Advances in Biology & Earth Sciences
Vol.10, No.2, 2025, pp.226-244
https://doi.org/10.62476/abes.102226

Jomard Publishing

SOIL FERTILITY MANAGEMENT IN THE GUSAR-GONAGKEND CADASTRAL DISTRICT OF AZERBAIJAN BASED ON AGROECOLOGICAL LAND ASSESSMENT

Garib Mammadov[1], Sara Mammadova[2], Mahluga Yusifova[1*], Sanam Isayeva[1], Sona Osmanova[1], Kamala Nuriyeva[2], Nazaket Ismayilova[1]

[1]Faculty of Ecology and Soil Science, Baku State University, Baku, Azerbaijan
[2]Institute of Geography, Ministry of Science and Education, Baku, Azerbaijan

Abstract. To create high-yield agro-landscapes in the Gusar-Gonagkend cadastral district of Azerbaijan and maintain their sustainability, a qualitative and agroecological land assessment was conducted. During the field-soil studies, 38 soil profiles were examined and their physical and chemical analyses were performed based on generally accepted methodologies. For the qualitative assessment of the district's soils, methodological recommendations by Karmanov, Mammadov and Mammadova were used. A primary bonitet scale was developed and detailed and final bonitet scales were compiled using correction coefficients. The average bonitet score of the cadastral district was 77. The "Map of soil quality assessment of the Gusar-Gonagkend cadastral district" (1:100,000 scale) was compiled. For the agroecological assessment of soils, a specialized evaluation scale was developed based on the degree of manifestation of specific soil characteristics in accordance with the ecological requirements of plant formations. Calculations showed that in the cadastral district, the highest agroecological scores in the high-mountain zone were attributed to mountain-meadow chernozem-like soils, while in the low-mountain zone, mountain-gray-brown dark and ordinary soils received the highest scores (93 points). Based on the assessment of soil fertility in the Gusar-Gonagkend cadastral district, a conceptual scheme has been developed to ensure the effective use and protection of the land.

Keywords: *Agricultural land, bonitet score, correction coefficients, evaluation scale, agroecological assessment, soil classification.*

Corresponding Author: *Mahluga Yusifova, Faculty of Ecology and Soil Science, Baku State University, Baku, Azerbaijan, e-mail: mehluqe_yusifli@mail.ru*

Received: *12 April 2025;* ***Accepted:*** *17 June 2025;* ***Published:*** *6 August 2025.*

1. Introduction

Issues related to the effective use and protection of land resources are among the key state concerns and are considered one of the main strategic directions of government policy.

In the modern era, with the rapid advancement of science and technology, alongside fundamental research on soil degradation processes, increasing importance has been given to developing new scientific-methodological, legal and organizational approaches aimed at regulating and assessing the ecological state of the natural environment and soils. These approaches take into account both natural conditions and the economic significance of specific regions. From this perspective, various methodologies used by scientists worldwide for soil fertility assessment and conservation stand out due to their innovation and effectiveness.

Khosravi Aqdam et al. (2023) assessed soil fertility in agricultural lands in northwestern Iran and identified the main limiting factors at different elevation levels. It was found that in all elevations $CaCO_3$ and soil salinity were not limiting factors, but high pH, low organic matter, total nitrogen, available phosphorus and micronutrients deficiencies were the major limiting factors for soil fertility in agricultural lands.

According to studies by Fatimazahra et al. (2025), countries such as India, China and Iran have transformed soil fertility mapping into a non-invasive, large-scale process that enhances agricultural decision-making. They promote GIS, RS, pedometrics and DSM, which are crucial for addressing environmental challenges.

Zaheri Abdehvand et al. (2024) assessed the soil fertility of winter wheat fields and classified the land based on the nutrient index, which was calculated according to the nutrient requirements of wheat. They found that elevated salinity levels and calcium carbonate equivalent levels in the soil had the most negative impact on the average wheat yield.

According to studies by Kibret et al. (2023), soil fertility is an indicator of soil health. However, the fertility status of most Ethiopian soils is considered poor due to severe soil erosion, high nutrient depletion and minimal use of external inputs, with likely negative consequences for soil health. The deficiency of N and P is the most common issue in almost all soils of the country.

Lal et al. (2024) conducted an interesting study comparing soil fertility assessments based on farmers' traditional knowledge passed down through generations with those obtained scientifically through laboratory analysis results.

Abdu et al. (2023) conducted a study to assess the soil quality of arable lands situated in the Nitisols and Luvisols based on 19 soil parameters. Two methods were applied: the determination of the Soil Quality Index and the determination of the Soil Fertility/Nutrient Index.

Chen et al. (2022) determined the soil qualities of alluvial fans and the factors affecting them. A Soil Quality Index was constructed and the soil of river terrace farmland was used as a control. The factors influencing the soil quality of the alluvial fan were studied using correlation analysis.

The aim of this study Negis and Seker (2020) was to facilitate the determination of soil quality, with soil properties selected by multi-cri teria application, in a shorter time compared to that of conventional soils tests. Based on the results of factor analysis, 12 soil characteristics were selected to assess the Soil Quality Index for each soil sample. It was determined that in areas with long-term intensive agriculture, soil quality assessment can be conducted using only four physical, five chemical and three biological properties.

Hammad et al. (2024) used two methods to assess soil fertility in their research: (1) a geostatistical approach involving the creation of digital maps of soil properties and fertility and (2) modeling, including Gaussian, linear, exponential and spherical models.

Regasa et al. (2024) assessed surface soil acidity under different land use types (natural forest, cultivated land, pasture and eucalyptus plantations) based on selected soil physicochemical properties. The study aimed to combat soil acidification and mitigate its adverse effects in agro-ecosystems for sustainable soil resource management. Analysis of variance was used to test the mean differences in soil physicochemical properties across various land use types.

Based on their research, Zhang et al. (2024) concluded that using a combination of Landsat 8 and Sentinel-2 bands to assess the soil fertility index on agricultural lands can improve the accuracy of soil fertility evaluation.

Demir (2024) assessed soil fertility using the Soil Quality Index (SQI) model on soils cultivated with onions. A total of 22 parameters (soil physical and chemical properties, macro- and micronutrients) were included in the soil quality index modeling, grouped into four classes. The calculated Soil Organic Matter (SOM) index had the highest weight, indicating that it can be considered the primary limiting factor restricting the functional potential of the soils.

Koné et al. (2022) assessed the evolution of soil fertility in the cotton basin of Côte d'Ivoire between 2013 and 2021. They determined that the soils have poor physicochemical properties and low fertility levels, threatening the sustainability of the cotton production system. Therefore, the application of organic and mineral amendments is crucial for improving nutrient content in these soils.

Mugo et al. (2020) conducted a study in the central and eastern highlands of Kenya to assess soil fertility status on smallholder potato farms. They determined that the percentage of farms with nutrient levels below critical thresholds ranged from 20% to 87%, highlighting the need to develop integrated soil fertility management strategies to restore depleted soil fertility in the study area.

AbdelRahman et al. (2022) studied soil fertility status to determine land degradation rates in the Nile Delta by analyzing soil physical and chemical properties and their impact on land degradation for the years 1985, 2002 and 2021. They grouped soils according to their fertility level into four classes.

Hounkpatin et al. (2022) modeled and developed digital soil maps of Benin, identified key covariates affecting soil nutrients and created soil fertility index maps using digital soil property maps. For each soil property, the modeling procedures involved using different covariates, including soil type, topographic, bioclimatic and spectral data, as well as a comparative evaluation of (CB) and Quantile Random Forest models.

Nhunda et al. (2024) assessed the soil fertility status of selected fields under maize production in the Kongwa District, Tanzania to understand soil fertility variability and recommend appropriate fertilizer application rates.

Breus and Yevtushenko (2023) conducted an agroecological assessment of the suitability of agricultural lands in the Steppe zone of Ukraine for ecological farming. Spatial modeling of nutrient availability in the steppe soil of Ukraine was performed using ArcGIS 10.1. Based on the obtained data and spatial modeling, an agro-industrial soil grouping was carried out according to the degree of suitability for ecological farming.

Nagornykh et al. (2023) in the context of the agroecological assessment of soils, examined key issues of soil formation energetics, which include the development of efficient technological systems to enhance the utilization of solar energy and create highly productive natural and agricultural biocenoses. The main issues of soil formation energetics include sources and expenditures of energy in soil formation, the amount of energy accumulated in the soil and other related aspects.

Rusakov et al. (2022) conducted an agroecological assessment of automorphic soils in several districts of the Yaroslavl region over 30 years. Ranking the soils based on the Soil Ecological Index (SEI) scores showed that in groups with lower scores, the climatic component contributed more significantly, whereas in groups with higher SEI scores, the shares of the agrochemical and soil components increased.

Stepanova et al. (2021) conducted an agroecological assessment of the effectiveness of contour- band organization and various fertilizer doses on the intensity of rain and snowmelt runoff, as well as the composition and properties of level slope gray forest soils.

Kiseleva et al. (2022) assessed the soil fertility indicators of agricultural lands in the northern forest-steppe of the Republic of Bashkortostan and found that water erosion processes develop in the studied area under the influence of anthropogenic and natural factors: sheet and linear erosion on slopes with a steepness of more than 2-3° and a high degree of agricultural land plowing.

It should also be noted that the primary objective of our research is the development of measures for the protection and effective management of the soil fertility of the Gusar-Gonakend cadastral district, located on the northeastern slope of the Greater Caucasus, based on an agroecological soil assessment.

2. Materials and Methods

The object of the study was the lands of the Gusar-Gonagkend cadastral district, with a total area of 453,932 hectares. During the research, materials on the soil cover of the Gusar-Gonagkend cadastral district were used, along with fund and literary sources from the Institute of Soil Science and Agrochemistry of ANAS, the soil map of the northeastern slope of the Greater Caucasus at a scale of 1:100,000, as well as the results of our soil field and laboratory studies.

When compiling the soil quality assessment scale for the Gusar-Gonagkend cadastral district, methodological recommendations by Karmanov (1975) and Mammadov (1997) were used. To achieve the set objectives, soil field studies were conducted, 38 soil samples were taken and laboratory analysis of the collected soil samples was carried out using the following methods: granulometric composition - pipette method according to Kachinsky; hygroscopic moisture - thermal method; total water extract - according to Ivanov's method; percentage content of total humus and total nitrogen - according to Tyurin's method; percentage content of total phosphorus - by X-ray spectral method; absorbed cations Ca^{+2} and Mg^{+2} - according to Ivanov's method; total carbonates - by calcimeter; pH of soil - by potentiometric method (Arinushkina, 1970).

Additionally, fund materials on soil fertility indicators were gathered.

For soil quality assessment, diagnostic indicators were selected - criteria for soil evaluation that have a significant and strong correlation between soil fertility indicators and agricultural crop yield. These include: total humus, nitrogen, phosphorus reserves (in tons per hectare) and the Cation Exchange Capacity (CEC) (in meq/100g) in layers of 0-20 cm, 0-50 cm and 0-100 cm.

To create the primary soil quality assessment scale, analytical data on soil types and subtypes were collected, grouped and subjected to mathematical processing.

The supply of the selected parameters for calculating soil quality indicators in the specified layers were determined using the following formula (1) (Karmanov, 1975):

$$S = \frac{(d \times p \times v)}{100}, \tag{1}$$

where:
S - supply of the main criteria, specifically humus, nitrogen and phosphorus, t/ha;
d - bulk density of the given soil layer;
p - percentage content of the main parameters; *v* - volume of the given soil layer, m^3/ha.

When compiling the primary soil quality assessment scale, a 100-point or percentage-based comparison system was adopted. The calculation was performed using the following formula (2):

$$B = \frac{Va}{Vs} \times 100, \tag{2}$$

where:
B - bonitet score;
V_a - actual value of soil properties;
V_s - value of the corresponding soil indicators of the standard soil.

The weighted average soil quality score for the studied area was calculated using formula (3) (Mammadov, 1997):

$$B = \frac{b_1 a_1 + b_2\ a_2 + b_3\ a_3 + \cdots}{A}\ , \tag{3}$$

where:
B – weighted average bonitet score for the area;
$b_1, b_2, b_3, \ldots$ – bonitet scores of soil types;
$a_1, a_2, a_3, \ldots$ – area of soil types (ha);
A – total area of the territory.

The studies on the agroecological assessment of the soils in the Gusar-Gonagkend cadastral district were conducted in accordance with the methodologies of Bulgakov (2002), Mammadov (1992) and Mammadova (2006).

According to the methodology, the formula (4) was used to calculate agroecological soil scores. In this formula, the parameters of various soil characteristics were compared with special evaluation scales reflecting the degree of these characteristics and their values were expressed in points Mammadova (2006).

$$A_s = \frac{(e_1 + e_2 + e_3 + \cdots . + e_n) + B + (s_{i1} + s_{i2} + s_{i3} + \cdots + s_{in})}{C_n}\ , \tag{4}$$

where:
As - agro-ecological score of a specific soil;
$e_1, e_2, e_3, \ldots e_n$ - environmental factor indicators used in the assessment, scores;
B - bonitet (soil quality) score, determined based on the main diagnostic soil indicators (humus, nitrogen, phosphorus, CEC);
$s_{i1}, s_{i2}, s_{i3}, \ldots s_{in}$ – indicators of other soil factors involved in the assessment, expressed in points;
Cn - number of agroecological evaluation criteria.

3. Results and Discussion

The Gusar-Gonagkend cadastral district is located on the northeastern slope of the Greater Caucasus and covers an area of 5.24% of the total territory of the republic. The cadastral district includes low-mountain and mid-mountain areas, as well as partially high-mountainous regions of the Gusar, Guba, Shabran, Siyazan and Khizi districts. The elevation of the territory ranges from 115-250 meters in the north to 950-1500-2300 meters in the south (Babayev *et al*., 2017).

In the high-mountain zone of the district, mountain-meadow soils are prevalent; in the mid-mountain zone, mountain-forest brown soils dominate; while in the low-mountain zone, mountain-cinnamon and mountain-gray-brown soils are widespread (Isayeva, 2018).

3.1. Conducting a Qualitative Assessment of the Soils of the Gusar-Gonagkend Cadastral District

In accordance with the methodology, the collected literary and fund materials on the fertility indicators of soil types and subtypes prevalent in the study area were integrated with soil parameters obtained from field and laboratory research. The reliability of the obtained data was verified through mathematical and statistical analysis.

At the next stage, reference soils were selected: for the high-mountain zone - mountain-meadow chernozem-like soils; for the mid-mountain and low-mountain zones - mountain-forest brown residual-carbonate soils.

Using Formula 1, the reserves of key criteria (humus, nitrogen, phosphorus) were calculated for the selected layers (0-20 cm, 0-50 cm, 0-100 cm). The soil quality scores for the studied area were determined using Formula 2 and the main soil bonitet (quality assessment) scale for the Gusar-Gonagkend cadastral district was developed (Table 1).

As shown in Table 1, the land resources of the Gusar-Gonagkend cadastral district consist of 18 soil subtypes, including: 6 subtypes of mountain-meadow soils in the high-mountain zone, 9 subtypes of forest and steppe soils in the mid-mountain and low-mountain zones, 2 subtypes of intrazonal soils.

According to the data presented in Table 1, the soils of the high-mountain zone exhibit high fertility (62-100 points), with the exception of mountain-meadow primitive soils, which have lower fertility (52 points). The soils of the mid-mountain and low-mountain zones are also quite fertile, with quality scores ranging from 58 to 100 points.

According to the soil quality assessment scale, mountain-forest soils in the region have higher fertility (87-100 points) compared to the soils of the steppe zone. Mountain-cinnamon soils exhibit higher fertility (66-84 points) than mountain-gray-brown soils (58-82 points). Alluvial-meadow soils, classified as intrazonal soils, received a score of 73 points.

In practical soil science, the calculation of soil quality scores for varieties is carried out using correction coefficients that account for the specific properties of each soil (Mammadov, 1997).

It has been established that the soil cover of the Gusar-Gonagkend cadastral district includes soils of varying thickness, salinity levels, degrees of erosion and levels of cultivation. Therefore, these positive or negative properties were considered using correction coefficients during the assessment to fully reflect the current state of the soil cover in the studied area (Table 2).

Table 1. The main bonitet scale of soils of the Gusar-Gonagkend cadastral district

Name of soils		**Humus, t/ha score**			**Nitrogen, t/ha score**		**Phosphorus, t/ha score**		**CEC, meq/100g soil**		**Bonitet score**
Classification of soils of Azerbaijan	**WRB 2022**	**0-20**	**0-50**	**0-100**	**0-20**	**0-50**	**0-20**	**0-50**	**0-20**	**0-50**	
Soils of the high mountain zone											
Mountain-meadow chernozem-like	Mollic Phaeozems	124,93 100	281,84 100	313,95 100	7,13 100	16,64 100	4,35 100	9,38 100	42,85 100	37,75 100	100
Mountain-meadow soddy-peaty	Haplic Umbrisols	122,50 98	266,76 95	-	6,96 98	16,64 100	3,83 88	8,84 81	39,37 92	33,25 88	93
Mountain-meadow soddy	Molic Umbrisols	96,22 77	222,56 79	-	5,57 78	13,0 78	3,31 76	7,28 67	34,13 80	30,71 81	77

Mountain-meadow primitive	Haplic Umbrisols	53,42 43	135,2 48	-	3,83 54	9,88 59	2,44 56	5,72 53	20,29 47	19,01 50	52
Mountain-meadow steppe	Chernic Phaeozems	87,62 70	165,88 59	128,80 41	5,39 76	13,0 78	3,65 84	7,28 67	31,17 73	27,10 72	62
Mountain-meadow forest	Gleyic Phaeozems	93,61 75	192,92 68	204,70 65	6,44 90	14,04 84	4,35 100	9,88 90	34,87 81	33,59 89	79
Mountain-forest soddy-carbonate	Calcic Cambisols	120,06 96	245,44 87	277,15 88	7,13 100	16,12 97	4,35 100	10.00 107	32,45 76	29,15 77	91
Soils of the mid-mountain and low-mountain zones											
Mountain-forest brown residual carbonate	Calcaric Cambisols	138,92 100	180,32 100	259,86 100	8,36 100	15,12 100	5,92 100	11,76 100	37,14 100	29,17 100	100
Mountain-forest brown typical	Dystric Cambisols	94,45 68	179,38 99	245,11 94	6,12 73	11,76 78	4,90 83	11,20 95	31,07 84	24,67 85	87
Mountain-cinnamon typical	Calcic Kastanozems	92,75 67	174,38 97	229,87 88	5,19 62	11,25 74	4,48 76	10,63 90	34,01 92	30,62 104	84
Mountain-cinnamon carbonate	Calcic Kastanozems	84,02 60	136,88 76	162,56 63	4,96 59	10,0 66	4,25 72	9,38 80	31,03 84	25,67 88	70
Mountain-meadow cinnamon	Gleyic Kastanozems	89,92 56	161,88 90	217,17 84	4,87 58	11,34 75	4,64 78	11,34 96	33,65 91	28,05 96	81
Mountain-cinnamon steppe	Skeletic Kastanozems	73,04 53	121,61 67	166,40 64	4,44 53	9,07 60	3,77 64	9,07 77	27,45 74	24,26 83	66
Mountain gray-brown dark	Hortic Kastanozems	88,30 64	180,6 100	183,48 71	5,95 71	13,55 90	5,24 89	12,26 104	31,04 84	29,74 102	82
Mountain gray-brown ordinary	Haplic Kastanozems	72,83 52	123,84 69	134,64 52	5,47 65	12,26 81	4,76 80	10,32 88	29,32 79	27,51 94	68
Mountain gray-brown light	Vertic Kastanozems	61,40 44	93,53 52	126,72 49	4,28 51	10,32 68	4,05 68	9,03 77	23,85 64	23,46 80	58
Mountain gray-brown meadow	Fluvic Kastanozems	72,62 52	128,96 72	135,20 52	5,8 69	12,4 82	4,08 71	9,3 79	29,97 81	29,30 100	68
Alluvial-meadow	Luvic Fluvisols	69,83 50	156,83 87	205,74 79	4,92 59	11,43 76	4,43 75	10,16 86	20,78 56	18,82 65	73

Table 2. Correction coefficients for various soil properties

Soils and plants	**Soil properties**			
	By the degree of erosion			
	Non-eroded	Weekly eroded	Moderately eroded	Severely eroded
Mountain-meadow soddy	1,00	0,80	0,60	0,30
Mountain-cinnamon steppe	1,00	0,80	0,50	0,20
By the degree of clayiness				
	Non-clayey	Surface-clayey	Moderately clayey	Deeply clayey
For all soils	1,00	0,97	0,44	0,33
By the degree of cultivation				
	Virgin	Weakly cultivated	Cultivated	Highly cultivated
For all soils	1,0	1,06	1,40	1,83
By the soft layer thickness				
	Powerful	Moderately powerful	Weakly powerful	
For all plants For all soils	1,00	0,80	0,60	
By the degree of alkalinity				
	Non-alkaline	Slightly alkaline	Moderately alkaline	
For all plants For all soils	1,00	0,90	0,75	

Source: Mammadov (1997)

Table 3. Final bonitet scale of soils of Gusar-Gonagkend cadastral district

No	Name of soils	Final bonitet score	Area	
			Ha	%
1	Mountain-meadow	83	142582	31,41
2	Mountain-meadow forest	83	20650	4,55
3	Mountain-forest soddy-carbonate	91	8741	1,92
4	Mountain-forest brown	85	40370	8,89
5	Mountain-cinnamon	82	146 824	32,34
6	Mountain gray-brown	62	40566	8,94
7	Mountain gray-brown meadow	69	17920	3,95
8	Alluvial-meadow	52	9860	2,18
9	Technogenic soils	20	21660	4,77
10	Soil complexes	69	4759	1,05
	Total	77	453932	100,00

The highest final score was recorded for mountain-forest soddy-carbonate soils at 91 points, while the lowest score was for alluvial-meadow soils, which cover 2.18% of the area and received 52 points. This can be attributed to the prevalence of primitive alluvial-meadow soils in the region.

A differential comparison of the final bonitet scores with the primary scores for the Gusar-Gonagkend cadastral district is illustrated in the diagram (Figure 1).

The diagram shows that various factors affecting soil fertility - such as erosion level, cultivation, reduction in the thickness of the fertile layer, salinity, etc. - significantly influenced the soil quality scores. The quality scores of mountain-meadow chernozem-like, mountain-cinnamon and mountain-cinnamon steppe soils have increased due to the cultivation of these soils.

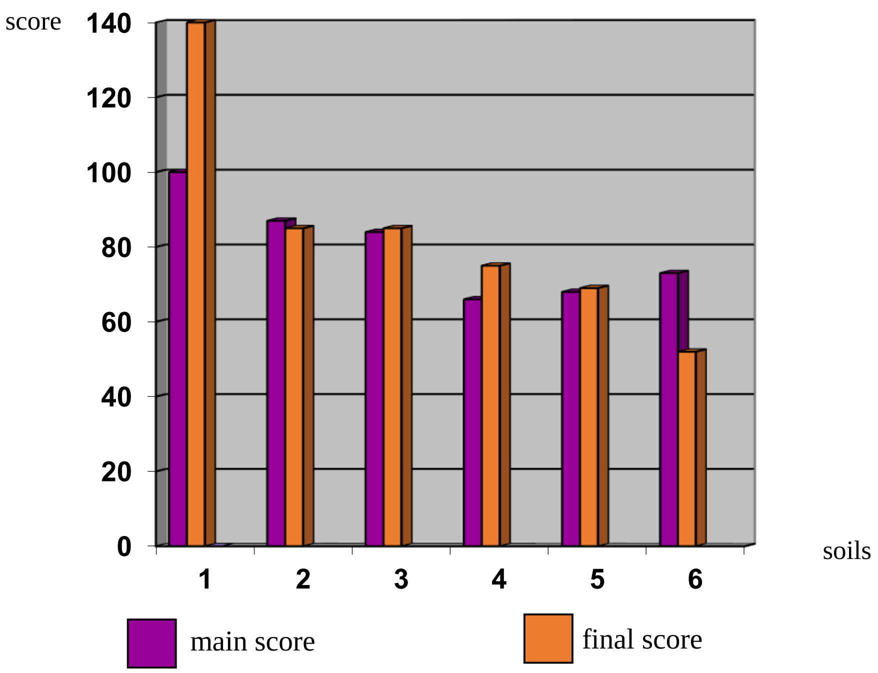
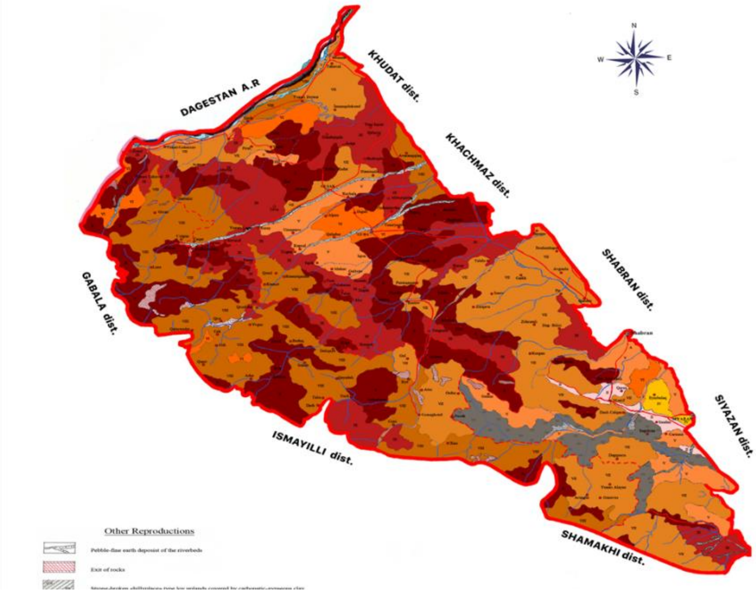


Figure 1. Comparison of final scores with the main bonitet scores of the Gusar-Gonagkend cadastral district: 1. Mountain-meadow chernozem-like; 2. Mountain-forest brown; 3. Mountain-cinnamon; 4. Mountain-cinnamon steppe; 5. Mountain gray-brown meadow; 6. Alluvial-meadow

As a result of the land assessment work carried out in the Gusar-Gonagkend cadastral district, a soil assessment map (1:100,000 scale) of the study area was compiled and in accordance with the methodology, the soils of the district were grouped into 10 soil quality classes (Figure 2).



Color	Soil quality class	Average soil quality score	Area	
			Ha	%
	X 100-91	100	101871	22,44
	IX 90-81	86	74778	16,47
	VIII 80-71	76	99287	21,87
	VII 70-61	67	100292	22,09
	VI 60-51	53	16934	3,73
	V 50-41	46	36710	8,09
	IV 40-31	31	2400	0,53
	II <20	<20	21660	4,77
		77	453932	100,0

Figure 2. Map of soil quality assessment of the Gusar-Ginagkend cadastral district. Scale: 1:100000

3.2. Conducting an Agro-Ecological Assessment of the Soils in the Gusar-Gonagkend Cadastral District

To carry out the agro-ecological assessment of the soils in the cadastral district, special evaluation scales were first developed based on the degree of manifestation of specific soil characteristics in accordance with the ecological requirements of plants. These special evaluation (ecological) scales provide differentiated information on various environmental parameters, including data on topography and soil-forming rocks, geology, climatic and hydrological conditions, soil cover, vegetation, etc. (Mamedov *et al*., 2017; Mamedov & Yusifova, 2013).

According to the methodology, an evaluation scale was developed based on the degree of manifestation of specific soil characteristics in the cadastral district, in accordance with the ecological requirements of the predominant plant formations (summer pastures, mesophytic forests, perennial plantations, cereal and vegetable crops) (Table 4).

The agroecological assessment of the soils in the Gusar-Gonagkend cadastral district was conducted using the aforementioned special evaluation scales.

Three data groups were used to calculate the agroecological scores of the lands in the Gusar-Gonagkend cadastral district:

1. Environmental factors shaping the soil and its fertility (altitude; slope steepness; precipitation; Md index; $\Sigma T > 10°C$);

2. Bonitet scores calculated based on stable diagnostic soil indicators;

3. Other soil parameters (pH, particle size distribution, salinity) that were not considered as criteria for calculating soil bonitet scores.

Table 4. Special evaluation scale for the degree of manifestation of specific soil characteristics in the Gusar-Gonagkend Cadastral District in accordance with the ecological requirements of plants

Indicators	**Plant formations**				
	Summer pastures	**Mesophytic forests**	**Perennial plantings**	**Cereals**	**Vegetables**
By terrain altitude (m)					
0-200	-	-	90	100	100
200-500	-	-	100	100	90
500-1000	70	80	100	90	80
1000-1500	90	100	80	80	50
1500-2000	100	100	60	60	30
2000-2500	100	80	-	-	-
By $\Sigma T>10$°C					
<1500	100	100	<50	<50	<40
1500-2500	90	90	60	60	60
2500-3500	80	80	70	90	70
3500-4500	60	50	90	100	100
>4500	-	-	100	100	100
By amount of precipitation (mm)					
<200	-	-	50	40	40
200-300	-	-	80	60	70
300-500	30	30	90	80	80
500-700	50	50	100	90	90
700-1000	80	80	90	100	100
1000-1500	100	100	80	80	90
>1500	80	90	50	60	40
By Md indicator (humidity index)					
>0,45	100	90	40	50	40
0,35-0,45	100	100	50	90	90
0,25-0,35	80	70	80	100	90
0,15-0,25	60	50	100	100	100
0,10-0,15	-	-	100	100	90
<0,10	-	-	80	70	50
By pH					
4-5	80	80	-	40	50
5-6	100	100	40	70	80
6-7	100	100	80	100	100
7-8	80	80	100	100	90
8-9	40	60	90	90	60
By soil texture (particles <0.01 mm, %)					
20-30	80	90	90	95	90
30-40	90	100	100	100	100
40-50	100	90	100	100	90
50-60	80	80	80	80	80
60-70	70	60	60	70	60
By salinity degree (%)					
<0,10	-	-	100	100	100
0,10-0,25	-	-	80	90	90
0,25-0,50	-	-	70	80	70
0,50-1,00	-	-	60	60	50
1,00-2,00	-	-	20	20	20
>2,00	-	-	-	<20	-
By slope steepness $(^0)$					
0-3	100				
3-10	100-83				
10-15	83-70				
15-20	70-58				
20-25	58-45				
25-30	45-33				
30-35	33-20				

Using all three groups of indicators, an agroecological assessment of the soils of the Gusar-Gonagkend cadastral district was carried out, taking into account the ecological requirements of the main plant formations (Table 5).

As a result of the research, it was established that for mountain-meadow soils in the high-altitude zone of the Gusar-Gonagkend cadastral district, the main limiting factors were slope steepness (33-45 points) among environmental factors and soil fertility indicators (humus, nitrogen, phosphorus, CEC) (52-86 points) among soil factors.

For mesophytic forests in the mid-mountain zone, the limiting factors were slope steepness (58 points) and the sum of active temperatures (80-90 points) among environmental factors, while pH level (80 points) and particle size distribution (80-90 points) were limiting soil factors.

The primary limiting environmental factors for perennial plantations, cereal and vegetable crops grown on low-mountain soils were precipitation levels (80-90 points) and soil fertility indicators (58-82 points). The main restrictive factors for vegetable cultivation on alluvial-meadow soils, were precipitation levels (70 points), Md index (90 points) and soil fertility indicators (73 points).

Table 5. Agroecological assessment of soils of the Gusar-Gonagkend cadastral district

Name of soils											
Classification of soils of Azerbaijan	**WRB 2022**	**Height ,m**	**Slope steepness, ^{0}**	**$\sum t>10^0C$**	**Precipitation, mm**	**Humidity index Md**	**Bonitet score**	**pH**	**<0,01 мм, %**	**Dry residue, %**	**Agroecological score**
Soils of the high mountain zone *Summer pastures*											
Mountain- meadow soddy-peaty	Mollic Phaeozems	2100/100	25/45	1500/100	1200/100	0,40/100	100	6,9/100	44,81/100	-	93
Mountain- meadow soddy	Haplic Umbrisols	2500/100	25/45	1200/100	1400/100	0,45/100	93	6,0/100	40,55/100	-	92
Mountain-meadow primitive	Molic Umbrisols	2600/100	30/33	1100/100	1500/80	0,45/100	52	6,1/100	36,14/100	-	82
Mountain-meadow steppe	Haplic Umbrisols	2100/100	25/45	1600/90	1100/100	0,40/100	67	7,4/80	48,69/100	-	85
Mountain-meadow forest	Chernic Phaeozems	1900/100	25/45	1800/90	1000/100	0,35/100	86	7,2/80	45,48/100	-	87
Soils of the mid-mountain and low-mountain zones *Mesophytic forests*											
Mountain- forest brown residual carbonate	Calcaric Cambisols	1500/100	20/58	2200/90	1000/100	0,40/100	100	7,4/80	51,83/100	-	88
Mountain- forest brown typical	Dystric Cambisols	1500/100	20/58	2500/80	1000/100	0,40/100	87	6,9/100	47,18/90	-	89
Perennial plantings											
Mountain-cinnamon typical	Calcic Kastanozems	900/100	15/70	3500/90	800/90	0,35/80	84	6,7/80	42,04/100	-	87
Mountain-cinnamon carbonate	Calcic Kastanozems	800/100	12/83	3800/90	700/90	0,35/80	70	7,2/100	49,77/100	-	89
Mountain-meadow cinnamon	Gleyic Kastanozems	800/100	10/83	3500/90	700/90	0,35/80	81	7,4/100	47,82/100	-	91
Mountain-cinnamon steppe	Skeletic Kastanozems	700/90	10/83	3800/100	700/90	0,30/100	66	7,4/100	52,61/100	-	89

Cereals											
Mountain gray-brown dark	Hortic Kastanozems	600 90	10 83	4000 100	600 90	0,30 100	82	7,5 100	42,80 100	0,15 90	93
Mountain gray-brown ordinary	Haplic Kastanozems	500 90	5 100	4000 100	600 90	0,30 100	68	7,9 100	46,58 100	0,18 90	93
Mountain gray-brown light	Vertic Kastanozems	400 90	5 100	4200 100	500 80	0,25 100	58	8,1 90	55,36 100	0,21 90	89
Vegetables											
Mountain gray-brown meadow	Fluvic Kastanozems	300 90	3 100	4200 100	500 80	0,25 100	68	7,9 90	43,64 90	0,18 90	90
Alluvial-meadow	Luvic Fluvisols	150 100	2 100	4200 100	500 80	0,25 100	73	7,2 90	38,51 100	0,20 90	92

Note: The numerator shows the indicators of environmental and soil factors;
The denominator shows the scores of these indicators obtained from evaluation scales

3.3. Protection and Effective Management of Land Fertility in the Gusar-Gonagkend Cadastral District

The study of the soils in the Gusar-Gonagkend cadastral district revealed significant issues related to the improper and inefficient use of land resources, highlighting the need to improve the system for the effective utilization of territorially designated lands that are intensively used in agriculture.

According to our research, each soil-climatic zone has undergone changes to varying degrees. Below is a brief description of the main issues arising in the use of land in the studied area:

Soil Erosion

Based on fund and cartographic materials, it was determined that 32.8% of mountain-meadow soils located in the high-altitude zone of the Gusar-Gonagkend cadastral district are not affected by erosion, while 67.2% (115,565 ha) are subject to erosion to varying degrees (Table 6).

Since primitive and soddy-peaty subtypes of mountain-meadow soils, which have steep slopes and a highly dissected relief, are more prone to erosion, severe erosion is observed in these soils (45.3%, 52,351 ha), while 31% of the area (35,825 ha) is affected by week erosion. It was found that moderate erosion is prevalent over an area of 27,389 ha of mountain-meadow soils (Isayeva, 2024).

Due to non-compliance with grazing regulations, as well as unregulated and excessive livestock grazing on summer pastures in the study area, the condition of pastures and hayfields has significantly deteriorated, leading to widespread pasture erosion.

Deforestation in the forested zone of the Gusar-Gonagkend cadastral district has intensified surface erosion, significantly degrading forest plantations and weakening natural regeneration. The terrain in areas where mountain-forest brown soils are prevalent consists of highly dissected mid-mountain sections and mountain-valley depressions, densely cut by mountain rivers, making it highly susceptible to severe erosion (Tagiyev, 2013).

Analyzing the degree of erosion in the mountain-forest zone of the Gusar-Gonagkend cadastral district, we observe that nearly half of the area (48.9%) is affected by erosion. Week erosion (53.2%, 10,502 ha) is more widespread in this region than moderate (24%) and severe erosion (22.8%) (Table 6).

The mountain-steppe cinnamon soil zone of the cadastral district is intensively used for perennial crops and according to Table 6, rapid erosion processes are observed here.

The terrain in these soil distribution areas is hilly and undulating, which is one of the main factors contributing to the relatively high erosion of soils formed under steppe vegetation, leading to the washing away of the topsoil layer.

Table 6. Degree of soil erosion in the Gusar-Gonagkend cadastral district

Soils	Total area, ha	Degree of erosion				
		Non-eroded area	Eroded area	including		
				week	moderate	severe
Mountain-meadow	171973 / 37,89	56408 / 32,8	115565 / 67,2	35825 / 31,0	27389 / 23,7	52351 / 45,3
Mountain-forest	40370 / 8,89	20629 / 51,1	19741 / 48,9	10502 / 53,2	4738 / 24,0	4501 / 22,8
Mountain-cinnamon steppe	146824 / 32,34	64456 / 43,9	82368 / 56,1	22075 / 26,8	27264 / 33,1	33029 / 40,1
Mountain gray-brown	58486 / 12,88	35576 / 60,8	22910 / 39,2	8797 / 38,4	8133 / 35,5	5980 / 26,1
Total	453932 / 100	212440 / 46,8	241492 / 53,2	100702 / 41,7	74380 / 30,8	66410 / 27,5

60-70% of virgin mountain gray-brown soils are eroded to varying degrees, while the more developed varieties are found in relatively gentle plain areas. Here, the slope steepness increases from 5-10° to 15°. Moderately and severely eroded mountain gray-brown soils, covered with shrubs and poorly developed steppe grass vegetation, are primarily used as grazing lands around villages. Mountain gray-brown soils cultivated for cereal and vegetable crops are mostly slightly eroded (38.4%).

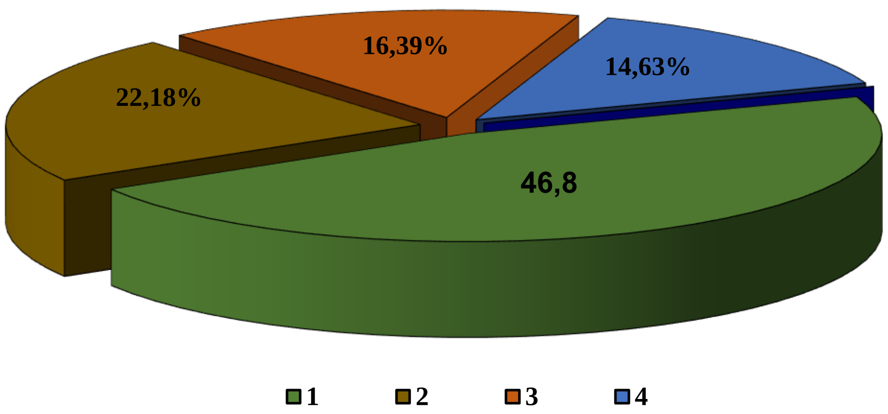


Figure 3. Land Erosion in the Gusar-Gonagkend Cadastral District: 1 - Not eroded; 2 - Weekly eroded; 3 - Moderately eroded; 4 - Severely eroded

The diagram illustrating the erosion status of the lands in the Gusar-Gonagkend cadastral district (Figure 3) shows that more than half of the territory (53.2%, 241,492 ha) is affected by erosion to varying degrees, with week erosion being the most prevalent (41.7%, 100,702 ha).

Reduction of Forest Resources

In the early 19th century, forests covered 30% of Azerbaijan's territory. Currently, the total area of Azerbaijan's forest fund is 1,213.7 thousand hectares, of which forested land accounts for 1,040.3 thousand hectares (11.8%), with approximately 0.12 hectares of green spaces per capita.

The forest cover in the Gusar-Gonagkend cadastral district is mainly located in mid-mountain and low-mountain areas at altitudes of 600–1,500 meters above sea level. Oak, hornbeam and beech play a dominant role in these forests, while subdominant species include steppe birch, alder, elm and eastern apple.

Experts attribute the lowering of the upper climatic boundary of forests to prolonged excessive and unregulated livestock grazing in pasture zones. It has been determined that the upper forest boundary in the Muhakhchay basin has dropped to 1,800-2,000 meters, in the Goshachay basin to 1,550-1,650 meters and in the Zakichay basin to 2,000-2,100 meters.

Our research indicates that the forest zone within the Gusar-Gonagkend cadastral district has been significantly affected by anthropogenic factors. Unregulated tree felling for firewood supply and land clearing for agricultural use, along with the absence of reforestation efforts, have led to a reduction in forested areas. This, in turn, has negatively impacted the soil cover and increased the extent of erosion-prone land. As shown in Table 6, 48.9% of forested lands (19,741 ha) in the study area have been affected by erosion to varying degrees. According to our research, forests in this district cover a relatively small area - 49,111 ha or only 10.81% of the total land area.

The study has revealed that due to anthropogenic influence, the following degradation processes are occurring in the forests of the Gusar-Gonagkend cadastral district: reduction of forested areas, degradation of tree species composition, decline in productivity, replacement of forest soils with steppe soils, loss of valuable plant species, deterioration of forest health conditions and depletion of timber resources.

Decline in Soil Fertility

According to the research of Aliyev (1990), in the eroded types of steppe mountain cinnamon soils in the Gusar and Guba districts, the amount of humus and absorbed bases decreases. In the upper layer of moderately eroded soils, the humus content has decreased by 1.75-1.79%, while in severely eroded soils, it has decreased by 0.98-1.1%.

In non-eroded soils, nitrogen content is 0.21-0.26%, soluble phosphorus is 28.5-34.0 mg/kg and exchangeable potassium is 880.6-440.7 mg/kg. However, in severely eroded soils, these values decrease to 0.06%, 9.6 mg/kg and 95.2 mg/kg, respectively.

In the Guba district, the humus content in non-eroded mountain gray-brown soils under pasture is 3.24%, decreasing to 1.44% in moderately eroded soils and 1.09% in severely eroded soils. In soils used for perennial crops, the humus content in non-eroded soils is 2.88%, while in moderately eroded soils, it decreases to 1.52%.

According to the research of Babayev et al. (2017), the humus content in mountain gray-cinnamon soils cultivated under monoculture (1.4-2.0%) has significantly decreased compared to virgin soils under shrubs and steppe vegetation (2.0-4.5%). The author attributes the decline in humus, total nitrogen and absorbed nutrients in cultivated mountain gray-brown soils to prolonged monoculture grain farming, insufficient application of organic and mineral fertilizers and failure to follow proper agronomic practices in crop rotation.

According to the research of Abdullayev (2014), 269 hectares of cultivated land in the study area have become completely unsuitable for agriculture, 393 hectares have undergone severe degradation, 7,791 hectares have suffered moderate degradation and 5,762 hectares have experienced week degradation.

Based on the analysis of our own research and fund materials, we have classified the lands of the Gusar-Gonagkend cadastral district into quality groups (Table 7). According to the table, 44.58% (65,458 ha) of the soil used for perennial plantations is classified as high-quality, 34.82% as good and 20.60% as medium-quality soil.

Table 7. Distribution of arable and perennial plantation lands in the Gusar-Gonagkend Cadastral District by bonitet groups

Soil Quality Groups	For perennial crops		For arable land	
	Ha	%	Ha	%
I – High-quality soils	65458	44.58	11562	16.92
II – Good-quality soils	51120	34.82	35460	51.88
III – Medium-quality soils	30246	20.60	18924	27.69
IV – Low-quality soils	-	-	2400	3.51
Total	146 824	100,0	68346	100,0

It has been determined that 16.92% of the high-quality group lands in the low-mountain zone are used for arable farming, along with 51.88% (35,460 ha) of the second-quality group (Figure 4).

Additionally, 27.69% of arable land is classified as medium-quality, while 2,400 ha (3.51%) fall into the low-quality category. All of the above once again confirms that the fertility of the lands in the Gusar-Gonagkend cadastral district has declined due to inefficient agricultural practices.

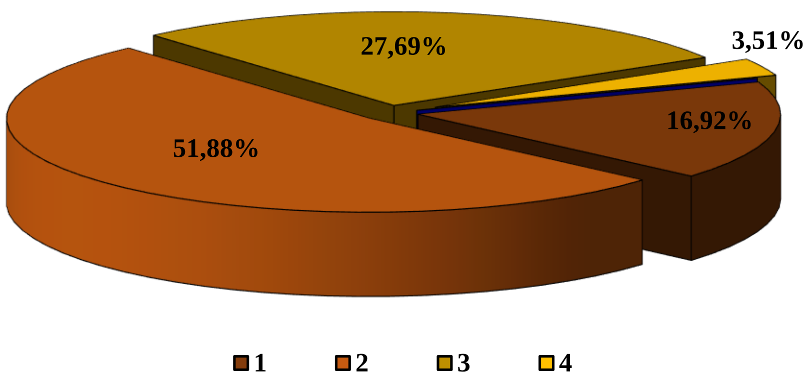


Figure 4. Distribution of Arable Land in the Gusar-Gonagkend Cadastral District by Quality Groups: 1 - high-quality soils; 2 - good-quality soils; 3 - medium-quality soils; 4 - low-quality soils

Soil Alkalinity

Alkalinity is one of the factors contributing to the decline in the productivity of crops grown on irrigated lands in our republic. According to research by Mammadov (2007), 11.2% (508,270 ha) of Azerbaijan's agricultural lands are alkaline, of which 75.5% are weakly alkaline, 20.1% moderately alkaline and 4.2% strongly alkaline. Among them, 2.8% of arable land, 10.3% of land under perennial plantations and 17.1% of pastures and grazing lands have undergone alkalinity.

According to the soil map of the Gusar-Gonagkend cadastral district, 2.2% (10,000 ha) of the total area of the studied territory is subject to alkalinity, observed only in mountain gray-brown soils - 24.6%, of which 23.4% (5,800 ha) are ordinary and 43% (4,200 ha) are light mountain gray-brown soils affected by weak alkalinity (Figure 5).

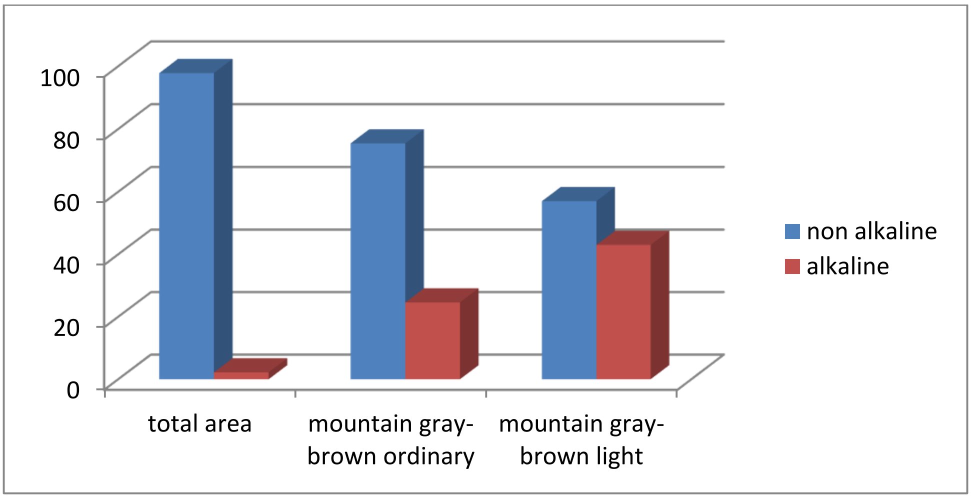


Figure 5. Soil alkalinity level in Gusar-Gonagkend cadastral district

Taking all the above into account, we have developed a conceptual framework to ensure the the effective management and protection of land resources based on the proper and effective spatial distribution and a system of corresponding agrotechnical regulations for the soils of the Gusar-Gonagkend cadastral district.

The main components of this framework include the implementation of anti-erosion measures, the protection and expansion of forested areas, the improvement of agricultural land use, the establishment of protective forest belts, the proper delineation of boundaries for farm enterprises, the expansion of perennial plantations, the prevention of soil alkalinity and other related actions.

4. Conclusion

A qualitative assessment of the lands in the Gusar-Gonagkend cadastral district has been conducted and a basic bonitet scale has been created. At that time, as a standard, mountain-meadow chernozem-like soils were selected for the high-mountain zone, while mountain-forest brown residual carbonate soils were chosen for the mid-mountain and low-mountain zones. It was established that soddy-peaty mountain-meadow (93 points) and soddy-carbonate mountain-forest (91 points) soils have high fertility, whereas primitive mountain-meadow (52 points) and light mountain gray-brown (58 points) soils have low fertility. To determine soil quality scores for the soil varieties distributed within the cadastral area, open and final soil bonitet scales were developed using adjustment coefficients (degree of erosion, soft layer thickness, gleying, alkalinity and cultivation). The weighted average bonitet score of the studied area's soils was 77 points. As a result of the study, a soil quality assessment map (scale 1:100,000 scale) of the Gusar-Gonagkend cadastral district was created.

Special evaluation scales have been developed to assess the compliance of various soil characteristics in the Gusar-Gonagkend cadastral district with the ecological requirements of summer pastures, mesophytic forests, perennial plantations and cereal and vegetable crops. Using these scales, an agroecological assessment of the district's soils was conducted, identifying the main limiting factors affecting soil fertility and calculating agroecological scores for soil subtypes. The highest agroecological scores were assigned to chernozem-like mountain-meadow soils in the high-mountain zone, as well as dark and ordinary mountain gray-brown soils in the low-mountain and mid-mountain zones (93 points).

To ensure environmental safety and ecosystem sustainability in the Gusar-Gonagkend cadastral district, the main directions for effective land resource management and protection have been identified. A conceptual framework has been developed, encompassing a system of relevant measures, including the implementation of anti-erosion initiatives, the protection and expansion of forested areas, the improvement of agricultural land use, the establishment of protective forest belts, etc.

References

AbdelRahman, M.A., Metwaly, M.M., Afifi, A.A., D'Antonio, P. & Scopa, A. (2022). Assessment of soil fertility status under soil degradation rate using geomatics in West Nile Delta. *Land*, *11*(8), 1256. https://doi.org/10.3390/land11081256

Abdu, A., Laekemariam, F., Gidago, G. & Getaneh, L. (2023). Explaining the soil quality using different assessment techniques. *Applied and Environmental Soil Science*, 1, 6699154.

Abdullayev, R.A. (2014). Degradation of the soil cover of the southeastern slope of the Greater Caucasus and ways to prevent it. Thesis of PhD dissertation, Baku, 20. (In Azerbaijani).

Aliyev, C.E. (1990). *Erosion Resistance of the Main Soil Types in the Agricultural Zone of the Northeastern Slope of the Greater Caucasus.* Baku. (In Azerbaijani).

Arinushkina, E.V. (1970). *Handbook of Chemical Analysis of Soils.* Moscow: Moscow University Publishing House. (In Russian).

Babayev, M.P., Jafarov, A.M. & Jafarova, Ch.M. (2017). *Modern Soil Cover of the Greater Caucasus.* Baku: Science. (In Azerbaijani).

Breus, D., Yevtushenko, O. (2023). Agroecological assessment of suitability of the steppe soils of Ukraine for ecological farming. *Journal of Ecological Engineering*, *24*(5), 229-236. https://doi.org/10.12911/22998993/161761

Bulgakov, D.S. (2002). *Agroecological Assessment of Arable Soils*. Moscow: Science. (In Russian).

Chen, T., Jiao, J., Zhang, Z., Lin, H., Zhao, C. & Wang, H. (2022). Soil quality evaluation of the alluvial fan in the Lhasa River Basin, Qinghai-Tibet Plateau. *Catena*, 209, 105829. https://doi.org/10.1016/j.catena.2021.105829

Demir, Z. (2024). Assessment of soil quality index for onion cultivated soils in a semiarid agricultural ecosystem. *Eurasian Soil Science*, *57*(6), 1057-1071. https://doi.org/10.1134/S1064229323603074

Fatimazahra, T., Krimissa, S., Ismaili, M., Eloudi, H., Elaloui, A., Nait-Taleb, O., ... & Badreldin, N. (2025). Systematic review and bibliometric analysis of innovative approaches to soil fertility assessment and mapping: Trends and techniques. *Applied Geomatics*, 1-39. https://doi.org/10.1007/s12518-025-00611-z

Hammad, J.A., M'nassri, S., Chaabane, B., Al-Bayati, A.H.I. & Majdoub, R. (2024). Assessing agricultural potential of abandoned land in the Euphrates basin: Soil fertility modeling and geostatistical analysis. *Modeling Earth Systems and Environment*, *10*(4), 4627-4639. https://doi.org/10.1007/s40808-024-01982-9

Hounkpatin, K.O., Bossa, A.Y., Yira, Y., Igue, M.A. & Sinsin, B.A. (2022). Assessment of the soil fertility status in Benin (West Africa) - Digital soil mapping using machine learning. *Geoderma Regional*, 28, e00444. https://doi.org/10.1016/j.geodrs.2021.e00444

Isayeva, S.Sh. (2018). Land fund of the Gusar-Gonagkend cadastral region. *Young Researcher Journal*, *4*(2), 103-108. (In Azerbaijan).

Isayeva, S.Sh. (2024). Main problems of land use in Gusar-Gonagkend cadastral district. *Bulletin of Science and Practice, 10*(12), 376-384. https://doi.org/10.33619/2414-2948/109/47 (In Russian).

Karmanov, I.I., Klopotovsky, A.P. (1975). *Methodical Instructions for Soil Appraisal in the*

USSR. Moscow. (In Russian).

Khosravi Aqdam, K., Asadzadeh, F., Rezapour, S. & Nouri, A. (2023). Comparative assessment of soil fertility across varying elevations. *Environmental Monitoring and Assessment, 195*(8), 1007. https://doi.org/10.1007/s10661-023-11610-1

Kibret, K., Beyene, S. & Erkossa, T. (2023). Soil fertility and soil health. In *The Soils of Ethiopia*, 157-192. Cham: Springer International Publishing. https://doi.org/10.1007/978-3-031-17012-6_8

Kiseleva, A., Asylbaev, I., Khasanov, A., Mirsayapov, R. & Kurmashev, N. (2022). Agroecological assessment of agricultural soils fertility in the Iglinsky region, the Russian Federation. *Journal of Water and Land Development*, 200-205. https://doi.org/10.24425/jwld.2022.142322

Koné, I., Kouadio, K.K.H., Kouadio, E.N.G., Agyare, W.A., Owusu-Prempeh, N., Amponsah, W. & Gaiser, T. (2022). Assessment of soil fertility status in cotton-based cropping systems in Cote d'Ivoire. *Frontiers in Soil Science*, 2, 959325.

Lal, B., Sharma, A., Gupta, A.K., Singh, S.S., Chaturvedi, S.K. & Jhariya, M.K. (2024). Soil fertility evaluation through farmer knowledge and scientific approaches of Bundelkhand region, Central India. *Environment, Development and Sustainability*, 1-32. https://doi.org/10.1007/s10668-024-05729-5

Mamedov, G.S., Yusifova, M.M. (2013). Agroecological evaluation of soils suitable for viniculture on the southeastern macroslope of the Great Caucasus (Azerbaijan). *Eurasian Soil Science*, 46, 918-924. https://doi.org/10.1134/S1064229313080061

Mamedov, G.S., Shabanov, J.A. & Kholina, T.A. (2017). Ecological assessment of soils in high-mountain landscapes of northeastern part of the Greater Caucasus (Azerbaijan). *Eurasian Soil Science*, 50, 630-635. https://doi.org/10.1134/S1064229317050118

Mammadov, G.Sh., Jafarov, A.B. (1997). *Soil Appraisal*. Baku: Science. (In Azerbaijani).

Mammadov, G.Sh. (1992). *Map of Ecological Assessment of Soils of Azerbaijan and its Significance*. Baku: Science. (In Azerbaijan).

Mammadov, G.Sh. (2007). *Socio-Economic and Ecological Foundations of Efficient Use of Land Resources of Azerbaijan*. Baku: Science. (In Azerbaijan).

Mammadova, S.Z. (2006). *Ecological Assessment and Monitoring of Soils of Lankaran Region of Azerbaijan.* Baku: Science. (In Azerbaijan).

Mugo, J.N., Karanja, N.N., Gachene, C.K., Dittert, K., Nyawade, S.O. & Schulte-Geldermann, E. (2020). Assessment of soil fertility and potato crop nutrient status in central and eastern highlands of Kenya. *Scientific Reports*, *10*(1), 7779. https://doi.org/10.1038/s41598-020-64036-x

Nagornykh, A., Dolgopolova, N., Philimonov, P. & Eremenko, O. (2024). Agroecological assessment and efficiency of potential fertility. In *BIO Web of Conferences*, 93, 03003. EDP Sciences. https://doi.org/10.1051/bioconf/20249303003

Negiş, H., Şeker, C. (2020). Estimation of soil quality of under long term sugar beet-wheat cropping system by factor analysis. *Communications in Soil Science and Plant Analysis*, *51*(4), 440-455. https://doi.org/10.1080/00103624.2020.1718689

Nhunda, D., Semoka, J.M. & Tindwa, H.J. (2024). Assessment of soil fertility status in selected fields under maize production in Kongwa District, Dodoma Region, Tanzania. *Journal of Agriculture and Ecology Research International*, *25*(1), 32-47. https://doi.org/10.9734/jaeri/2024/v25i1570

Regasa, A., Haile, W. & Abera, G. (2024). Assessment of soil acidity and fertility status under different land uses types in Sayo District of Western Ethiopia. *Russian Agricultural Sciences*, *50*(2), 172-184. https://doi.org/10.3103/S1068367424700137

Rusakov, A.V., Simonova, J.V., Popov, A.I., Ryumin, A.G., Lemeshko, N.A., Mirin, D.M. & Volina, O.V. (2022). Assessment of the agroecological state and trends of evolutionary changes in arable soils of the Yaroslavl Volga Region over 30 years based on the soil-ecological index. *Moscow University Soil Science Bulletin*, *77*(5), 343-355. https://doi.org/10.3103/S0147687422050088

Stepanova, L.P., Petelko, A.I., Pisareva, A.V., Nakonechny, A.G. & Bolmat, T.N. (2021). Agroecological assessment of the effectiveness of different systems of soil protection measures in the reproduction of fertility of slope gray forest soils. In *IOP Conference Series: Earth and Environmental Science*, 723(3), 032104. IOP Publishing. https://doi.org/10.1088/1755-1315/723/3/032104

Tagiyev, F.D. (2013). The problem of erosion of soils widespread in the territory of the Guba region. *Soil Science and Agrochemistry*, *21*(1), 622-627.

Zaheri Abdehvand, Z., Karimi, D., Rangzan, K. & Mousavi, S.R. (2024). Assessment of soil fertility and nutrient management strategies in calcareous soils of Khuzestan province: A case study using the Nutrient Index Value method. *Environmental Monitoring and Assessment*, *196*(6), 503. https://doi.org/10.1007/s10661-024-12665-4

Zhang, M., Khosravi Aqdam, M., Abbas Fadel, H., Wang, L., Waheeb, K., Kadhim, A. & Hekmati, J. (2024). Evaluation of soil fertility using combination of Landsat 8 and Sentinel-2 data in agricultural lands. *Environmental Monitoring and Assessment*, *196*(2).