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ECOLOGICAL STATE OF SOIL-LANDSCAPE COMPLEXES IN AZERBAIJAN REPUBLIC

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SUMMARY

The following study focused on the identification of the current ecological state of soil-landscape complexes and ecological assessment of the plants and animals' needs for their protection and rational use in the Shirvan Region, Azerbaijan. For the first time, an ecological-energetic assessment of soil-landscape complexes occurred, with a detailed soil bonitet scale compiled, coefficients of their comparative values determined, and maps of soil ecological-energetic assessment assembled with ecological massifs. Agrochemical measures succeeded development for surface and radical improvement of landscape complexes. The environmental assessment maps with scientifically based set of measures aimed at protecting the landscape ecosystems for managing soil fertility and increase their productivity. The main prerequisites for the development of desertification in Azerbaijan with an area of 1.3 million hectares were their high susceptibility to anthropogenic loads (unsystematic grazing, extreme overloads, and plowing of pasture lands) and the natural fragility. Pasture plants also revealed insufficient supply of nutrients: digestible protein, phosphorus, carotene, and the indicated microelements, and the deficiency is around 24%–28%.

Keywords: Plants, nutrients, landscape complexes, ecological-energetic assessment, microelements, ecological assessment, ecological state

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Key findings: The inaugural conduct of an ecological-energetic assessment of soil-landscape complexes compiled a detailed soil bonitet scale, determined the coefficients of their comparative values, and assembled soil ecological-energetic assessment maps by ecological massifs. For surface and radical improvement of landscape complexes, the study developed agrochemical measures.

INTRODUCTION

In the natural resource potential, causes of the primary negative agroecological variations comprised the plowing of lands, large-scale melioration work, overloading of pastures with small animals, and man-made impacts (Ahmadi *et al.,* 2022). The bioproductivity of lands, soil properties, and the soil scores mainly depended on the intensity of soil use for agricultural purposes (AzStat, 2024). The effective soil fertility was largely dependent on climatic conditions. Different soils formed under certain combinations of soil-forming factors should be beneficial for economic purposes. Soil grading has an important agronomic, ecological, and economic significance (Aliev, 2021; Aliyeva and Mammadova*,* 2023). Currently, the meadow landscapes bear significant anthropogenic impact in Azerbaijan (Babaev *et al.,* 2017). However, the influence of soil properties on the bonitet also varies (National Encyclopedia of Azerbaijan, 2018).

Based on plants' needs for soil and the environment, an ecological assessment of soils commenced according to special assessment scales and revealed the limiting factors for the development of phytocenoces—lack of moisture, which eventually leads to soil salinization, desertification, and degradation. Soil properties affecting the crop yield are often not within the topsoil but in deeper horizons of the soil's profile (Dospekhov, 1985; Baybekov*,* 2018). The influence of individual soil properties on the grain yield of various crops grown in these specific regions varies (FAO, 2020). According to existing methods, soil quality assessment relied on the properties of the arable and upper humus layers (Garcia *et al*., 2020).

The crop plant's roots penetrate deeper than 25 cm, and the properties of subsurface layers can influence the soil quality to a greater extent, as in the case of soil salinization. Today, the loads on them are ten-times higher than the norm. For using natural resources, a defined ecological direction worldwide has become a guide, particularly to preserve the natural environment, develop resource-saving programs, and prioritize developmental projects for rational use of said resources. During the process of deepening degradation in the original properties of landscape ecosystems, convergence occurs, leading to the emergence of unproductive soils (Hasanova *et al.,* 2021).

In the main chain, the problem comprises livestock growth and the excessive loads of land depletion. Soil degradation leads to the reduction in biological diversity and the destruction of the biocenotic structure of natural ecosystems, which hinders the occurrence of natural processes of self-restoration (Hossain, 2019). The unique nature of complex landscapes as a habitat for zonal plants and animals requires developing measures to preserve the biological diversity, since formulating appropriate measures is necessary for a successful solution to the rational use of soil resources (IUSS Working Group, 2006, 2015).

Studies are insufficient on the technology for assessing the ecological state of landscapes and forecasting methods for carrying out special agrochemical measures, as well as the issues of permissible loads, serving as the basis for selecting the research (Kazakov, 1990). The wind regime is also one of the crucial climatic factors. Coastal breezes and the Absheron khazri are especially regular. Khazri has a detrimental effect on plant growth, especially ephemeral plants, during the autumn-winter and early spring periods. The climate of the studied areas is dry subtropical, with long, hot summers and mild winters (Methodological Recommendations on Soil Bonitation of Fodder Lands of Azerbaijan SSR, 1978; National Encyclopedia of Azerbaijan, 2018).

From East to West, as the terrain rises above sea level, toward the foothill slopes of the Greater and Lesser Caucasus, the climate gradually becomes moderately warm due to a decrease in the hottest months to three. Meanwhile, the rational decrease in the coldest month temperature is 0 °C - -1 °C. According to annual precipitation, three main zones are distinct in the territory, i.e., coastal, transitional, and continental, which differed sharply in the time of occurrence with maximum and minimum showers (Nasirova *et al.,* 2022). In the selected complex landscapes of Azerbaijan, the climate characteristics are insufficient precipitation during the year, uneven distribution of precipitation by seasons, high average temperature during summer months, relatively warm winter, and sometimes accompanied by cold winds.

In the Shirvan Region, the following tasks comprised eight immediate plans. These will begin to analyze current environmental conditions in the eco-landscapes, characterize the impact of natural and anthropogenic factors on the soil and vegetation cover, and conduct an appraisal and agro-industrial grouping of soils. Other tasks will compile the scales in accordance with plant requirements and an environmental assessment of soils and conduct an environmental and energy assessment of landscape complexes, considering livestock requirements. Subsequently, activities include to calculate the average weighted grade and the comparative advantage coefficient of each landscape complex and compile maps of the environmental and energy assessment of soil and landscape complexes of the main massifs. Finally, the plans hope to develop the system of agrochemical measures aimed at managing and increasing fertility, productivity, and protecting the ecosystem (Hasanova *et al*., 2022).

Soil appraisal preceded the qualitative assessment of forage lands, then a qualitative assessment of ecosystem lands continued, with the assessment reliant on the type of phytocenosis, and the criterion for assessment is the productivity of forage plants (Rowell, 1999). Based on the appraisal and qualitative assessment of natural forage soils, an economical and environmental assessment succeeded. This developed conditions for carrying out land cadastral work in the Republic, as well as for forecasting the forage crops yield and soil protection. For other zonal soils, the climatic coefficient's calculation was relative to the standard, i.e., for other types of soil (0.99), and for types of gray soils and for light chestnut (0.95). It becomes clear that moisture deficiency negatively affects flat soils used for forage crops. Thus, by using the soil indicators and soil type quality scores based on the main scale, the final quality scale reached compilation.

MATERIALS AND METHODS

The state of landscape is the major component of the ecosystem and also one of the essential factors allowing the assessment of the natural environment's ecological situation (Dospekhov, 2005). The landscape research developed the basis for a systematic approach to solving environmental problems. Atmospheric precipitation also plays a significant role in landscape development (Straalen and Lokke*,* 2012). During 2021–2024, the selected objects of the research were massifs, with a total area, i.e., Mugan-Salyan lowland (416,210 ha), Shirvan steppe (127,700 ha), and Mil-Karabakh steppe (124,600 ha) (Talibi and Hasanova*,* 2022).

In solving the tasks during the entire research period, experimental work proceeded to identify the agroecological features of soil properties and quality, as well as the productivity of forage lands. The studies transpired on selected non-grazed areas in all arrays, covering 40 key sites measuring 10 m × 10 m and 20 m × 10 m (296 sections) on mountain dark chestnut, gray-brown, gray-meadow, and meadow-marsh soils. The sites selected were on the main and most common types of soil, considering the degree of erosion, salinity, granulometric composition, and thickness. The laying of soil pits occurred in key areas, with soil and plant samples collected for laboratory studies. The tasks comprised accomplishing the following steps for soil analyses: hygroscopic moisture – using the gravimetric method, measured total nitrogen and humus according to I.V. Tyurin; granulometric composition – detected by the N.A. Kachinsky method; determine the pH of an aqueous suspension by potentiometric technique; exchangeable Na employing the K.K. Hedroits method; exchangeable Ca^{2+} and Mg^{2+} – applying the D.I. Ivanov method; CO_2, $CaCO_3$ by using a calcimeter; obtaining phosphorus according to the method of Meshcheryakov and potassium by Smith's approach; and complete water extract according to D.I. Ivanov.

By studying the vegetation, the guidelines used were from V.G. Iglovikov, L.G. Ramensky, and T.A. Rabotnov. During the period of the stationary study, an account of the biological productivity of each phytocenosis took place by the mowing method. For calculating the yield of phytocenosis herbage, ephemerals, and other herbaceous vegetation received manual mowing at the height of 2 cm from the soil surface. The yield of ephemerals incurred determination in late April to early May, and for wormwood and arborescent saltwort, in late October to early November. The weight and recording of wormwood formation plants proceeded at the end of April, and for bearded-dry-steppe, in mid-May.

The determination of yield consisted of an area of 1 $m^2 \times 2.5$ m^2, while weighing the cut mass during a wet and dry state, and subsequent conversion of the yield per hectare. In feed samples, the following components determined included raw ash by combustion, crude protein by Kjeldahl, crude fat by Soxhlet apparatus, fiber according to Ginzburg and Stoman, and measuring the hygroscopic moisture and nitrogen-free extractive substances by calculation (Rowell, 1999).

The chemical analysis results served to convert natural feed into feed and energy units. Microelements determination used the atomic absorption method (Jackson, 1958). The main criterion for assessing the quality of forage soils should be their genetic and agro-production properties, which affect the fertility of the soil and the forage yield. Such indicators include reserves of humus, nitrogen, phosphorus, potassium, and absorption capacity in 0–20, 0–50, and 0–100 cm layers of the main types and subtypes of soils, as properties that determine their fertility. The selection of data, systematized by genetic horizons for different soils, was successful by their characteristics. As a result of statistical analysis of each soil indicator, data, standard deviation, variation coefficient, and other characteristics were notable. The selected agrochemical indicators in t/ha of stock in soil layers achieved calculations by using generally accepted methods. In the presented research, the maps of soil and vegetation cover and the literary and cartographic fund were tools used at the Institute of Soil Science and Agrochemistry, Baku, Azerbaijan.

RESULTS AND DISCUSSION

In climatic factors, the wind regime is one of the important issues, and the coastal breezes and the Absheron khazri appeared regular (Babaev *et al*., 2017). Khazri has a detrimental effect on the plant growth, especially ephemeral plants, during the autumn-winter and early spring periods. The climate of the studied areas was dry subtropical, with long, hot summers and mild winters. An ecological direction has been a guide worldwide for using natural resources, giving preference to preserving the natural environment and establishing resource-saving programs and projects for rational use of natural resources. In the original properties of landscape ecosystems, the process of deepening degradation and convergence occurs, leading to the emergence of unproductive lands.

The soils' bioproductivity depended on the intensity of the grazing load, causing a decrease in plants' above-ground biomass, an increase in the mass of excrement and variations in plant associations, humus state, mineralogical composition, and the nature of soil salinization. Moreover, the valuable species for forages got replaced by less valuable ones (Talibi and Hasanova, 2022). The ratio of dry leaf mass to its area (LMA) is a considered key parameter associated with plant growth. With an increase in the grazing load, from one to five per ha, the biomass decreased in summer from 37.7 to 19.5 t/ha, while in autumn, from

Table 1. The soil quality scale in Kura-Araz lowland.

Soil groups	Average weighted final score	Land comparative advantage coefficient	Area	
			Hectares	%
Gray-brown	73	130	87420	14.93
Light gray-brown	65	1.16	104220	17.79
Gray-meadow	49	0.88	187130	31.95
Light meadow-gray	48	0.86	128300	21.90
Marsh-meadow	52	0.93	22770	3.89
Unsuitable lands	10	0.18	55891	9.54
Total	56	1.0	585731	100

64.2 to 34.6 t/ha. Taking the average weighted score of the territory as one unit led to the calculation of the coefficient of comparative land value (Table 1).

An agro-industrial land grouping is the combination of similar taxonomic soil units based on the soil quality scores, ensuring the bioproductivity of agrocenoses in forage lands. In forage plants' ecological assessment on their provision with microelements, one of the major problems in studying landscape ecosystems was the limited information about the microelements in natural objects and the patterns of their distribution in the arid zone. Factually, the microelements contents in different types of soils are unalike, as associated with soil formation factors and soil-forming rocks. As earlier established, sedimentary rocks (sandstone, limestone, and marl) emerged poor in cobalt (9–35 mg/kg), boron (11–30 mg/kg), and copper (12–25 mg/kg).

The microelements content varies depending on the environmental conditions of soil formation, humus content, and the mechanical composition of the soil (Hasanova *et al*., 2022). The percentage of microelements mobility in the soil showed a close association to the presence of $CaCO_3$ in the soil. The presence of $CaCO_3$ (>7%) contributes to a decrease in the mobility of microelements in soils, and therefore, despite the sufficient content of gross reserves in the main types of meadow soils, a complex deficiency of assimilable forms of microelements exists. The analysis on various arrays showed forage plants received insufficient nutrients. Thus, forage plants of the Shirvan steppe – copper and Mugano-Salyan steppe – copper, zinc, and selenium, require consideration in the layscapes environmental assessment, since this factor also affects the livestock's health and productivity, as their diet mostly consists of 78% grass (Sadigov *et al*., 2024).

Soil is one of the main factors of the ecological environment, with exceptional importance, which is crucial in the development of the ecosystem. In general, the saline soils distribution is typical for the soils of mountain meadow landscapes. Lands with average salinity gradations (0.5%–1.0%) are relatively widespread (Babaev *et al.,* 2022). The least saline massifs are prevalent mostly in the foothill areas. The altitude above the sea level both affects the salt's quantity and their qualitative composition. In the foothill areas, the salinization with sulfate (SO_4^{2-}) type is abundant, and chloride is in the lowlands. The chief source of salinization are salt-bearing rocks of lagoon genesis.

Under the presented study, the primary types of soils include gray-brown (chestnut), gray-brown, sierozem, and meadow soils (Figure 1). The gray-brown soil types are widespread in the foothill areas and among the zonal soil types of the Kura-Araz lowland (Figure 2). Moving on to the description of the floristic composition of the vegetation cover of winter pastures, the total number of species was 953, as distributed per biological characteristics—shrubs (35 species, and 7.0%) semi-shrubs (19 species, and 2.0%), perennial grasses (397 species, and 40%), and annual grasses (519 species, and 53%). About the endemics of the regions, it is noteworthy that the regions were not particularly rich in their species composition. The flora of the semidesert and foothill-steppe

Figure 1. Soil samples collected in studied regions.

regions of Azerbaijan has 69 endemic species and were 8.2% of their total number.

In past years, as a result of geobotanical studies, it was evident that the desert vegetation of the Shirvan territory mainly occurred through a vegetation cover, consisting of saltwort and wormwood. The dominant species identified included mesophytes (*Aegilops geniculata* or ovate goatgrass*, Avena pilosa, Poa pulbosa, Medicago minima)*; halophytes (*Aeluropus repens, Eremopyrum orientale, Hordeum geniculatum, Halostachys caspica, Petrosimonia brachata, Sasola crassa, Salsola ericoides, Salsola dendroides)*; mesohalophytes (*Salsola nodulosa, Tamarix ramosissima, Artemisia srowitsiana)*; hygrophytes (*Balloschoenus maritimus, Jancus maritimus)*; and psammophytes (*Astragalus hyrcanus, Plantago indica,* and *Artemisa scoparia)* (Hasanova and Asgarova, 2021; Jalilova and Hasanova Baba-zade, 2024).

On winter pastures, valuable forage plants comprised *Anisantha rubens* L. Nevski, *Bromus japonicus* Thunb. and others, which are part of the ephemeral ones. These and many others bloom in early spring and are well-eaten by sheep and cattle.

The Salsoletum formation develops in different ecological conditions, in arid subtropical regions resistant to salinization, drought and heat, in most cases, on saline rocks (Macnunlu *et al*., 2025). It is widespread in the foothills of the sole, according to the mechanical composition, which is formed in heavy, saline, solonchakous, dry soil. The *Salsoletum nodulosa* formation can be considerably a genetic stage developing in saline soils from the point of view of differentiation of soil horizons replacing each other and decomposition of salts (Ikhtiyar and Bahram, 2023).

The individual landscape areas with low productivity can refer to the presence of weeds and harmful plants in natural grass stands. In the subtropical semidesert and dry steppe, the main plant groups with forage characteristics include potash, halostachys, fat-saltwort, haemanthus, heather-saltwort, semideserts, heather-saltwort-wormwood, wormwood, ephemeral dry steppes, wormwood-beard, wormwood-feather-grass, bearded, steppes, and meadow vegetation (Huseynova *et al*., 2024; Shukurov, 2024). The maps showed the forage productivity and the maximum load per hectare (IUSS, 2015). The 20 chief plant groups identified on the pastures include semidesert (6), dry-steppe plain (7), dry-steppe foothill (5), and meadow-like (2). The productivity of the most typical and valuable for forage were ephemeral-wormwood, wormwood, heather-wormwood, and pastures, which varies with 0.45–0.55 t/ha, and a considered very low indicator (Sadigov *et al*., 2024).

In steppe landscapes, the grazing rate was 2.1 heads/ha, productivity was 0.635 t/ha, the average weighted score of the landscape

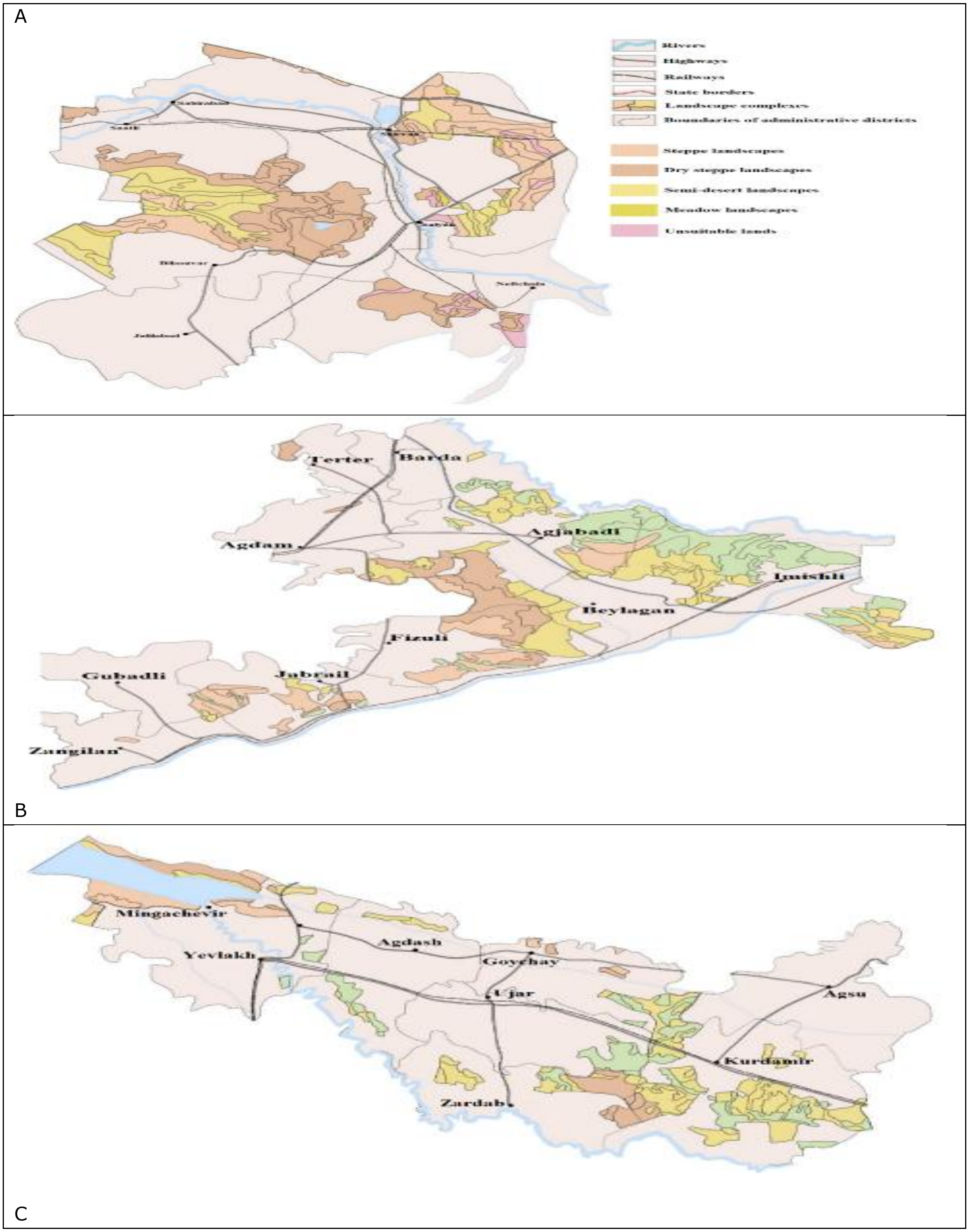

Figure 2. Map of complex landscapes of the Kura-Araz lowland. A) Shirvan Plain, B) Mugano-Salyan Plain, and C) Mil-Karabakh Plain.

complex was 74, and the quality score of microelements in soils was 73. Moreover, the quality score for feed energy was 83 and the ecoenergy quality score was 74 (Figure 2). In dry steppe landscapes, the recorded variables were: grazing rate (1.8 heads/ha), productivity (0.366 t/ha), the average weighted score of the landscape complex (59), the quality score of microelements in soils (57), the quality score for feed energy (72), and the ecoenergy quality score (63). For semidesert landscapes, the said parameters consisted of grazing rate (1.72 heads/ha), productivity (0.224 t/ha), the average weighted score of the landscape complex (49), the quality score of the microelements in soils (44), the quality score for feed energy (59), and the ecoenergy quality score (51). In meadow landscapes, the grazing rate was 1.7 heads/ha, productivity was 0.357 t/ha, and the average weighted score of the landscape complex was 52. Meanwhile, the quality score of the microelements in soils was 50, the quality score for feed energy was 55, and the ecoenergy quality score was 53. In unsuitable soils, the quality score of the microelements was 10, the quality score for feed energy was 9.0, and the ecoenergy quality score was 10 (Table 1).

In the Kura-Araz lowland, the ecological assessment of the soils as a whole revealed that the soils were of massif type, with the highest ecological potential (79 points) (Talibi and Hasanova*,* 2022). However, the greatest ecological potential was dominant in pastures on gray-brown powerful soils (89 points), while the least was in the gray earth-meadow soils (74 points) and marsh-meadow soils occupying an intermediate position (78 points). The plants' chemical analysis continued according to generally accepted methods. Based on the analysis, identifying biochemical parameters of the main phytocenoses on gray-brown soils of the semidesert zone succeeded. Qualitative parameters of the most common phytocenoses were in absolutely dry matter (Nasirova *et al*., 2022).

The amounts of nutrients are as follows: protein (8.63), fat (3.65), fiber (38.3), and ash (13.38). In one kilogram of feed, it contains feed units (0.36 kg), digestible protein (0.43 g/kg), calcium (2.45), magnesium (0.31), potassium (1.36), sodium (0.03), copper (9.1 mg/kg), iron (230.0), zinc (28.6), manganese (112.0), and cobalt (0.50 mg/kg). The soil quality scale in Kura-Araz lowland appears in Table 1. Meadow soils occupy lowered relief elements of the alluvial-accumulative region. These soils, formed under the increased moisture conditions, reflected with higher humus content (2%–3%). Gray and meadow-gray soils mainly contribute to the dry subtropics of Azerbaijan (Sadigov *et al.,* 2024).

In general, the ecological assessment of the arrays (74–83 points) indicates the best ecological potential of the soils for plant development, as also evidenced by the obtained results of the biological productivity of steppe, dry steppe, and meadow landscapes. They have a biological productivity coefficient close to and even higher than 1.0. However, the lack of moisture was the limiting factor, and the pastures of the semidesert ecological region had low indicators, which needs further improvement (Nasirova *et al*., 2022).

Based on the results, the maps of ecological-landscape complexes of the main massifs of Azerbaijan, as compiled, successfully identified the areas of soil-landscape complexes of mountain steppes, dry steppes, and semideserts (Macnunlu *et al*., 2025). It also carried out their ecological-energy assessment, with the productivity and its limiting factors also recorded (IUSS, 2015; National, 2018). Maps of complex landscapes of the Kura-Araz Lowland, Shirvan Plain, Mugano-Salyan Plain, and Mil-Karabakh plain are available in Figure 3.

Therefore, the study recommended to use maps for systematic grazing and not to exceed the load in the steppes of approximately 2.0 heads/ha, in dry steppes (1.7–2.0 heads/ha), and in semideserts and meadow landscapes (1.1–1.6 heads/ha) (Figure 4). The total number of plant species was 572, and most of them were annual and ephemeral plants (331 species and 53%), perennial grasses (211 species and 40%), and the remaining species of shrubs and sub-shrubs (30 species and 7%). The winter

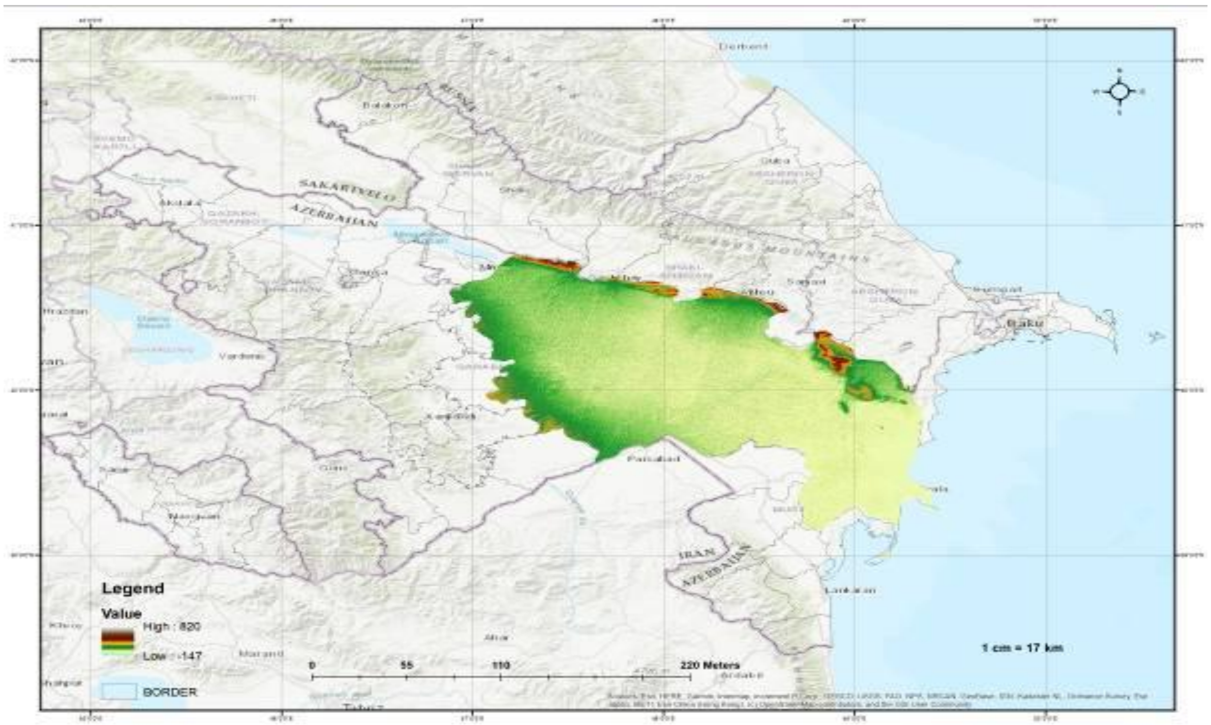

Figure 3. Digital elevation model (DEM) of Kura-Araz Plain for 2021–2024.

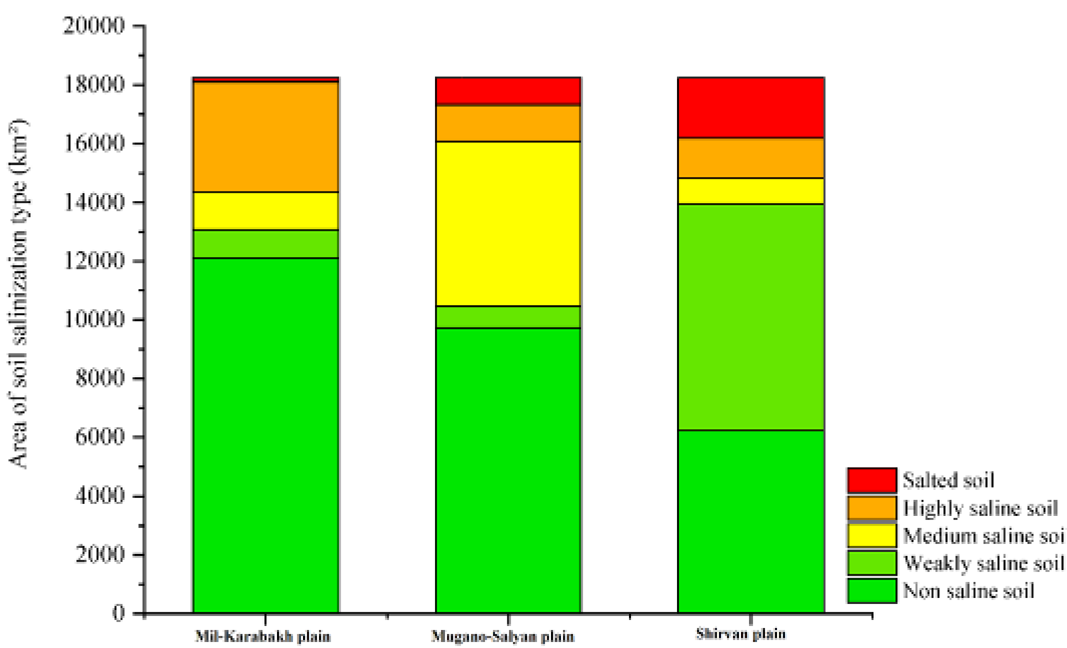

Figure 4. Areas of different soil salinization types at the 0–25 cm depth for 2021–2024.

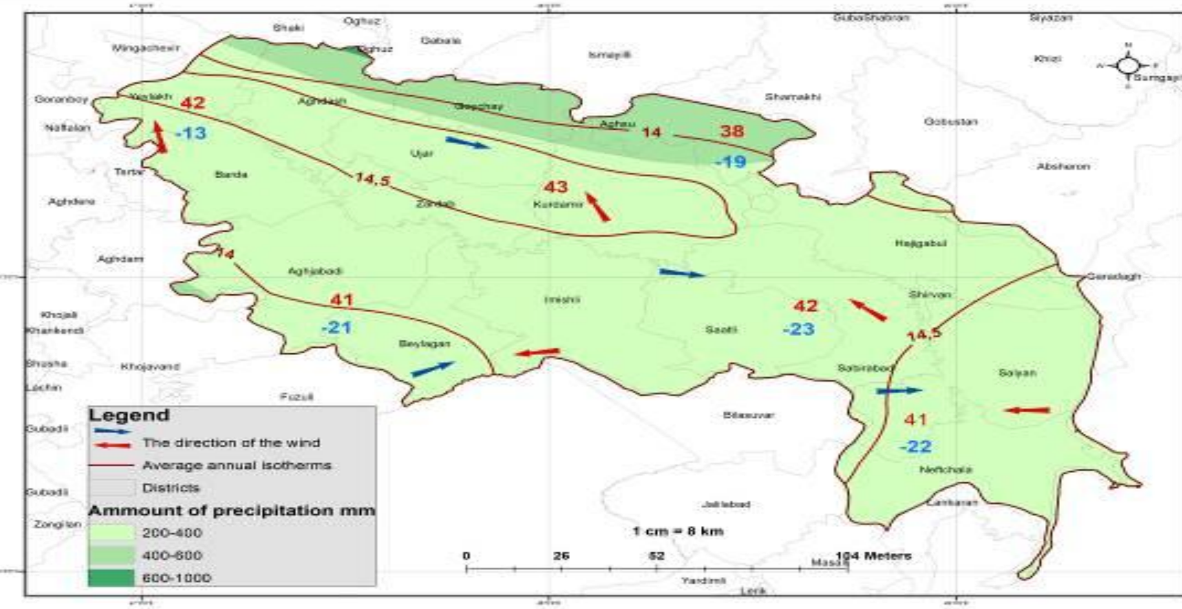

Figure 5. Climate of Kur-Araz lowland for 2021–2024.

pastures flora contains about 40 species (8.0%) of endemic plants, including *Artemisia hanseniana, Onobrychis cyri, Astragalus stevenianus, Vicia cinerla, Pulcinella bulbosa,* and *Trifolium sachokianum*.

Along with unique plants making up the biodiversity, many weedy plants (>50%) existed, with 7.0% of which were poisonous (National, 2018). Determining gray-brown, light gray-brown, gray-meadow, light meadow-gray, and marsh-meadow soil parameters were remarkable (Table 1). Areas of different soil salinization types at the 0–25 cm depth for 2021–2024 occur in Figure 4, with climate conditions of Kur-Araz lowland in the last years shown in Figure 5.

CONCLUSIONS

The main prerequisites for the development of desertification in Azerbaijan with an area of 1.3 million hectares were their high susceptibility to anthropogenic loads (unsystematic grazing, extreme overloads, plowing of pasture lands) and the natural fragility. These soils are prevalent in an extremely arid zone with saline (>17%) and swampy (>3.0%) nature. Steppe, dry-steppe, and semidesert soil types emerged on complex landscapes, with the varieties of gray-brown (chestnut) and light gray-brown soils (>73.0%) undistinguished by the higher fertility. The digital elevation model (DEM) of Kura-Araz plain appears in Figure 4. Groundwater is similar in composition and mineralization to river water. This type shows the characteristic of a decrease in the level and mineralization of groundwater in accordance with changes in the river flow. The mineralization of groundwater has decreased over many years by 2.6–3.4 g/l, and the level has decreased by 0.5–0.8 m.

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REFERENCES

Ahmadi F, Mohammadkhani N, Servati M (2022). Halophytes play important role in phytoremediation of salt-affected soils in the bed of Urmia Lake. *Iran Sci. Rep*. 12(1): 12223. https://doi.org/10.1038/s41598-022-16266-4.

Aliev RZH (2021). Comprehensive approach of the decision existing problems of protection and stabilization of water and soil resources in Azerbaijan. *J. Emerg. Trends Econ. Manag. Sci.* 12(2): 65–68.

Aliyeva MM, Mammadova RN (2023). Determination of phytomass species diversity in mountain-forest brown and mountain-forest brown soils in recent years. *Adv. Biol. Earth Sci.* 8(1): 103–106.

AzStat (2024). State Statistical Committee of the Republic of Azerbaijan. Agriculture, Forestry, and Fishing/Plant-Growing. Available online: https://stat.gov.az/ source/agriculture/?lang=en (accessed on May 3, 2024).

Babaev MP, Ismayilov AI, Huseynova SM (2017). Integration of Azerbaijan's national land classification into the international system. *Monograph – Baku Sci.* 2017, 272*.* ISBN: 978-9952-514-33-9.

Baybekov RF (2018). Nature-like technologies are the basis for sustainable development of agriculture. *Agriculture* 2: 3–6.

Dospekhov BA (1985). Methodology for Field Experiments. Moscow. Agropromizdat.

FAO (2020). FAOSTAT - Food and Agriculture Data. USA: Food and Agriculture Organization of the United Nations. Available at http://www.fao.org/faostat/en/home (accessed on November 06, 2020).

Garcia JS, França MGC, Prasad MNV (2020). Haloremediation for amelioration of salinity. In: M.N. Grigore (ed.), Handbook of Halophytes*.* 1–19. Springer, Cham, Switzerland, https://doi.org/10.1007/978-3-030-17854-3_88-1.

Hasanova Baba-zade R, Amiraslanova M (2024). Digital mapping of soil research results in Ujar Region using a methodological approach. Proceedings of the 5th International scientific and practical conference ''Concepts for the development of society's scientific potential'' held on January 19-20, 2024. Prague, Check Republic. 45(185): 438–445. https://doi.org/10.51582/interconf.19-20.01.2024.053.

Hasanova TA, Asgarova GF (2021). Phytomass of gray-brown soils forming in arid ecosystem of Azerbaijan. Publishing Center Science and Practice, Nizhnevartovsk. *Bull. Sci. Prac. J. Russia* 7(9): 110–115, http://doi.org/10.33619/2414-2948/70.

Hasanova TA, Mammadova GI, Bunyatova LN, Gahramanova AY (2021). Importance of biodiagnostics and irrigation grey-brown soils. *Univers. J. Agric. Res.* 9(3): 63–69. http://doi.org/10.13189/ujar.2021.090301.

Hossain MS (2019). Present scenario of global salt affected soils, its management and importance of salinity research. *Int. Res. J. Biol. Sci.* 1(1): 1–3.

Huseynova SM, Ismayilov AI, Babayev MP, Jafarov AM (2024). Taxonomic attribution of the haplic gleysols of the Azerbaijan Republic in world reference base for soil resources. *Int. J. Adv. Appl. Sci.* 13(1): 116–122. http://doi.org/10.11591/ijaas.v13.i1.pp116-122.

Ikhtiyar AN, Bahram FV (2023). Determination of feed quality and mallow organic residues. *C.R. Acad. Bulg. Sci.* 76(5): 803–809. https://doi.org/10.7546/CRABS.2023.05.17.

IUSS Working Group WRB (2006). World reference base for soil resources 2006 - A framework for international classification, correlation and communication, Rome, Food and Agriculture Organization of the United Nations.

IUSS Working Group WRB (2015). International soil classification system for naming soils and creating legends for soil maps. World soil resources report No. 106. FAO, Rome.

Jackson ML (1958). Soil chemical analysis. Prentice Hall, Inc. Englewood Cliffs. *N.J.J. Soil Sci*. 64(1): 92–103.

Jalilova A, Hasanova Baba-zade R (2024). The influence of global climate change on the hydromorphological regime of river waters in the Sabirabad and Ujar regions. Proceedings of the 6th International Scientific and Practical Conference «*Scientific Goals and Purposes in XXI Century*» held on March 19-20, 2024. Seattle, USA. 43(193): 380–386. https://doi.org/10.51582/interconf.

Kazakov GI (1990). Agrophysical indicators of soil fertility as the scientific basis for its cultivation. In the book: Resource-Saving Soil Cultivation Systems. Moscow. Agropromizdat*,* pp. 32–37.

Methodological Recommendations on Soil Bonitation of Fodder Lands of Azerbaijan SSR (1978). Elm, Baku, (in Russian).

Macnunlu K, Hasanova Baba-zade R, Hasanova T (2025). Ecological sustainability of agroecosystem and productivity assessment in the barda area using NDVI and SAVI. *Advan. in Biology & Earth Sci*. Jomard publ. 10(1): 148-157, http://doi.org/10.62476/abes.101148.

Nasirova AI, Aliyeva MM, Mammadova RN, Hasanova TA (2022). Bioecological edificators of gray-brown soils in ganja-gazakh massif (Azerbaijan). *J. Environ. Ecol. Res.* 10(3). 392–397. http://doi.org/10.13189/eer. 2022.100307.

National Encyclopedia of Azerbaijan (2018). Baku: Azerbaijan National Encyclopedia Scientific Center, *Enols-Fed*. 8: 598.

Rowell DL (1999). Soil Science: Methods & Applications. First Edition. Longman Scientific & Technical; Wiley, Harlow publ. 1994. U*K,* London*.* pp. 368. https://doi.org/10.4324/9781315844855.

Sadigov RA, Mustafayev MG, Azimov AM (2024). Analysis of the erosion process in undeveloped mountain gray cinnamon (chestnut) soils in the Shamkirchay water reservoir basin. *SABRAO J. Breed. Genet.* 56(5): 2067–2078, 2024. http://doi.org/ 10.54910/sabrao2024.56.5.29.

Shukurov KhS (2024). Mapping of soil salinity in Absheron soil based on SENTINEL-2 using LightGBM. *C.R. Acad. Bulg. Sci.* 77(12): 1879–1887. https://doi.org/10.7546/ CRABS.2024.12.17.

Straalen NM, Lokke H (2012). Ecological Risk Assessment of Contaminants in Soil. Reprint of the original First Ed. 1997. Publisher Springer, Chapman and Hall.. 350.

Talibi SM, Hasanova TA (2022). Environmentally significant indicators of mountain meadow soils in Azerbaijan. *Bull. NVSU* 57(1): 102–107. https://doi.org/10.36906/2311-4444/22-1/11.