plant diversity against SOC content; B - Regression of plant diversity against soil carbonate; C - Correlation between plant biodiversity and soil carbonate content across soil layers; D - Correlation between plant biodiversity and SOC content across soil layers; Note: I - Plant number; II - Topsoil (0-30 cm); III - Subsoil (30-60 cm); IV - Deepsoil (60-100 cm).

— Fitted curves of plant diversity + Topsoil (0-30 cm) properties  
 — Fitted curves of plant diversity + Subsoil (30-60 cm) properties  
 — Fitted curves of plant diversity + Deepsoil (60-100 cm) properties



biotopes revealed some changes in the mesofauna complex related to different ecological groups. The natural community is home to mesofauna species adapted to arid habitats, actively utilizing virgin vegetation as food resources and adaptation mechanisms to the natural landscape. Research has identified the following dominant ecogroups: *Lepidoptera*; *Cerambycidae*; *Carabidae*; *Diptera*; and *Pentatomidae*, which account for 62.5% of the total population. The remaining 37.5%, or approximately 37.5%, are comprised of associated groups: *Isopoda*; *Mollusca*; and *Arachnidae*.

The alfalfa agrocenoses is distinguished by a different invertebrate composition. Here, groups directly or facultatively gravitate toward humid environmental conditions predominate. The dominant invertebrate ecogroup consists of: *Hamoptera*; *Lepidoptera*; *Coccinellidae*; *Odonatoptera*; *Diptera*; *Pentatomidae*, i.e., 56%, and the remaining 44%; accompanying groups are: *Mollusca*; *Lumbricidae*; *Isopoda*; *Arachnidae*. The occurrence of individual invertebrate groups in both cenoses indicates their common evolutionary development under similar environmental conditions. Microorganisms are an important component of the soil biotope. The most important function of microorganisms is their active participation in the global biological cycle

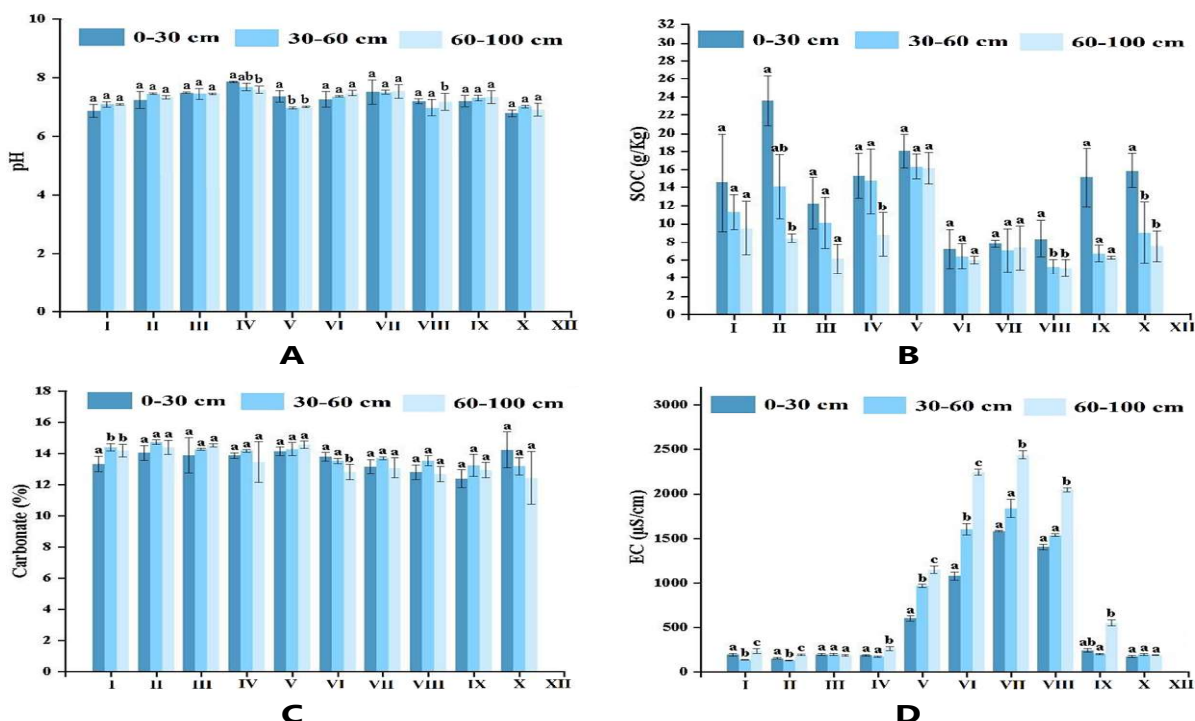
of substances. Microorganisms, together with other representatives of the soil fauna, provide complex biochemical processing of organic and mineral components of various etiologies into humic substances and organomineral complexes. Microbiological analyses revealed that the total microbial population varied significantly across individual layers of natural and cultivated communities, averaging 1,902,500–2,737,180/g soil. The microbial group composition included approximately 51.5% non-spore-forming bacteria, 17.7% spore-forming bacteria, 46.7% actinomycetes, and 1.9% microscopic fungi. In arid environments, spore-forming bacteria and fungi play a key role in the decomposition of virgin vegetation, alongside xerophilic invertebrate groups. As is known from the literature, pore formation for bacteria and fungi is not only an important form of adaptation to extreme soil conditions but also a potential means of joint activity when favorable environmental conditions arise in their habitat. In the soil samples of the studied cenoses, dominant representatives of spore-forming bacilli and microscopic fungi were identified. The composition of bacilli is formed by the following species: *Bacillus cereus*; *Bacillus megaterium*; *Bacillus mesentericus*; *Bacillus subtilis*; *Bacillus idosus*, and for fungi, the main four genera are:

*Aspergillus*; *Fusarium*; *Penicillium*; *Alternaria*, with the latter often found in cultivated soils. Research has established that for both groups, the most favorable hydrothermal conditions for development are the range of temperature (T) - 14-20°C and humidity (W) - 20-25%. All groups of soil biota, creating direct and indirect interspecific relationships, participate in the complex biochemical transformation of plant and animal biomass, the end product of which is the creation of new, energy-intensive organic matter - humus. Thus, humus is a complex, dynamic complex of organic compounds that influences the thermal, water, and air properties of soils and is an important factor in their fertility. Determining the total humus content in soil samples from the studied communities revealed uneven distribution across individual layers. Thus, while humus in the 0-30 cm layer of virgin soil ranges from 3.1-2.3-1.8%, in the alfalfa agrocenoses, these values range from 3.9-3.2-2.7%. The decrease in humus content across individual soil layers indicates a gradual decrease in the condensation of molecules and a weakening of the aromatic ring of newly formed humic acids. In our experiments on virgin soils, a sharp decrease in humus content across layers was accompanied by weak condensation of the aromatic core of humus. In alfalfa agrocenoses, balanced biological parameters resulted in more pronounced polymerization and condensation of the aromatic core of humus.

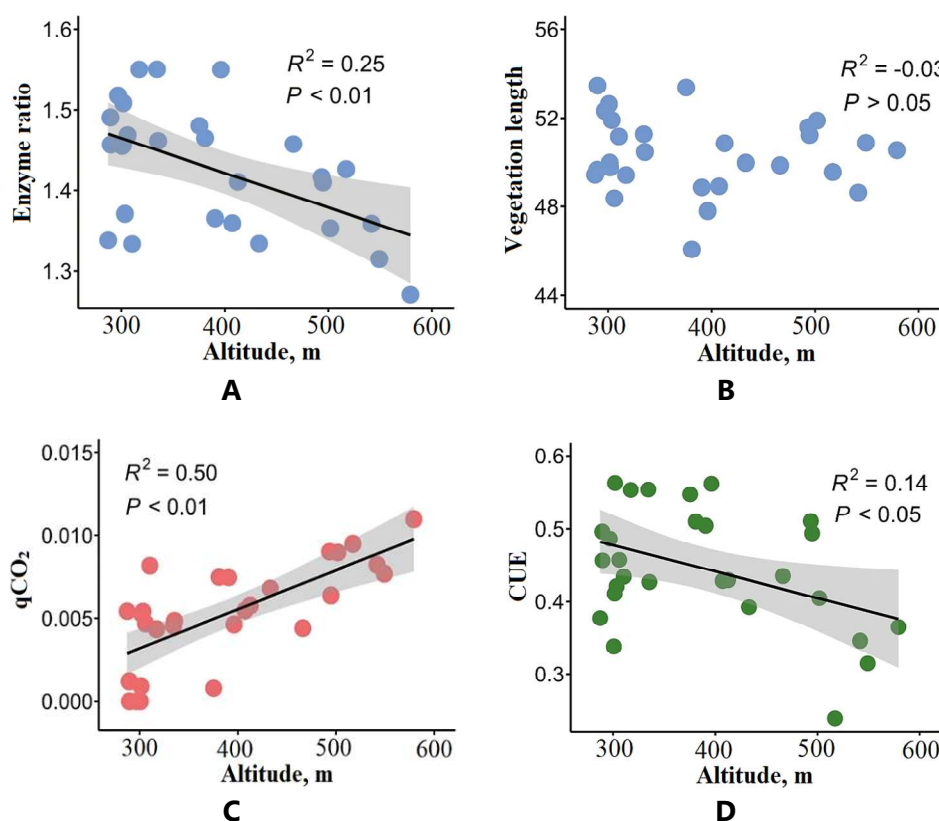
Biological factors are important components of the ecosystem, ensuring the circulation of substances, the transformation of solar energy within individual biogeocenoses units, and its accumulation in the soil humus unit. The humus profile of a specific soil type gradually develops. The quantitative relationship

between certain biological indicators of humus formation - phytomass, microorganisms, and total humus and organic matter content has been studied (Fig. 3 A-D). Considering that the initial breakdown of phytomass and the inoculation of decomposition products by bacterial microflora are carried out by invertebrates (saprophages), it becomes clear how important it is to study the biological factors of humus formation. Studies of some physicochemical properties revealed that a carbonate layer is present at a depth of 60-70 cm ( $B_{ca}$  horizon) in the form of mycelium or carbonate powder. A compacted clay layer is observed in the  $B_{ca}$  horizon. Based on their particle size distribution, the soils studied are clayey and heavy clayey. Among the absorbed cations, calcium accounts for 88-98%, while the clay fraction and physical clay content reach 33-24% and 64.2%, respectively, concentrated in the middle part of the profile at a depth of 30-40-50 cm ( $B_{im}$  horizon). Clay minerals consist primarily of montmorillonite, hydromica, and sesquioxides, which in turn increase the soil absorption capacity to 36-42 mg eq/100 g of soil. Due to their high dispersion and sorption properties, clay components form complex clay-humus compounds with humus, especially in the illuvial soil horizon. The relationship between the soil absorption capacity and the total humus content are adequately interconnected (Fig. 4A-D).

Soil enzymes and soil microorganisms play an important role in maintaining biochemical balance in the soil. The soils of the Karabakh steppe have a fairly high buffering capacity and, when an excess or insufficient factor appears, after its elimination, they return to their characteristic stable state (Fig. 4A-D).



**Fig. 3:** Physicochemical properties of forest soil samples from Karabakh steppe; Note: A - Soil pH; B - Soil Organic Carbon (SOC); C - Soil Carbonate Content; D - Electrical Conductivity (EC). Different letters after the columns indicate significant differences at different depths ( $P < 0.05$ ).



**Fig. 4:** A - Enzyme ratio quantified the relative P + N-acquiring enzyme activities, and higher Enzyme ratio represented relatively higher P + N acquisition strategies; B - microbial resource acquisition strategy. The Vegetation length quantified the relative C + nutrient N and P acquiring enzyme activities, and lower Vegetation length indicated relative higher nutrient acquisition strategies (relative to C); C - carbon use efficiency (CUE); D - Metabolic efficiency, including metabolic quotient ( $qCO_2$ , respiration per unit biomass,  $\mu g CO_2-C \mu g^{-1} MBC h^{-1}$ ).

## DISCUSSION

The interactions between biological organisms and soil form a complex ecosystem, where microorganisms, plants, and soil fauna (worms, insects) participate in the decomposition of organic matter, nutrient cycling, and humus formation. These processes, including soil formation and nitrogen fixation, directly impact soil fertility, soil health, and ecosystem stability (Samadov, 2023; Shukurov et al., 2025b). The Table 1 shows Pearson correlation coefficients ( $r$ ) between plant diversity and soil parameters determine a linear relationship (from -1 to +1), where the  $p$ -value indicates its statistical significance (usually  $p < 0.05$ ). Values of  $(p < 0.05)$  confirm that the identified relationship is not random. Specific coefficients vary greatly depending on the ecosystem (forests, meadows, deserts). Regression analysis links plant diversity to the organic carbon (Corg) content of the soil (topsoil, subsoil, deepsoil), as Corg is a key indicator of soil fertility, structure, and plant growth. Regression analysis relates plant diversity to soil carbonate content, as carbonates ( $CaCO_3$ ) directly influence soil pH, nutrient status, and water retention capacity (Schroeder et al., 2021; Samadov, 2024; Sadigov et al., 2025). High carbonate content creates an alkaline environment, often supporting specific calciphilic species but suppressing calciphobes, allowing species richness to be modeled through linear or nonlinear regression. A positive correlation is typically observed: the higher the humus content, the greater the productivity and species diversity of the ecosystem. Soils often contain components that influence biodiversity, such as humus horizons. A positive relationship with fertility (nitrogen,

humus) and a negative relationship with acidity or salinity are often noted. When soils are introduced into agricultural production, their morphological, physical, and chemical properties inevitably change (Verdiyeva et al., 2025). The consequences of this impact are manifold and affect key aspects of the functioning of the soil ecosystem. Agricultural land use has a significant impact on soil biota, due to mechanical action during tillage, the application of fertilizers and pesticides, and other factors, as well as changes in the habitats of soil organisms. A study of the natural cover of mountain gray-brown (dark) soils showed that the phytostructure of the natural biotope consists of three dominant families and five genera: family *Compositae* Adans. (genus *Artemisia* L.), family *Gramineae* juss. (genus *Antropodon* L.; genus *Festukal* L.; genus *Stipa* L.), family *Capparidaceae* Lindl. (genus *Capparis* L.). Along with studying the systematic composition of vegetation, the phytomass of natural and cultivated cenoses was also determined. Accounting of the phytomass showed that it varies respectively between 613-667  $g/m^2$ . Fig. 1 specifically shows the relationship between plant diversity and soil properties, a regression analysis of plant diversity depending on soil organic carbon content, as well as a regression analysis of plant diversity depending on soil carbonate content and the correlation between plant biodiversity and soil carbonate content by layer. In essence, the complex correlation between plant biodiversity and soil organic carbon content by layer. Organic matter that can be mineralized to  $CO_2$  due to its quality and availability to microorganisms is called potentially mineralizable (Nasirova et al., 2026). The decomposition of organic matter in the soil occurs only if a

water film, active enzymes, an accessible and enzyme-receptive substrate, as well as favorable conditions of temperature, aeration, and pH are present in the same place and at the same time. Since the soils studied develop on a carbonate weathering crust, an important part of our research was the study of CO<sub>2</sub> emissions from soil layers associated with biological processes and the hydrothermal destruction of carbonates. It was found that in the upper (0-10; 10-20 cm) layers, the volumetric content of CO<sub>2</sub> was 2.40-3.8%, while in the middle (20-30; 30-40 cm) and lower (50-60 cm) layers, the volumetric amount of released CO<sub>2</sub> varied within the ranges of 4.7-9.7% and 9.9-10.1%, respectively. While certain volumes of CO<sub>2</sub> produced in the upper layers are explained by the activity of aerobic microflora and surface-dwelling invertebrates, in the lower layers this function is performed by anaerobic (chemotrophic) microorganisms, which utilize carbonate transformation as energy, as well as soil weathering processes. The obtained results show that, with a volumetric amount of CO<sub>2</sub> entering the soil of 1.0-1.5-2.0%, biological processes in natural (virgin) and cultivated (alfalfa crops) communities proceed in a fairly balanced manner. Analyzing the entire range of biological and physicochemical studies, it was established that the obtained results are characteristic of mountain gray-brown (dark) soils and determine the specific features of their development in the ecological conditions of the dry subtropical zone. Fig. 2 shows significant differences ( $p < 0.05$ ) in pH, SOC, carbonates, and EC at different depths reflect soil heterogeneity. Typically, the upper layers (0–20 cm) contain higher carbon (SOC), while the lower layers contain higher carbonates and EC. The distribution depends on leaching, humification, and soil formation processes, requiring separate analysis for an accurate assessment. At all links in the complex transformation chain of organic matter in the soil, sequentially acting enzyme systems accumulated in the soil and functioning within and on the surface of living microorganisms are involved.

The hydrolytic breakdown of high-polymer organic compounds produces intermediate breakdown products (amino acids, nucleotides, organic acids, monosaccharides) or end products of mineralization (CO<sub>2</sub>, NH<sub>3</sub>, PO<sub>4</sub>, SO<sub>4</sub>). Enzymes not only participate in individual stages of humus biogenesis in the soil, but also, through their enzymatic activity, which is an integral expression of the soil's biochemical activity, determine the mechanism of humus formation and its quality (Samadov, 2023). According to the kinetic theory of humification, the depth of humification ( $C_i; C_f$ ) is determined by the intensity of biochemical processes in the soil. Enzymatic activity is an indicator of the main soil characteristic - the level of fertility, in the creation of which biochemical processes play both a direct and indirect role. Mechanical tillage, chemical and water reclamation, and the use of mineral fertilizers and pesticides cause significant changes in the soil's water-air balance. Increased osmotic pressure of the soil solution, changes in the balance of mineral nutrients for plants and microorganisms, and the qualitative and quantitative composition of organic matter entering the

soil all lead to modifications in the structure of the microbial complex and the biochemical processes occurring in the soil. The interactions between microorganisms and agricultural crops also undergo changes, which ultimately impacts crop rotation productivity. Fig. 3 describes an ecological principle according to which the length/size of vegetation (or its associated structures) is correlated with investment in resource acquisition. Smaller length/size often indicates higher relative enzyme activity (C-phosphatase, N-acetylglucosaminidases) aimed at assimilating limiting nutrients (N and P) relative to carbon (C), indicating more aggressive or effective adaptation strategies.

### Conclusion

Phytomass determination in virgin and cultivated (alfalfa crops) communities revealed variations between 613 g/m<sup>2</sup> and 667 g/m<sup>2</sup>. Invertebrate assemblages in the studied communities are composed of xerophilic and mesophilic ecogroups, consisting of dominant (62.5-56%) and associated (37.5-44%) representatives. Microorganism abundance averaged 1902.50 g soil in the 0-30 cm soil layer in virgin soil and 2737.18 g soil in the alfalfa agrocenoses. Total humus content in the 0-30 cm soil layer in the virgin and cultivated communities varied, on average, between 2.40 and 3.26%. Relationships between humus and biological and physicochemical parameters were also established. The obtained biological indicators can be used as a biological test in the diagnosis of mountain gray-brown (dark) soils. The results of the diagnostics of the effectiveness of state management of land relations in the Karabakh region show an increase in the intensity of processes in the context of the main regulatory mechanisms.

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**Author's Contribution:** P. Samadov: Conceptualization, Supervision; A. Rzayeva, V. Mammadzade, Gulnar Shirinova and Tarana Aghayeva: Data curation, Methodology,

Supervision, Writing – original draft; A. Rzayeva and A. Nasirova, R. Mammadova: Investigation, Validation, Visualization, Data curation, Formal analysis; M. Aliyeva, A. Nasirova, A. Rzayeva, V. Mammadzade: Software, Validation, Writing – Review & Editing, P. Samadov, A. Nasirova, M. Aliyeva, R. Mammadova, Gulnar Shirinova and Tarana Aghayeva: Data curation, Verification, Writing – Editing. All authors have read and approved the final version for publication.

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