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ECOLOGICAL EVALUATION OF SOILS OF THE MUGAN PLAIN OF AZERBAIJAN

Anthropogenic impact on soil occurs due to environmental factors that affect the process of soil formation, the survival and functioning of soil organisms, energy and mass exchange, and determine the general ecological state. Therefore, when assessing the ecological state of soils, a comprehensive study of soil-biological, geomorphological, geochemical, geophysical, and other factors and parameters that determine the state of soils is required. In this regard, there is a need for comprehensive studies to assess the ecological state of soils of the Mugan Plain. According to the results of analyzes and mathematical-statistical processing of soil-field and laboratory studies conducted in the Mugan steppe in 2016-2020, as well as fund and literary soil materials, the bonitet scores of soils in the study area were calculated. According to the methods of D.Bulgakov, G.Mamedov, S.Mamedova, special assessment scales have been developed for the compliance of individual soil characteristics with the environmental requirements of agricultural plants cultivated here. Using these assessment scales, an ecological assessment of the soils of the Mugan Plain was carried out, the main limiting factors affecting the fertility of the soils of this zone were determined, and the ecological scores of the soils were calculated. It was found that the limiting factors for the soils of the Mugan Plain are the salinity of the territory (20-60 scores) and the aridity of the climate (70 scores). The highest ecological scores in the study area were obtained by dark gray-brown (91 points), ordinary gray-brown (90 points) and dark gray-meadow (87 points) soils.

Key words: Mugan Plain, environmental assessment, limiting factors, special assessment scale.

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Әзербайжандағы мұған жазығының топырақтарын экологиялық бағалау

Топыраққа антропогендік әсер ету топырақ түзілу процесіне, топырақ организмдерінің тіршілігі мен қызмет етуіне, энергия мен масса алмасуына әсер етіп, жалпы экологиялық жағдайды анықтайтын экологиялық факторлардың әсерінен болады. Сондықтан топырақтың экологиялық жағдайын бағалау кезінде топырақтың күйін анықтайтын топырақ-биологиялық, геоморфологиялық, геохимиялық, геофизикалық және басқа да факторлар мен параметрлерді жан-жақты зерттеу қажет. Осыған байланысты Мұған жазығы топырақтарының экологиялық жағдайын бағалау үшін кешенді зерттеулер қажет. 2016-2020 жылдары Мұған даласында жүргізілген топырақ-далалық және зертханалық зерттеулердің, сондай-ақ қор және әдеби топырақ материалдарының талдаулары мен математикалық-статистикалық өңдеу нәтижелері бойынша зерттелетін аймақтағы топырақтардың бонитет баллдары есептелді. Д.Булгаков, Г.Мамедов, С.Мамедова әдістері бойынша мұнда өсірілетін ауылшаруашылық өсімдіктерінің жеке топырақ ерекшеліктерінің экологиялық талаптарға сәйкестігіне арнайы бағалау шкалалары жасалған. Осы бағалау шкалаларын пайдалана отырып, Мұған жазығының топырақтарына экологиялық бағалау жүргізілді, осы зона топырағының құнарлылығына әсер ететін негізгі шектеуші факторлар анықталды, топырақтардың экологиялық баллдары есептелді. Мұған жазығының топырақтары үшін шекті факторлар аумақтың тұздылығы (20-60 балл) және климатының құрғақтығы (70 балл) екені анықталды. Зерттелетін аумақтағы ең жоғары экологиялық баллды қара сұр-қоңыр (91 балл), кәдімгі сұр-қоңыр (90 балл) және қара сұр-шалғынды (87 балл) топырақтар алды.

Түйін сөздер: Мұған жазығы, экологиялық бағалау, шектеуші факторлар, арнайы бағалау шкаласы.

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Экологическая оценка почв Муганской равнины Азербайджана

Антропогенное воздействие на почву происходит за счет факторов внешней среды, определяющих общее экологическое состояние и влияющих на процесс почвообразования, выживание и функционирование почвенных организмов, на обмен энергией и массой. Поэтому при оценке экологического состояния почв необходимо комплексное изучение почвенно-биологических, геоморфологических, геохимических, геофизических и других факторов и параметров, определяющих состояние почв. В связи с этим возникает необходимость комплексных исследований по оценке экологического состояния почв Муганской равнины. По результатам анализов и математико-статистической обработки почвенно-полевых и лабораторных исследований, проведенных в Муганской степи в 2016-2020 гг., а также фондовых и литературных почвенных материалов рассчитаны баллы бонитета почв изучаемой территории. По методикам Д. Булгакова, Г. Мамедова, С. Мамедовой разработаны специальные оценочные шкалы соответствия индивидуальных характеристик почв экологическим требованиям возделываемых здесь сельскохозяйственных растений. С использованием этих оценочных шкал проведена экологическая оценка почв Муганской равнины, определены основные лимитирующие факторы, влияющие на плодородие почв этой зоны, и рассчитаны экологические баллы почв. Установлено, что лимитирующими факторами для почв Муганской равнины являются засоленность территории (20-60 баллов) и засушливость климата (70 баллов). Наивысшие экологические оценки на исследуемой территории получили темно-серо-коричневые (91 балл), серо-коричневые обыкновенные (90 баллов) и темно-сероземно-луговые (87 баллов) почвы.

Ключевые слова: Муганская равнина, экологическая оценка, лимитирующие факторы, специальная оценочная шкала.

Introduction

Until the middle of the last century, soil scientists usually carried out research on the state of natural and agricultural lands and their use in agriculture. The spread of degraded, polluted and technogenic soils with the development of industry and the exacerbation of environmental problems has led to the systematization of lands in zones subject to environmental stress, the study of ecological functions and properties of soils.

In modern times, scientists and soil specialists carry out numerous works to study the features and determine the direction of natural and anthropogenic processes occurring in natural ecosystems [1- 6]. Numerous studies have shown that as a result of constantly changing soil-environmental conditions and increased anthropogenic impact, there is an increase in the impact of the physicochemical properties of soils on the environment, since any changes in the soil cover lead to a change in environmental conditions. Currently, it is relevant to develop a system of soil properties used in soil assessment, while the selected features must meet the following requirements: 1) Quantitative assessment of soil suitability should be carried out, 2) Depending on the direction of land use, soils should be assessed for resistance to collapse, degradation and destruction.

The emergence of the scientific direction “Soil ecology” in Soil science began in the 50-60s of the last century, due to the increased anthropogenic impact on the environment, including the soil cover, and the aggravation of environmental problems associated with land use; and since the 1950s, there has been a rapid development of this area. Since the beginning of the 90s of the last century, the scientific direction “Ecological evaluation of soils” has been developing within the framework of the science “Soil ecology”, the scientific- theoretical foundations and methodology of this area of Soil science have been created [7].

For the first time in the former Soviet Union, the term “Soil ecology” was introduced into the Soil Science and scientific- theoretical principles were developed by the outstanding soil scientist of Azerbaijan Academician Volobuev [8]. In the early 90s of the 20th century, Academician Mamedov developed the scientific, theoretical and methodological foundations for the ecological evaluation of soils [9].

As a preliminary stage of these studies, ecological evaluation maps were developed. Maps of ecological assessment of soils differed significantly from other previous soil maps in the combination of ecological features of soils. These maps have taken an integrated approach to assessing environmental

resources. The method of an integrated approach has simplified the identification of areas with a homogeneous lithological, geomorphological structure, soil cover and climatic conditions on maps of ecological evaluation of soils. Later, in Azerbaijan, under the leadership of academician Mamedov [9], comprehensive studies were carried out in the field of ecological evaluation of soils [10-12].

At the beginning of the 21st century, with the development of the scientific field of soil ecology, it became necessary to develop new concepts and methods in the field of environmental evaluation of soils [13]. Studies on the ecological evaluation of soil in Republic of Azerbaijan were carried out according to the method of Mamedov until 2005, when Mamedova [14] proposed a new concept in this area. The methodology of Mamedova [14] was more perfect, because in previous studies, when assessing the soil-ecological parameters of soils in accordance with environmental requirements, the concepts of "high", "good", "medium", "low", expressing quality, were used, but here it was scoring system used. A formula was suggested for calculating the ecological scores of soils, these scores were calculated on the basis of the ratio of the plant to the appearance degrees of the separate soil signs. At present, numerous studies are being carried out all over the world in this direction, where methodological approaches to assessing the ecological state of soils are being improved [15-27].

Materials and methods

The object of research was the soils of the Mugan Plain of Azerbaijan, the total area of which is 455332.5 ha. In the course of the research, materials on the soil cover of the Mugan Plain, fund and literary materials of the Institute of Soil Science and Agrochemistry of ANAS, the soil map of the Mugan Plain created by us on a scale of 1: 100 000 (2021), fund materials of the Azerbaijan State Institute of Land Management, as well as the results of soil-field and laboratory studies conducted by us in 2016-2020 were used.

Studies on the ecologicaal evaluation of the soils of the Mugan Plain were carried out in accordance with the methods of Bulgakov [13], Mamedov [9], Mamedova [14] in the following sequence:

1. The main soil-ecological factors affecting the fertility of the soils of the Mugan Plain were identified and a mathematical- statistical analysis was carried out to clarify the reliability of the data obtained;

2. A qualitative assessment of the soils of the study area was carried out, the basis bonitet scale was developed;

3. Special evaluation scales have been developed for the appearance degrees of the separate soil features in accordance with the environmental requirements of plants;

4. The ecological scores of the soils of the Mugan steppe were calculated.

When compiling the basis bonitet scale, we adopted a 100-score comparison system, where we calculated according to the following formula (1) [28]:

$$B = \frac{M_a}{M_s} \cdot 100 \quad (1)$$

where, *B* – the bonitet score of the soil parameter;

Ma – the actual value of the soil parameter;

Ms – the value of the same feature of the soil, taken as a standard.

In accordance with the methodology for calculating the ecological scores of soils, the following formula was used, in which the parameters of a particular soil characteristic were compared with special rating scales for the appearance degrees of these characteristics and a value expressed in points was obtained [14].

$$E_s = \frac{(e_1+e_{2+}e_3+\cdots.+e_n)+B_s+(s_1+s_2+s_3+\cdots+s_n)}{S_n} \quad (2)$$

where, E_s – the ecological score of a particular soil;

e_1, e_2, e_3, ... e_n – indicators of environmental factors involved in the assessment, in scores;

Bs – bonitet score found on the basis of the main diagnostic indicators of the soil (humus, nitrogen, phosphorus, the sum of absorbed bases);

s_1, s_2, s_3 ... s_n – indicators of other soil factors involved in the assessment, in scores;

S_n – number of ecological assessment criteria.

Results and discussion

The Mugan plain is located in the southeastern part of the Kur-Araz lowland, the arid zone of Azerbaijan. The Mugan plain borders the Kur and Araz rivers in the north and northeast, the Kur-Akusha and Lenkoran plains in the southeast, and Islamic Republic of Iran in the south and southwest. The Mugan Plain occupies an area of 455332.5 ha and is located in the form of a plain (slope 0.0001–0.0003) from northwest to southeast and below sea level [29]. The climate is semi-arid subtropical.

The Mugan Plain consists of alluvial deposits with underlying marine deposits, the thickness of which reaches 10-12 cm. Modern alluvial deposits consist mainly of clayey and loamy deposits, as well as sandy and layered ones.

Volobuev, Mamedov, Salayev, Babayev and others studied of the soil cover and reclamation features of the Kura-Araz lowland and the Mugan plain [30]. The following types of soils are common in the study area: gray-brown, gray-meadow, meadow-gray, alluvial-meadow and boggy-meadow soils [29].

Gray-brown soils are located in the western and southwestern parts of the Mugan Plain at an altitude of 200-300 m above sea level. According to the morphological structure, these soils are characterized by an average thickness, a humus profile (40-50 cm), and a dense structure. The amount of humus in the upper layer ranges from 2.78 to 3.15%, the amount of total nitrogen ranges from 0.20 to 0.24% in the upper layer and from 0.17 to 0.20% in the half-meter layer in proportion to humus. The amount of bases absorbed by gray-brown soils: 24.13 – 41.80 meq. pH indicates that the soil medium is slightly alkaline -6.9-8.0.

The fertility of *gray-meadow* soils is lower than that of gray-brown soils. The amount of humus is 2.0-2.92% in the upper layer, 1.00-2.2% in the 50-centimeter layer, the amount of total nitrogen fluctuates in the range of 0.16-0.19%. The amount of absorbed bases varies considerably in the upper layer from 18.75 to 38.80 meq depending on the composition of the absorbed bases, in these soils is marked weak salinity.

The amount of humus in the *meadow-gray* soils was 1.90-2.2% in the upper layer (0-20 cm), 1.2-2.0% in the half-meter layer, 1.04-1.76% in the meter layer. There is also a gradual decrease in the amount of total nitrogen with depth: in the 0-20 cm layer – 0.10-0.17%, in the 0-50 cm layer – 0.10-0.15%. The availability of total phosphorus in these soils is low: 0.16-0.23% According to the degree of availability of absorbed bases, these soils are classified as medium and highly saturated: 30.10-53.40 meq.

Alluvial-meadow soils stretch along the banks of the Kur-Araz River in the form of a narrow strip. These soils form on young alluvial deposits with low levels of ground moisture and no stagnant surface water. Due to the amount of physical clay, these soils are clayey and heavy. The content of humus in the upper layers is 2.5-2.7%, nitrogen 0.15-0.18%. The sum of saturated bases in these soils is 28-30 meq per 100 g of soil. Among them, calcium predominates.

In accordance with the methodology, the soil fertility level of the research object was first determined, then a qualitative assessment of the soils was carried out, a bonitet scale was compiled, where dark gray-brown soils were taken as a standard, and quality indicators of other soils were determined from it. Below is the basis bonitet scale of the soils of the Mugan Plain (Table 1).

At the next stage, special rating scales were prepared for the appearance degrees of individual soil features in accordance with the environmental requirements of plants. It should be noted that the ecological evaluation of soils is carried out using specially prepared ecological scales that provide differentiated information about various parameters of environmental conditions. Ecological scales include data on relief and soil-forming rocks, geology, climatic and hydrological conditions, soil cover, vegetation, etc.

According to Mamedova's methodology [14], for the first time we prepared an assessment scale for the appearance degrees of individual soil features of the Mugan Plain in accordance with the environmental requirements of agricultural plants cultivated in this area (Table 2).

The ecological evaluation of the soils of the Mugan Plain was carried out using the above-mentioned special assessment scales.

Calculation of ecological scores for soils in the Mugan Plain

Three groups of data were used in calculating the ecological scores of the soils of the Mugan Plain:

1. Environmental factors that form the soil and its fertility (altitude, slope steepness, precipitation, Md index; $\Sigma T > 10^0C$);

2. Bonitet score calculated on the basis of stable diagnostic indicators of soils;

3. Other soil parameters (pH, particle size distribution, salinity) that have not been accepted as criteria for soil evaluation.

Using all three groups of indicators, an ecological scale of soils in the study area was compiled, taking into account the ecological requirements of the main plant formations and an ecological evaluation map (scale 1:100,000) of the soil cover of the Mugan Plain was compiled (Figure 1).

Table 1 – Basis bonitet scale of the soils of Mugan plain

Soils	Humus, $\frac{t/h}{score}$			Nitrogen, $\frac{t/h}{score}$		Phosphorus, $\frac{t/h}{score}$		Sum of absorbed bases, $\frac{meq}{score}$		Bonitet score
	0-20 cm	0-50 cm	0-100 cm	0-20 cm	0-50 cm	0-20 cm	0-50 cm	0-20 cm	0-50 cm	
Dark gray-brown	75,60/100	173,88/100	284,70/100	6,00/100	12,60/100	6,72/100	15,2/100	38,10/100	36,41/100	100
Ordinary gray-brown	71,7/95	151,20/87	247,00/87	5,28/88	11,34/90	6,00/89	13,23/88	32,0/84	32,53/89	88
Light gray-brown	48,48/64	108,36/62	200,20/70	3,84/64	8,82/70	4,80/71	10,71/71	29,32/77	28,07/77	70
Meadow-gray	52,48/69	116,28/67	213,00/75	3,58/60	8,84/70	4,86/72	11,56/76	37,94/99	37,50/102	76
Lght meadow-gray	45,57/60	106,76/61	186,02/65	3,33/56	7,48/59	4,35/65	9,52/63	34,37/90	35,27/97	68
Dark gray-meadow	64,50/85	161,93/93	247,38/87	5,00/83	10,8/86	5,95/88	13,34/88	33,47/88	33,08/91	87
Ordinary gray-meadow	58,07/77	140,34/81	206,15/72	4,52/75	9,53/76	5,24/78	11,43/76	31,60/83	31,21/86	77
Light gray-meadow	41,17/54	92,08/53	159,60/56	3,33/55	7,62/60	4,05/60	9,53/63	28,35/74	27,97/77	60
Boggy-meadow	38,06/50	87,00/50	141,45/50	3,08/51	6,96/55	3,74/56	8,12/54	25,35/66	24,45/67	54
Alluvial-meadow	48,72/64	104,55/60	184,15/65	3,94/66	9,23/73	5,57/83	12,30/81	34,40/90	33,05/91	72

As a result of our research, a map of the ecological evaluation of the soils of the Mugan Plain at a scale of 1: 100 000 was prepared. As can be seen from the legend of the map (Figure 2), 10 types and subtypes of soils belonging to different regions (Saatly, Sabirabad, Imishli, Bilasuvar, Salyan) are common in the study area. The main bonitet scores were calculated according to the fertility of these soils, and dark gray-brown soils (100 points) were taken as a standard soil.

If we look at the legend of the map, we see that only dark gray-brown soils have a bonitet score lower than the ecological score, and the rest of the soils have higher ecological scores. This indicates that only dark gray-brown soils are sufficiently fertile, and factors such as climate aridity (Md 80 points) and salinity (80 points) play a negative role here, leading to a decrease in the ecological score of these soils (92 points).

According to the ecological indicators of the ordinary gray-brown soils of the area, these soils, located at an altitude of 500 m, received 85 points for height, 95 points for particle size <0.01 mm, 80 points for climate aridity and salt content, which led to a slight increase in the ecological score (90 points) compared with a bonitet score.

For light gray-brown soils, the main limiting factors were soil salinity (60 points) and fertility indicators (70 points). Optimal environmental characteristics and the reaction of the soil solution led to an increase in its ecological score (85 points).

If we look at the ecological assessment of meadow-gray soils, we will see that the salinity factor is the main limiting factor in both subtypes of these soils (20 scores). Other limiting factors include heavy particle size distribution (80 scores) and arid climate (70 scores). Due to the low fertility of these soils, the final environmental scores of these soils were low – 77 and 78 points.

Table 2 – A special rating scale for the appearance degrees of individual soil characteristics of the Mugan Plain in accordance with the environmental requirements of plants

pH

Characteristic	Evaluation, score
6,0-6,5	70
6,5-7,0	80
7,0-7,5	100
7,5-8,0	100
8,0-8,5	95
8,5-9,0	80

Dry residue, %

Characteristic	Evaluation, score
<0,10	100
0,10-0,25	90
0,25-0,50	80
0,50-1,00	60
1,00-2,00	20

Soil texture (particles <0.01 mm, %)

Characteristic	Evaluation, score
20-30	70
30-40	100
40-50	95
50-60	80
60-70	60

∑ T>10^{0}C

Characteristic	Evaluation, score
< 2000	<50
2000-3000	80
3000-4000	90
4000-5000	100
>5000	100

Height, m, a.s.l.

Characteristic	Evaluation, score
1000-1500	20
500-1000	40
200-500	85
>28-200	100

Precipitation, mm

Characteristic	Evaluation, score
<200	<30
200-300	70
300-500	90
500-700	100
700-1200	85

Md index

Characteristic	Evaluation, score
<0,10	<50
0,10-0,15	80
0,15-0,25	100
0,25-0,35	90
0,35-0,45	85
>0,45	<50

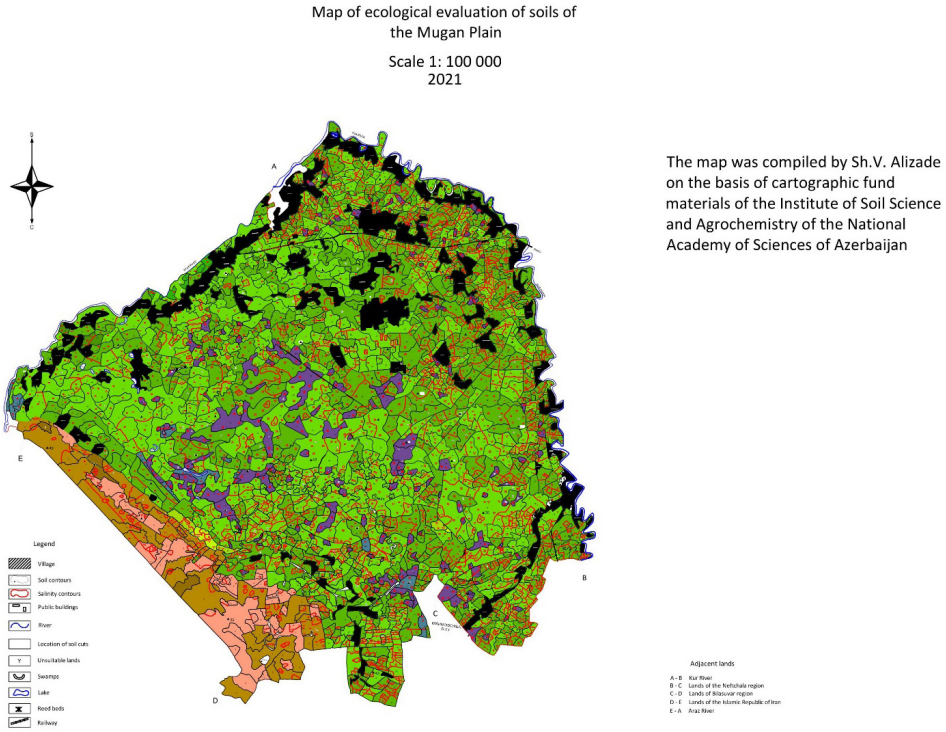

Figure 1 – Map of the ecological evaluation of soils of the Mugan Plain

L E G E N D

Color	Name of soils	Height, m	Precipitation, mm	Md	∑T>10 C	Bonitet score of soil	<0,01mm,%	pH	Dry residue, %	Ecological score
	Dark gray-brown	500/85	316/90	0,15/80	4000/100	100	41,21/95	7,7/100	0,36/80	91
	Ordinary gray-brown	500/85	316/90	0,15/80	4000/100	88	41,8/95	7,7/100	0,41/80	90
	Light gray-brown	300/85	316/90	0,15/80	4000/100	70	49,24/95	7,9/100	0,58/60	85
	Meadow-gray	200/100	294/70	0,1/80	4200/100	76	55,17/80	8,1/95	1,06/20	78
	Light meadow-gray	200/100	294/70	0,1/80	4200/100	68	59,41/80	8,2/95	1,2/20	77
	Dark gray-meadow	200/100	294/70	0,1/80	4200/100	87	50,18/95	8,0/100	0,85/60	87
	Ordinary gray-meadow	100/100	250/70	0,1/80	4400/100	77	49,2/95	8,0/100	1,01/60	85
	Light gray-meadow	50/100	230/70	0,1/80	4460/100	60	52,61/80	8,1/95	1,16/20	76
	Boggy-meadow	50/100	250/70	0,1/80	4460/100	54	48,3/95	8,1/95	1,06/20	76
	Alluvial-meadow	50/100	250/70	0,1/80	4460/100	72	41,75/95	8,1/95	0,51/80	87

Figure 2 – Legend of the Map of the ecological evaluation of soils of the Mugan Plain

If we consider gray-meadow soils, although the lack of precipitation is a limiting factor for the cultivation of agricultural crops on these soils (70 points), the height above sea level and the sum of active temperatures were optimal (100 points). Of the soil indicators, only the reaction of the soil solution is at the optimal level (100 points), the rest of the indicators are below optimal. In the final assessment, both the quality index and the ecological score of dark gray-meadow soils were 87 scores, while for ordinary gray-meadow soils it increased by 8 points and reached 85 scores.

The situation is somewhat different in light gray-meadow soils, where the main limiting factors are soil salinity (20 scores) and low fertility (60 scores), as a result of the combination of other environmental and soil factors, the ecological score of these soils was 76.

The optimal values for boggy-meadow soils are only the height factor and the sum of active temperatures (100 scores). The most important limiting factors for these soils are soil salinity (20 points) and low soil fertility (54 points). Since the rest of the ecological and soil indicators are also below optimal (between 70-95 points), boggy-meadow soils can be attributed to the soils with the lowest ecological indicators for the Mugan Plain (76 scores).

The situation is somewhat different in alluvial-meadow soils, where a small amount of precipitation (70 scores) is considered a limiting factor. These soils are quite fertile (72 points), slightly saline variants of these soils are also found in this area (80 points), the altitude data and the sum of active temperatures are optimal (100 scores), the granulometric composition and reaction of the soil solution are satisfactory (95 points). As a result of the total impact of all environmental factors, the ecological score of this soil increased to 87 scores.

In conclusion, considering the ecological state of the soils of the Mugan Plain, it can be summarized that the most ecologically suitable soils for growing crops in this area are dark gray-brown (91 scores) and gray-brown (90 scores) soils, but dark gray-meadow and alluvial-meadow soils are quite suitable (87 scores) soils.

Conclusion

1. A qualitative assessment of the soils of the Mugan Plain of Azerbaijan was carried out, the main bonitet scale was compiled, while dark gray-brown soils were chosen as the standard (100 scores) and relative to it the bonitet scores of the rest of the soils were determined. Ordinary gray-brown soils received 88 points, dark gray-meadow soils – 87 scores, but boggy-meadow soils have the lowest fertility (54 scores).

2. A special assessment scale has been prepared for the appearance degrees of individual features of the soils of the Mugan Plain in accordance with the environmental requirements of the crops cultivated here.

3. Ecological evaluation of the soils of the Mugan Plain was carried out using special assessment scales, the main limiting factors affecting the fertility of the studied soils were identified, and the ecological scores of the soils were calculated. It was established that the highest ecological scores in the study area were obtained by dark gray-brown (91 scores), ordinary gray-brown (90 scores) and dark gray-meadow (87 scores) soils. As a result of the research, an ecological evaluation map (scale 1:100,000) of the soil cover of the Mugan Plain was compiled.

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