CHAPTER 3

Ecological state of modern soil cover in agrocenoses of the Greater Caucasus Sheki region

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Abstract

The article presents climate data, soil moisture, humus content, nitrogen and other key microbiological indicators of the territory (2023–2024). Agricultural production has made great strides in the last two decades and occupies a leading position not only in the Sheki region, but also in the country. Deforestation to meet the growing needs of the population for firewood is a very sad situation. Forestation work in the Sheki region, considered the most beautiful tourist center of Azerbaijan, is one of the most important issues posed by the state to environmentalists. The article presents the results of forest restoration work carried out on the experimental site of the Sheki Regional Research Center, as well as studies carried out on soils spread under trees that are already 80 years old. Soil surveys conducted using modern methods are considered an innovation for Azerbaijan. The results obtained can be used in subsequent studies coordinates are 41°15'45.0"N 47°12'57.6"E; 41°15'54.8"N 47°13'12.5"E; 41°16'03.8"N 47°13'14.2"E; 41°16'03.3"N 47°13'34.9"E; 41°16'29.6"N 47°12'52.0"E. The study of microbial mass is very important for the ecological assessment of the studied soils. The maximum number of actinomycetes was found in the virgin gray forest soil on the hillock, where it amounted to 360 thousand CFU/g, which is 5 times more than in the same soil horizon of the depression on the natural soil and 30 times more than in the soils of both elements of the microrelief on the fallow land. In taxonomic terms, micromycetes in the studied gray forest soil are represented by the following dominant species: *Penicillium notatum*, *Penicillium chrisogenum*, *Trichoderma viride*, *Trichoderma lignorum*, *Aspergillus niger*, *Mucor* ssp., *Paecilomyces* ssp., *Crustosum* ssp. Representatives of the genera *Fusarium* and *Monatospora* are rare. As a result of the analysis of the obtained data, the total reserves of organic matter of the secondary spruce forest were determined, which amount to from 21.5 to 32.7 kg·m^{-2}.

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Keywords
Forest resources, vegetation, reforestation, correlation, regression analysis, soil-microbiological characteristics, organic matter.

3.1 Introduction

To assess the sustainability of agrocenoses, it is advisable to use a set of criteria and indicators that allow quantitative interpretation of its variability under the influence of agrogenic factors. Microbiological and biochemical indicators reflect the dynamic properties of soils and serve as indicators of life processes in the soil [1, 2]. Currently, the issue of efficient land management and rational use of forest resources is acute. The world community is increasingly aware of the need to preserve and restore forests. One of the most important production tasks of forestry in the area of forest reproduction is the cultivation of high-quality planting material of trees and shrubs. The quality of planting material and its hereditary properties largely determine the productivity and sustainability of future plantings [3, 4]. The issue of efficient land management and rational use of forest resources is acute. The world community is increasingly aware of the need to preserve and restore forests [5].

The development of livestock industries entails an increase in the need for feed grain, coarse and succulent feed, therefore, it will be necessary to expand existing agricultural lands at the expense of lands that were not previously cultivated or were long ago transferred to a fallow state. As for planting material for reforestation, there is currently a shortage of high-quality raw materials (seedlings) in the Azerbaijan, existing nurseries use old methods used since Soviet times for growing.

Successful reforestation (afforestation) requires a significant number of seedlings and saplings grown in forest nurseries. Effective implementation of reforestation measures is possible only on a soil-typological basis, in connection with which the consideration of soil and ground factors comes first [6]. This becomes especially relevant when growing planting material in forest nurseries, under conditions of intensive agricultural technology, which makes nursery farms similar to agricultural production [7]. Currently, the main ways of intensifying work in the agricultural sector are in the area of implementing precision farming systems (**Fig. 3.1**).

Similar approaches can be fairly transferred to the organization of work in forest nurseries. Precision farming is based on digital field maps compiled using geographic information systems. This allows systematizing the available information on the state of the soil, as well as updating it, receiving visual data in the form of various maps and cartograms, automating the accounting of all economic activities on the territory of the nursery, and providing information support for decision-making [8, 9].

Fig. 3.1 Cartogram of the current state of the fields in the Sheki Regional Center: *a* – soil plan of part; *b* – soil pH; *c* – acidity level of soils

3.2 Methods

The research was conducted on the territory of the Sheki Regional Center of the educational and experimental forestry enterprise in Sheki. The forest nursery with an area of 33 hectares is located on the territory of the Sheki-Zagatala economic district in the 11th quarter of the district forestry. The nursery provides planting material for forestry production in Sheki and other farms in Sheki-Zagatala economic district; the assortment is dominated by coniferous species, most often used in reforestation. The work program included a soil-agrochemical survey of the nursery fields using GIS technologies (laying and morphological description of sections, sampling to determine the physical, physicochemical and chemical properties of the soil), conducting a topographic survey of the nursery territory, determining the degree of weed infestation of the nursery fields. All collected information was digitized and combined into a single geographic information system. Georeferencing of soil survey points, relief topographic survey points, and nursery fields was carried out using GPS/GLONASS navigation and the NextGIS mobile application. In the soil laboratory of the Institute of Soil Science and Agrochemistry, the main physical (density, solid phase density, moisture), chemical and physicochemical properties of soils (actual, exchangeable, hydrological acidity, the sum of exchangeable bases, cation absorption capacity, base saturation, content of available forms of nitrogen, phosphorus and potassium, humus content) were determined for the selected soil samples. The QGIS system was chosen as the software for creating the nursery GIS. QGIS is a free, cross-platform, open-source system. It supports a wide range of vector and raster formats, has a convenient Russified interface and a large number of accessible methodological materials. In addition, QGIS is directly linked to the NextGIS Mobil mobile application, as these are related developments. The SAS program was used to obtain a georeferenced topographic base [10–13].

3.2.1 Physicochemical properties

The work uses generally accepted methods for studying the physical, chemical and physicochemical properties of soils. Phytotoxicity of soils was carried out according to the method of N. Krasilnikov in an aqueous extract obtained from humus and buried horizons of the studied soils when comparing them with the control (distilled water). Identification of microscopic fungi was carried out according to the Identifier of M. Litvinov, actinomycetes – according to the Identifier of G. Gause et al., eubacteria – according to the Identifier of Bergey's bacteria. The methodological approach for conducting laboratory analyses of the biochemical activity of soils was the express method of T. Aristovskaya, M. Chugunova, the essence of which is that the rate (in hours) of decomposition of a nitrogen-containing organic compound (urea) and changes in the pH of the air by 1.5–2.0 units due to the release of ammonia are recorded. Agrophysical properties are considered to be among the most important elements of soil fertility. The main physical properties include bulk density and solid phase, porosity, structural-aggregate composition and water resistance of structural units [14, 15].

3.3 Results

3.3.1 Microbiocenoses

The studies were conducted in a long-term stationary experiment, established in 2023–2024 on gray forest medium loamy soil in the southern region of the Greater Caucasus. A fairly high humus content is observed in the organogenic horizons. Its amount decreases rapidly with depth, especially noticeable in the soils of the pits located on elevated elements of the microrelief. Thus, at a depth of 30–50 cm of pit 1 on the deposit, there is less than 2% humus, and in the upper horizon of pit 3 on natural soil – a little more than 2.5%, which is due to the greater mineralization of humus here compared to depressions, caused by higher soil heating. In depressions, both on virgin soil and on deposits, the amount of humus decreases slowly down the profile and even at a depth of 50–70 cm remains quite high, amounting to more than 3%. The upper horizon of section 4 is significantly enriched with humus, which is 3 times more than the similar horizon of section 3. Fallow and virgin gray forest soils have significant differences in the content of actinomycetes. In fallow soils, their number is 10–11 thousand CFU/g on the micro-elevation and significantly lower in the subsurface and buried horizon of the micro-depression (2.5–1.6 thousand CFU/g). Consequently, the processes of organic mineralization due to actinomycetes in fallows occur less deeply and less intensively, as also evidenced by the large range of C:N. However, in virgin gray forest soil, especially on the elevation, the number of actinomycetes is maximum (300 thousand CFU/g), which is consistent with the smaller range of C:N and the low content of organic matter in the horizon, A (10–20), due to its active mineralization by actinomycetes. In taxonomic terms, the dominant actinomycetes that we were able to identify to the species level belong to the *Albus* section of the *Albus* series, *Streptomyces/Albus* species, and to the *Cinereus* section, *Achromogenes* series, *Streptomyces sporocinereus* species. The quantitative index of denitrifiers taken into account on the Giltai medium is very low (0.1). They were found only in the depressions of the deposit and natural soil.

Consequently, the processes of nitrate reduction, the amount of which is apparently insufficient due to the shallow degree of mineralization of organic matter in the deposit, are greatly slowed down [14]. In all horizons of the studied gray forest soils of the fallow and natural lands, a large number of oligonitrophilic and nitrogen-fixing eubacteria are present on both elements of the microrelief, counted by the standard method on the Ashby medium. The number of oligonitrophils on the fallow land is from 9.0 million CFU/g to 12 million CFU/g in the soil of the upland and

15 million CFU/g in the depression. On the natural soils, their number is even higher: 50 million CFU/g on the hillock and 60 million CFU/g in the depression.

The high number of oligonitrophils in the microbiocenoses of the studied samples of gray forest soil compared to other ecotrophic groups of microorganisms can be explained by small reserves of nitrogen, the amount of which is "compensated" by both the process of nitrogen fixation, enriching the soil with nitrogen, and the activity of dissipotrophs assimilating low concentrations of nitrogen present in the soil in a "dispersed" state [15]. In taxonomic terms, free-living oligonitrophils – dissipotrophs in the gray forest soil of the region are represented mainly by pseudomonads and bacilli, and diazotrophs are rare and are represented by Azotobacter.

3.3.2 Vegetation

It should be noted that the humus content in the deposit is 1.5 times less than in natural soils, which is associated with the activation of soil dehumification processes during development. However, the differences in humus content between soils of different positions along the microrelief are insignificant and amount to less than 1% in the upper horizons. Due to surface leveling and mechanical mixing of the soil, many indicators, including humus content, have become closer in their values [16, 17]. During the field stage of the research, it was established that the nursery soils are classified as arable gray medium or light loamy. A satellite image from the operator DigitalGlobe was used as the basis for the placement of all spatial objects [18]. Shapefile format was chosen as the format for presenting GIS data. The soil plan was directly constructed using the interpolation method depending on the genesis and morphology of the soils, the granulometric composition and the terrain [19–21]. When determining the degree of weed infestation in the fields, it was found that perennial weeds have the greatest species diversity, the most common weeds being *Taraxacum officinale*, *Phleum pratense* and *Tripleurospermum inodorum*, *Stellaria media* L., *Galinsoga quadriradiata*, *Eragrostis curvula*, *Eragrostis pectinacea* (Michx.), *Eragrostis tef* (Zucc.), *Echinochloa crus-galli* (L.), *Fagopyrum tataricum* (L.), *Capsella bursa-pastoris* (L.), *Tripleurospermum inodorum* (L.), *Myosotis arvensis* (L.) *Viola tricolor* (L.), *Apera spica-venti* (L.), *Cirsium arvense* (L.), *Sonchus arvensis* (L.), *Barbarea vulgaris*, *Vicia cracca* (L.), *Potentilla anserina* (L.), *Lupinus polyphyllus* (L.), *Ranunculus repens* (L.), *Equisetum arvense* (L.), *Calamagrostis epigejos* (L.), *Tussilago farfara* (L.), *Geum urbanum* (L.), *Artemisia vulgaris* (L.), *Tanacetum vulgare* (L.), *Centaurea jacea* (L.), *Plantago major* (L.), *Deschampsia cespitosa* (L.), *Phleum pratense* (L.) and others. On natural cenoses, the pits were laid on a gentle slope of western exposure with a slope of less than 3°C, in its lower part (**Fig. 3.2**). In the course of scientific research conducted over many years, the bioecological properties of tree species, which are of great importance in various landscapes of Azerbaijan, have been widely studied.

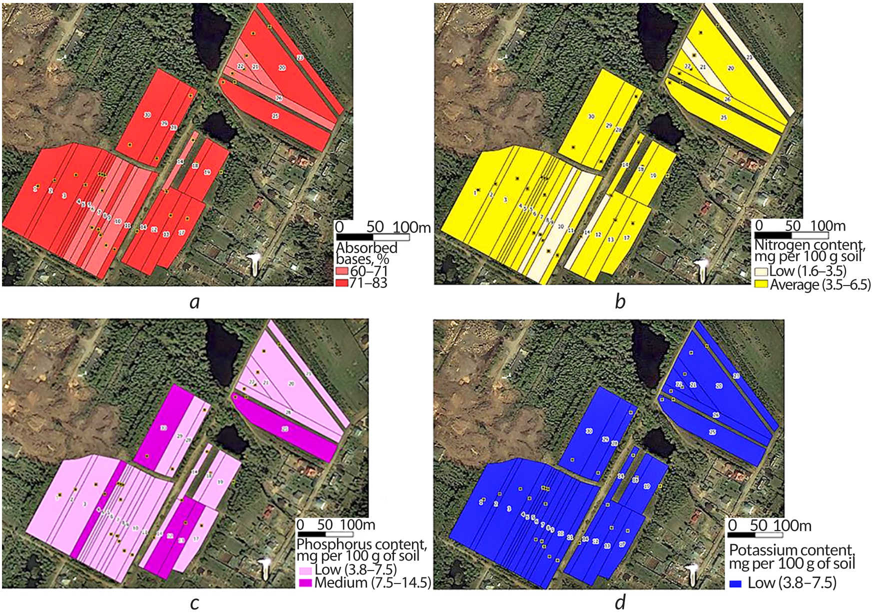

Fig. 3.2 Cartogram of some content's degree in the soils:
a – base saturation; *b* – nitrogen content; *c* – phosphorus content; *d* – potassium content
Source: by authors in 2024 year

The pits are located on a gentle slope with a western exposure with a slope of less than 4°C, in its lower part. Vegetation: mixed grass. The elevation above the depression in the forest according to the leveling traverse was 3.1 m, the diameter of the mound was 22 m. The soil on the mound effervesces from 10% HCl from a depth of 70 cm. Profile formula: O-Ad-A-AE-BE-BT-Cca, soil name: gray forest typical residual-carbonate. In the depression, the soil does not effervesce from 10% HCl throughout the profile. Profile formula: O-Ad-A-AE-A_1-A_2-A_3, soil name: gray forest with a buried humus horizon.

At the turn of the century, the period of traditional cartography was replaced by a period of geoinformation mapping and the active use of computer technologies. On the fallow land, the pits were laid on a gentle slope of southern exposure with a slope of less than 2°C (**Fig. 3.3**).

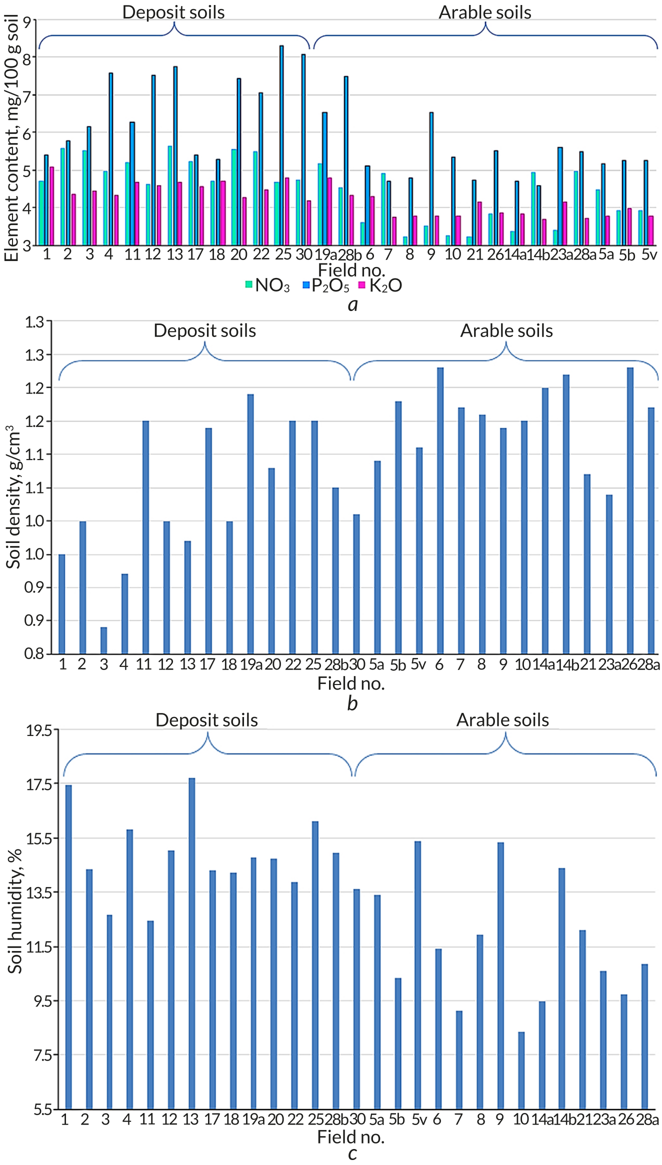

Fig. 3.3 Comparative indicators of soil parameters in the selected fields of Sheki Regional Center: *a* – element content; *b* – soil density; *c* – soil humidity

The vegetation is represented by lush forbs with birch and aspen undergrowth. The height of the micro-elevation was 40 cm, the diameter was 38 m. The soils do not effervesce from 10% HCl throughout the profile. The soil profile formula on the micro-elevation is A_1-A_1/p-AE-BE-BT-Cg, the name of the soil is gray forest gleyic. In the micro-depression, the profile formula is: A_1-A_1/p-A-AE-BE-BT-Cg, the name of the soil is gray forest with a buried humus horizon. According to the 2004 Classification, the soils on both elements of the microrelief belong to the same type – agro-gray gleyic soils of the texturally differentiated soils of the postlithogenic trunk, with the profile formula: A-AY-AEL-BEL-BT-Cg. Comparative indicators (soil density, humidity) of soil parameters in the selected fields (deposit and arable) of Sheki Regional Center were determined (**Fig. 3.3**).

The goal of analyzing the dependence of stand productivity on soil conditions based on production materials: field soil survey and forest management data. The average height of the stand (in meters) at the age of 80 years, i.e. the stand quality class, expressed in an arithmetic scale, was chosen as the indicator of stand productivity. To characterize the soil conditions, those indicators were selected from the soil survey materials that can be expressed in arithmetic scales [22], 4,549 pine stands were analyzed. Correlation analysis confirms the dependence of the stand quality (average height at 100 years) on the selected soil indicators (**Table 3.1**). Multiple R = 0.67, normalized R_2 = 0.45 with a standard error of 1.77. Of the selected soil indicators, the least significant were the capacities of the humus and podzolic horizons.

The remaining indicators have a significant impact on the productivity of pine forests and should be taken into account when forecasting forest development and forestry planning. The next stage of our analysis was to test the hypothesis about changes in the productivity of pine forests with age. The presented investigations mainly assessed the current state, dynamics, and comparative parameters of erosion, emphasizing its repercussions on fertility indicators of agricultural soils. Expanding the research was imperative to highlight the correlation between soil erosion and its consequences on the local ecosystem. Beyond the immediate impact on soil fertility, erosion can lead to enhanced sedimentation in water bodies, affecting water quality and aquatic habitats [23, 24]. Multiple linear correlation analysis confirms the dependence of the productivity of stands (average height of a stand at 80 years) on age and soil parameters (**Table 3.2**). Multiple R = 0.74, normalized R_2 = 0.54 with a standard error of 1.61. It should be noted that the coefficient of the variable "age of a stand" is significant. To confirm the independence of the sample from the age of the stands, it is possible to analyze the dependence of the age of pine forests on soil parameters (**Table 3.3**). Multiple R = 0.14, normalized R_2 = 0.02 with a standard error of 30.00.

Table 3.1 Results of multiple linear regression analysis of the dependence of planting productivity on soil properties

Variables	Regression coefficients	Standard error	*t*-statistic	*R*-value	Lower 95%	Upper 95%
Y-intersection	3.627E+01	9.889E−01	3.668E+01	3.300E−258	3.433E+01	3.821E+01
Org. hor. thickness	−9.457E−02	2.584E−02	−3.659E+00	2.556E−04	−1.452E−01	−4.390E−02
Hum. hor. thickness	1.063E−02	6.949E−02	1.530E−01	8.784E−01	−1.256E−01	1.469E−01
A_2 hor. thickness	1.477E−02	9.648E−03	1.531E+00	1.259E−0	−4.145E−03	3.368E−02
% Phys. clay	1.176E−02	4.718E−03	2.493E+00	1.270E−02	2.513E−03	2.101E−02
Moisture cont.	−1.012E−01	1.424E−02	−7.103E+00	1.411E−12	−1.291E−01	−7.325E−02
Upper gleyization layer	−1.638E−02	9.370E−04	−1.748E+01	3.039E−66	−1.821E−02	−1.454E−02
Degree of claying	−1.120E−01	7.735E−03	−1.449E+01	1.610E−46	−1.272E−01	−9.688E−02
% Phys. clay of parent rock	7.300E−03	1.794E−03	4.069E+00	4.798E−05	3.783E−03	1.082E−02

Table 3.2 Results of multiple regression analysis of the dependence of plantation productivity on age and soil properties

Variables	Regression coefficients	Standard error	*t*-statistic	*R*-value	Lower 95%	Upper 95%
1	2	3	4	5	6	7
Y-intersection	3.779E+01	9.016E−01	4.192E+01	0.000E+00	3.602E+01	3.956E+01
Soil age	−2.445E−02	7.977E−04	−3.065E+01	1.008E−187	−2.602E−02	−2.289E−02
Org. hor. thickness	−1.049E−01	2.353E−02	−4.460E+00	8.400E−06	−1.510E−01	−5.880E−02
Hum. hor. thickness	−2.406E−02	6.327E−02	−3.804E−01	7.037E−01	−1.481E−01	9.997E−02

Continuation of Table 3.2

1	2	3	4	5	6	7
A_2 hor. thickness	8.570E–03	8.785E–03	9.756E–01	3.293E–01	–8.652E–03	2.579E–02
% Phys. clay	1.405E–02	4.296E–03	3.270E+00	1.083E–03	5.626E–03	2.247E–02
Moisture cont.	–8.517E–02	1.298E–02	–6.563E+00	5.872E–11	–1.106E–01	–5.973E–02
Upper gleyization layer	–1.531E–02	8.536E–04	–1.794E+01	1.428E–69	–1.699E–02	–1.364E–02
Degree f claying	–1.119E–01	7.041E–03	–1.589E+01	2.419E–55	–1.257E–01	–9.805E–02
% Phys. clay of parent rock	5.947E–03	1.634E–03	3.640E+00	2.754E–04	2.744E–03	9.150E–03

Table 3.3 Results of multiple regression analysis of the dependence of planting age on soil properties

Variables	Regression coefficients	Standard error	*t*-statistic	*R*-value	Lower 95%	Upper 95%
Y-intersection	6.205E+01	1.675E+01	3.705E+00	2.142E–04	2.921E+01	9.488E+01
Org. hor. thickness	–4.235E–01	4.376E–01	–9.678E–01	3.332E–01	–1.282E+00	4.345E–01
Hum. hor. thickness	–1.419E+00	1.177E+00	–1.206E+00	2.281E–01	–3.726E+00	8.885E–01
A_2 hor. thickness	–2.535E–01	1,634E–01	–1.551E+00	1.209E–01	–5.738E–01	6.682E–02
% Phys. clay	9.344E–02	7.991E–02	1.169E+00	2.423E–01	–6.322E–02	2.501E–01
Moisture cont.	6.547E–01	2.412E–01	2.714E+00	6.677E–03	1.817E–01	1.128E+00
Upper gleyization layer	4.345E–02	1.587E–02	2.738E+00	6.198E–03	1.234E–02	7.456E–02
Degree of claying	7.822E–03	1.310E–01	5.971E–02	9.524E–01	–2.490E–01	2.646E–01
% Phys. clay of parent rock	–5.533E–02	3.038E–02	–1.821E+00	6.866E–02	–1.149E–01	4.235E–03

Based on production materials, the dependence of pine forest productivity on such soil properties as the thickness of organogenic horizons, the granulometric composition of the soil and parent rock, the degree of soil profile moisture, the depth of gleyed horizons and the degree of gleyization is confirmed. The change in the quality of pine forests during their growth is also statistically confirmed. All this indicates the need and possibility of developing growth standards for tree plantations taking into account soil information [25].

Modern soil cover of natural and cultivated cenoses used in agriculture of Greater Caucasus southern slope plains horizontal distribution shows the difference in relief structure of the territory (**Fig. 3.4**).

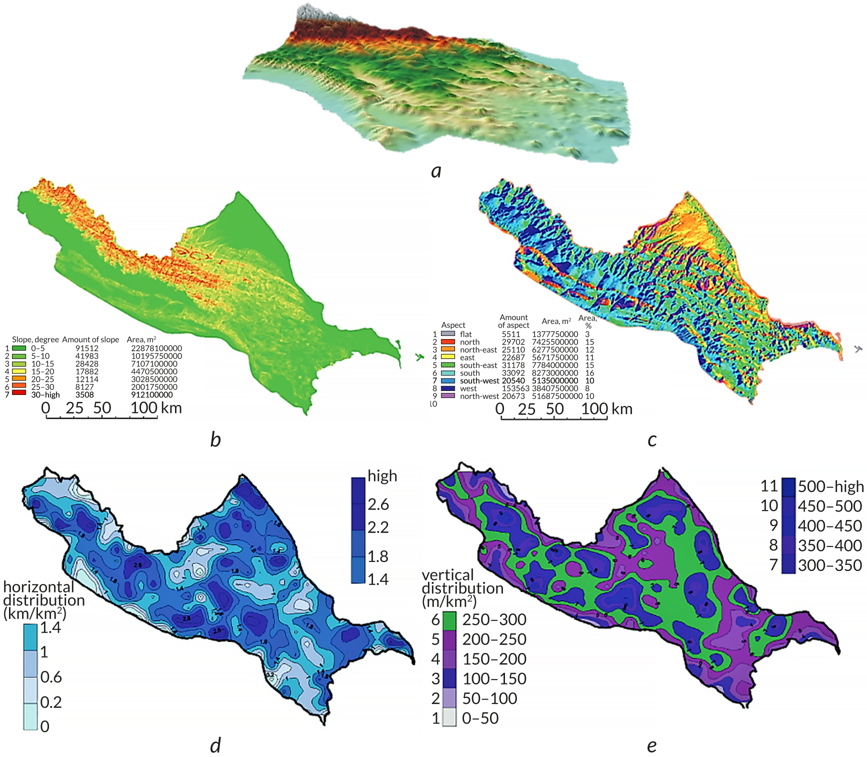

Fig. 3.4 Maps of the Greater Caucasus: *a* – map of the southeastern part of the Greater Caucasus in 3D forma; *b* – slope map of Greater Caucasus plains; *c* – aspect map of the Greater Caucasus plains; *d* – horizontal and distribution maps of the Greater Caucasus plains; *e* – vertical distribution maps of the Greater Caucasus plains

3.3.3 Discussion of the results

In developing countries, special attention is paid to the agricultural sector, which is the main condition for social sustainability. Anthropogenic impact on ecosystems creates a number of environmental problems. Unsustainable natural landscapes are destroyed under the influence of irrational management methods. There is widespread irrigation degradation, secondary salinization and other adverse phenomena that contribute to the alienation of hundreds of thousands of hectares of fertile land from agricultural use. The main soil ecological indicators of Greater Caucasus natural and cultivated cenoses were studied. These studies of modern soil cover are of great importance for the development of agriculture in the country. The selected territory of the study is the most important tourist area due to the enrichment of natural vegetation and the beauty of relief landscapes. The obtained results show the differences and similarities in environmental parameters between soil sections. Horizontal and vertical distribution maps showed southern slopes of Greater Caucasus landscapes in Azerbaijan. The statistical parameters of multiple regression analysis of the dependence of plantation productivity on the age and properties of the soil showed deviations in different horizons. Currently, in order to solve the above problems, the creation of interactive electronic soil ecological assessment maps and maps of soils is relevant. The presented work was to study the current state of typical mountain-forest brown, residual carbonate mountain-forest brown and mountain-gray-brown soils formed on the north-eastern slope of the Greater Caucasus, to analyze their morphogenetic horizons of the structure based on the International WRB system and to determine the possibility of their use in agriculture.

3.4 Conclusion

Microscopic mold fungi, the main destructors of organic matter, were found in all the studied samples of gray forest soil, which is due to favorable physicochemical conditions for them: acidic reaction of the environment (pH 5.9), sufficient amount of nutrients (organic content is 4.9–4.7%), and high humidity (23.7–27.9%). At the same time, in the soil of microdepressions on the fallow land, their number is the highest and amounts to 7.0–8.0 thousand CFU/g in the A and A_1 horizons. The maximum number of actinomycetes was found in the virgin gray forest soil on the hillock, where it amounted to 360 thousand CFU/g, which is 5 times more than in the same soil horizon of the depression on the natural soil and 30 times more than in the soils of both elements of the microrelief on the fallow land. In taxonomic terms, micromycetes in the studied gray forest soil are represented by the following dominant species: *Penicillium notatum*, *Penicillium chrisogenum*, *Trichoderma viride*, *Trichoderma lignorum*, *Aspergillus niger*, *Mucor* ssp., *Paecilomyces* ssp., *Crustosum* ssp. Representatives of the genera *Fusarium* and *Monatospora* are rare. As a result of the analysis of the obtained data, the total reserves of organic matter of the secondary spruce forest were determined, which amount to from 21.5 to 32.7 kg·m^{-2}. When small-leaved forests transition to the total biomass of perennial parts of the stand increases, which contributes to the accumulation of organic matter by the ecosystem. The greatest contribution to the accumulation of organic matter by the studied plant communities is made by perennial parts of the forest stand (up to 88%) and litter of the forest stand (up to 15%), which determines the need for a more detailed assessment of these components of forest ecosystems during monitoring observations. The C content of microbial biomass in humus horizons of sod soils ranges from 0.49 to 1.29 mgC/g. Its reserves in the 0–35 cm layer vary from 1.39 to 2.74 tC/ha, which can be assessed as significant for this type of soil. Microbiological and biochemical indicators can be used in assessing technological methods to determine the rational use of gray forest soils.

References

1. Kaplan, G., Gašparović, M., Alqasemi, A. S., Aldhaheri, A., Abuelgasim, A., Ibrahim, M. (2023). Soil salinity prediction using Machine Learning and Sentinel – 2 Remote Sensing Data in Hyper – Arid areas. Physics and Chemistry of the Earth, Parts A/B/C, 130, 103400. https://doi.org/10.1016/j.pce.2023.103400
2. State statistical committee of the Azerbaijan Republic. Agriculture, Forestry, and Fishing/Plant-Growing. The State Statistical Committee of the Republic of Azerbaijan. Available at: https://stat.gov.az/source/agriculture/?lang=en Last accessed: 03.05.2024
3. Taghadosi, M. M., Hasanlou, M., Eftekhari, K. (2019). Retrieval of soil salinity from Sentinel-2 multispectral imagery. European Journal of Remote Sensing, 52 (1), 138–154. https://doi.org/10.1080/22797254.2019.1571870
4. Chen, H., Wu, J., Xu, C. (2025). Optimization of Multi-Source Remote Sensing Soil Salinity Estimation Based on Different Salinization Degrees. Remote Sensing, 17 (7), 1315. https://doi.org/10.3390/rs17071315

5. Nasirova, A. I., Aliyeva, M. M., Mammadova, R. N., Hasanova, T. A. (2022). Bio-ecological Edificators of Gray-Brown Soils in Ganja-Gazakh Massif (Azerbaijan). Environment and Ecology Research, 10 (3), 392–397. https://doi.org/10.13189/eer.2022.100307
6. Hasanova, T. A., Mammadova, G. I., Bunyatova, L. N., Gahramanova, A. Y. (2021). Importance of Biodiagnostics and Irrigation Gray-Brown Soils. Universal Journal of Agricultural Research, 9 (3), 63-69. https://doi.org/10.13189/ujar.2021.090301
7. Allahverdi, H. T. (2015). Complexes (Ecogroups) of the Invertebrates, Phytomass and Dynamics of Microbiological Population and Their Importance at Grey-brown Soils Diagnostics in Azerbaijan. Universal Journal of Agricultural Research, 3 (4), 130–134. https://doi.org/10.13189/ujar.2015.030403
8. Hasanova, T., Abasova, N. (2024). Statistical analysis of the soil activity in Sheki-Zagatala economic region. EUREKA: Life Sciences, 3, 3–10. https://doi.org/10.21303/2504-5695.2024.003564
9. Nazim, R., Oqtay, A. (2024). Study of Bio-ecological Indicators of Oak Species in Azerbaijan. Proceedings of the Bulgarian Academy of Sciences, 77 (10), 1466–1473. https://doi.org/10.7546/crabs.2024.10.06
10. Bunyatova, L. N., Mammadova, G. I., Hasanova, T. A., Gahramanova, A. Y., Akhundova, S. M., Alakbarli, G. Y. (2025). Main eco-properties of hazelnut (Corylus avellana L.) on the Sheki-Zagatala economic region. International Journal of Advances in Applied Sciences, 14 (1), 77–85. https://doi.org/10.11591/ijaas.v14.i1.pp77-85
11. Mirzezadeh, R., Hasanova, T., Asgarova, G. (2025). Comprehensive studies of greater caucasus river valleys soils. EUREKA: Life Sciences, 1, 11–18. https://doi.org/10.21303/2504-5695.2025.003654
12. Macnunlu, K., Hasanova Baba-Zade, R., Hasanova, T. (2025). Ecological Sustainability of Agroecosystem and Productivity Assessment in the Barda Area using NDVI and SAVI. Advances in Biology & Earth Sciences, 10 (1), 148–157. https://doi.org/10.62476/abes.101148
13. Ismayil, A., Alakbar, R., Gudrat, V., Islam, R., Allahverdi, T. (2025). Soil Salinization in Ujar Region of Azerbaijan with Index Application and Various Methods Comparison. Proceedings of the Bulgarian Academy of Sciences, 78 (6), 946–954. https://doi.org/10.7546/crabs.2025.06.18
14. Ismayilova, A. A., Shukurov, S. Kh., Hasanaliyeva, L. H., Osmanova, S. F., Asgarova, G. F., Hasanova, T. A. (2025). Modern soil cover of natural cenoses and agrosenoses landscapes of the Kur-Araz plain. Advances in Biology & Earth Sciences, 10 (2), 122–137.

15. Shukurov, S. Kh., Mammadova, G. I., Aliyeva, M. M., Nasirova, A. I., Hasanova-Baba-Zade, R. A. (2025). Ecological state of soil-landscape complexes in Azerbaijan. SABRAO Journal of Breeding and Genetics, 57 (3), 1136–1147. https://doi.org/10.54910/sabrao2025.57.3.25
16. Mammadova, A. O., Mammadova, R. N., Ashurova, N. D. (2024). Ecological assessment of pastures semi-deserts and dry steppes of Azerbaijan. International Journal of Advances in Applied Sciences, 13 (2), 439–446. https://doi.org/10.11591/ijaas.v13.i2.pp439-446
17. Aliyeva, M. M., Mammadova, R. N. (2023). Determination of phytomass species diversity in mountain-forest brown and mountain-forest brown soils in recent years. Advances in Biology & Earth Sciences. Jomard publishing, 8 (1), 103–106.
18. Săvan, G., Păcurar, I., Roșca, S., Megyesi, H., Fodorean, I., Bilașco, Ș. et al. (2024). GIS-Based Agricultural Land Use Favorability Assessment in the Context of Climate Change: A Case Study of the Apuseni Mountains. Applied Sciences, 14 (18), 8348. https://doi.org/10.3390/app14188348
19. Mammadova, G., Gahramanova, A., Bunyatova, L., Babayeva, T., Huseynova, L. (2024). Determination of Main Properties and Fertility Capacity of Soils under Hazelnut Cultivation in Azerbaijan. Proceedings of the Bulgarian Academy of Sciences, 77 (4), 618–626. https://doi.org/10.7546/crabs.2024.04.18
20. Akhundova, S. M., Mammadova, G. I., Bunyatova, L. N., Alakbarli, G. Y., Ahmadova, A. B., Aliyev, F. T. et al. (2025). Study of the modern bio-ecological state Absheron coastlines. Advances in Biology & Earth Sciences, 10 (1), 168–176. https://doi.org/10.62476/abes.101168
21. Wang, Y., Hu, B., Hong, Y., Chen, S., Zhao, C., Peng, J. (2024). Minimize of moisture effects from laboratory simulations of in-situ Vis-NIR spectral for the prediction of soil salinity. Infrared Physics & Technology, 137, 105194. https://doi.org/10.1016/j.infrared.2024.105194
22. Mammadzada, V. T., Aliyeva, M. M., Rzayeva, 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. http://doi.org/10.54910/sabrao2025.57.3.29
23. 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. http://doi.org/10.54910/sabrao2024.56.1.24

24. Sadigov, R. A., Mustafayev, M. G., Azimov, A. M. (2024). Analysis of the erosion processin undeveloped mountain gray-cinnamon (chestnut) soils in the shamkirchay water reservoir basin. Sabrao Journal of Breeding and Genetics, 56 (5), 2067–2078. https://doi.org/10.54910/sabrao2024.56.5.29