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MODERN AGROECOLOGICAL CHARACTERISTICS OF THE SOILS OF THE MUGAN PLAIN

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Abstract. To determine the current level of soil fertility in the Mugan Plain, the territory of which is characterized by the high degree of development and extensive use of irrigated agriculture, a comprehensive agroecological characterization of the main types and subtypes of soils is carried out. For this purpose the agrophysical and agrochemical properties of these soils are studied on the basis of field soil, fundamental and laboratory studies. It is determined that the soil-ecological conditions of the study area are favorable for the cultivation of many agricultural crops under irrigation, the leading of which are cotton and cereals. It is established that cultivated gray-brown and meadow-gray soils are highly productive, since in gray-brown soils the amount of humus in the upper layer of the profile is 2.78-3.15%, the amount of total nitrogen is 0.20-0.24 %, the sum of absorbed bases -24.13-41.80 meq; in meadow-gray soils - 2.02-2.91%, 0.16-0.24% and 18.85-38.61 meq, respectively.

Keywords: *Mugan Plain, parameters of fertility, gray-meadow soils, irrigation, salinization.*

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1. Introduction

When studying the ecological state of soils, it is necessary to consider the soil cover, first of all, as an indispensable and most important component of the Earth's biosphere, including all terrestrial biocenoses. The soil, which is a part of the natural anthropogenic complex, constantly interacts with the air, water, biogenic and technogenic environment. At this time, the soil is exposed to anthropogenic impact, changes itself and directly or indirectly affects other components of the biosphere.

To optimize the strategy and practice of the rational use of agrobiogeocenoses, a system of their comprehensive agroecological assessment is required as an integral natural and anthropogenic organism, the functioning of which should be aimed at achieving a given level of productivity and ensuring a favorable environmental situation. At the present time, scientists are carrying out numerous works to study the features of the direction of natural and anthropogenic processes and their consequences occurring in soil ecosystem (Agegnehu *et al.*, 2014; Yusifova & Nuriyeva, 2014; Vanlauwe *et al.*, 2017; Legese & Gelanew, 2019; Nira & Miura, 2019; Zatserkovnyi *et al.*, 2019; Eugenio *et al.*, 2020; Inoue *et al.*, 2020; Asmare1, 2021; Carmo & Domingos, 2021; Mosier *et al.*, 2021; Strock *et al.*, 2022). From this point of view, when studying the agroecological state of the soils of the Mugan Plain, it became necessary to conduct comprehensive studies in order to obtain an agroecological characteristic.

2. Methods and materials

The object of research is the territory of the Mugan Plain, the total area of which is 455332.5 ha. To fulfill the tasks of studying the soil cover, we conducted field soil researches in 2016-2020 in this area, set 36 soil profiles, in addition, we reviewed, studied and summarized the results of fund and literary materials of soil researches on the Mugan steppe of the Institute of Soil Science and Agrochemistry National Academy of Sciences of Azerbaijan (Babayev, 1984; Mustafayeva, 2005; Babayev & Gurbanov, 2010; Bayramov, 2010; Akhmedova, 2012) and Azerbaijan State Scientific Research Institute of Land Management (Report on soil cover of Sabirabad region, 2013; Report on soil cover of Saatli region, 2015). Physical and chemical analyzes of soil samples taken were carried out in the laboratory of "Agroecology and soil evaluation" of the Institute of Soil Science and Agrochemistry of the National Academy of Sciences of Azerbaijan according to the following method: humus and total nitrogen - according to I.V. Tyurin, granulometric composition - according to N.A. Kachinsky, pH - aqueous suspension - pH meter, CO_2 carbonates - calcimeter, gross phosphorus - according to A.M. Meshcheryakov, full water extract - according to D.I. Ivanov (Arinushkina, 1970).

3. Results and discussion

The Mugan Plain is located in the southeastern part of the Kur-Araz Plain. The Mugan plain borders the Kur and Araz rivers in the north and northeast, the Kur-Akusha in the southeast, the Lankaran plain in the south, and Islamic Republic of Iran in the south and southwest. The Mugan Plain is divided into Northern, Southern and Central parts; it is separated from the North and the Center by the collector of the irrigation system. The area of the Mugan Plain occupies an area of 455332.5 ha, has the shape of a plain from northwest to southeast (slope 0.0001-0.0003) and is located below sea level (Babayev, 1984).

The relief of the Mugan Plain is quite complex. Northern Mugan, its relief and soils owe their origin to the accumulative activity of the Kur and Araz. The forming factor of Central Mugan is only the Araz River. The formation of Northern Mugan is relatively new and its formation continued until recently. As a result of periodic floods of the Kur and Araz rivers, these waters flowed towards the Northern Mugan region. Accumulative activity in the region of central Mugan ceased long ago, and the processes that led to the modern relief are of a denudation nature. It is necessary to mention the ancient origin of the Araz River, which is below sea level. These formations are separated by very large alluvial-accumulative formations, deep dry old channels with high banks and embankments along the channel.

A significant part of the Mugan Plain is below sea level. The modern form of the relief is predominantly accumulative, but in the foothill zone surrounding it from the north, the denudation-erosion type of relief prevails. The slope of the surface is 0.003-0.004. Heavy soils are scattered along the edges.

I.V. Figurovsky, V.R. Volobuev, E.I. Shikhlinsky noted that the Kur-Araz lowland belongs to the semi-desert subtropical zone in terms of landscape and climate (Babayev, 1984). The average annual temperature on the Mugan Plain ranges from 14 to 14.2^0 C. The coldest month is January, the average January temperature is $2.3\text{-}2.5^0$C. The maximum temperature reaches $27\text{-}27.5^0$C in July-August. The amount of precipitation during the year varies between 200-400 mm. The maximum precipitation falls in spring and autumn. The air humidity is high: 60-80%. In summer it decreases - 60-65%, and on the Kur Plain it fluctuates around 70%, and in winter it reaches 90% (Huseynova, 2018). The high air humidity of the Kura-Araz plain is explained by the influence of the Caspian Sea. Evaporation decreases during the year by an order of 1 mm, least of all in winter. It is at its highest level in the middle of summer - 4 mm per day. In September, evaporation drops sharply.

In the vegetation of the Mugan plain, there were mainly three types of plants: wormwood, saltwort, and shrubs. Wormwood is typical for non-saline virgin areas. Salt plants developed in salt settlements. shrubs - characteristic of places with high humidity. A large area is occupied by groups with a predominance of *Petrosimonia brachiata* (Huseynova, 2018).

The study of the soil cover of the Kur-Araz valley and the Mugan plain has always attracted various scientists. The first study of the area was carried out by S. I. Turemnov, A.S. Preobrazhensky, N.A. Dimo at the beginning of the last century. Later, more systematic studies and generalization of the reclamation features of the Kur-Araz lowland were carried out by Volobuev (1951), Mammadov (2012), Babayev (1984) and others (Azizov & Guliyev, 1999; Abdullayev, 2009; Hashimov, 2012; Mustafayev, 2018) and general characteristics of the genesis and properties of the soil cover of the studied region were given. The following types of soils are common in the study area: gray-brown; gray-meadow; meadow-gray; alluvial-meadow; boggy-meadow and solonchaks. In accordance with the goals and objectives of our study, we present a comprehensive agro-ecological characteristic of these soils.

Gray-brown soils. There are 3 subtypes on the territory: dark, ordinary and light gray-brown soils. These soils develop in dry deserts under wormwood-ephemeral cenoses. Soil-forming rocks consist of deluvial and deluvial-proluvial carbonate loams. According to the morphological structure, these soils are characterized by an average thickness, a humus profile (40–50 cm), a dense structure, and a clay structure in the lower layers. Usually they boil away from the upper layers. The presence of carbonates gives some density to the illuvial layer (8-10%). The amount of humus in layer A is more than 2.78-3.15%, total nitrogen is 0.22-0.25% (Table 1). According to their mechanical composition, these soils are mainly clayey and heavy loamy. An increase in the silt fraction is confirmed by signs of claying in the middle part of the profile. More than half of this soils are used for agricultural crops.

Gray-meadow soils have developed under semi-hydromorphic conditions, so the process of soil formation occurs under the influence of surface and soil moisture. As a result of an increase in the drainage of the territory and a decrease in the level of groundwater during the time of the Caspian Sea, gray-meadow soils underwent a large degree of aridization. This process is confirmed by the nature of the change of vegetation and the significant presence of ephemera. As a result of steppe formation, profound changes occurred in the morphology of these soils. The hydrogeological conditions of the plain, mainly the level and regime of groundwater, play an important role in the genesis of these soils. The predominant intervals of groundwater occurrence are 3-5 m. Depending on the nature of the soil, the degree of drainage of the area and anthropogenic human activity, a sharp differentiation in the level of groundwater is observed. Soil-forming rocks for gray-meadow soils are deluvial-alluvial gravel, usually carbonate, as well as ancient Caspian saline deposits. These soils are characterized by the following soil profile structure. The thickness of the humus layer in virgin soils is -

20-30 cm, in cultivated massifs -40-60 cm. The illuvial carbonate layer is slightly elongated (Huseynova, 2016).

Table 1. Physico-chemical parameters of gray-brown, gray-meadow and meadow-gray soils

Indicators	Soils		
	Gray-brown	Gray-meadow	Meadow-gray
Humus,%			
0-20 cm	2,78-3,15	1,90-2,33	2,2-2,91
0-50 cm	2,32-2,48	1,25-2,00	1,60-2,10
0-100 cm	1,85-1,95	0,93-1,31	1,04-1,76
Nitrogen, %			
0-20 cm	0,22-0,25	0,12-0,18	0,16-0,24
0-50 sm	0,17-0,20	0,10-0,15	0,10-0,19
Phosphorus, %			
0-20 cm	0,23-0,27	0,16-0,23	0,20-0,24
0-50 cm	0,18-0,23	0,12-0,20	0,15-0,21
Sum of absorbed bases, meq			
0-20 cm	24,13-41,80	18,85-38,61	30,10-53,40
0-50 cm	23,30-37,60	17,6-39,4	28,00-45,90
Particular size			
<0,01,%, 0-100 cm	40,80-42,80	42,0-59,40	48,80-69,00
<0,001,%, 0-100 cm	9,5-11,5	9,00-22,50	22,64-33,72
pH, 0-100 cm	6,9-8,0	7,5-8,5	7,8-8,2
Dry residue, %, 0-100 cm	0,18-0,75	0,30-1,52	0,24-1,90

Table 2. Physico-chemical parameters of boggy-meadow and alluvial-meadow soils

Indicators	Boggy-meadow		Alluvial-meadow	
	Interval	M	Interval	M
Humus,%				
0-20 cm	1,50-1,95	1,73	1,40-2,50	2,10
0-50 cm	1,30-1,70	1,50	1,90-2,00	1,70
0-100 cm	1,00-1,30	1,15	1,00-1,70	1,45
Nitrogen, %				
0-20 cm	0,12-0,16	0,14	0,13-0,20	0,17
0-50 sm	0,10-0,14	0,12	0,11-0,19	0,15
Phosphorus, %				
0-20 cm	0,13-0,19	0,17	0,22-0,26	0,24
0-50 cm	0,11-0,17	0,14	0,17-0,23	0,20
Sum of absorbed bases, meq				
0-20 cm	25,00-25,95	25,35	24,90-43,90	34,40
0-50 cm	24,00-24,70	24,45	25,30-40,00	33,05
Particular size				
<0,01,%, 0-100 cm	41,30-55,30	48,30	39,50-44,00	41,75
<0,001,%, 0-100 cm	16,68-23,72	19,51	10,50-13,70	12,10
pH, 0-100 cm	7,9-8,5	8,1	7,8-8,5	8,1
Dry residue, %, 0-100 cm	0,24-1,72	1,06	0,16-0,68	0,51

Table 3. Fertility indicators of the soils of Mugan plain

Soils	Humus,%			Nitrogen,%		Phosphorus,%		SAB, meq	
	0-20	0-50	0-100	0-20	0-50	0-20	0-50	0-20	0-50
Dark gray-brown	3,15	2,76	2,19	0,25	0,20	0,28	0,24	38,10	36,41
Ordinary gray-brown	2,99	2,40	1,90	0,22	0,18	0,25	0,21	32,0	32,53
Light gray-brown	2,02	1,72	1,54	0,16	0,14	0,20	0,17	29,32	28,07
Dark gray-meadow	2,71	2,55	1,86	0,21	0,17	0,25	0,21	33,47	33,08
Ordinary gray-meadow	2,44	2,21	1,55	0,19	0,15	0,22	0,18	31,60	31,21
Light gray-meadow	1,73	1,45	1,20	0,14	0,12	0,17	0,15	28,35	27,97
Meadow-gray	2,05	1,71	1,50	0,14	0,13	0,19	0,17	37,94	37,50
Light meadow-gray	1,78	1,57	1,31	0,13	0,11	0,17	0,14	34,37	35,27
Alluvial-meadow	2,10	1,70	1,45	0,17	0,15	0,24	0,20	34,40	33,05
Boggy-meadow	1,73	1,50	1,15	0,14	0,12	0,17	0,14	25,35	24,45

Light gray-meadow soils are characterized by a weak profile and low humus content: the amount of humus in the arable layer is 1.90-2.33%. The structure of the soil is unclear, uneven, the soil is carbonated from the top layer, the soils of the highlands are favorable for the development of agricultural plants, while the soils of the lowlands tend to be hard and brittle, which creates difficulties in their cultivation.

Meadow-gray soils. These soils are divided into 2 subtypes: ordinary and light meadow-gray. Their development took place under the influence of surface waters, so the role of groundwater is insignificant, and the vegetation is seasonal and depends on irrigation. Therefore, the level of groundwater temporarily rises and amounts to 3.5-5 m. These soils are characterized by a short humus profile, and in the virgin soil, the formation of a sod layer on the upper surface is noted. Its general characteristic features are: dark gray, gray, light gray color, the upper layer is soft, has a clod structure in depth. The upper surface of the profile is slightly damp, moist in depth. carbonates occur at a depth of 50–60 cm (Jalilova, 2013). There are rusty remains of the former meadow regime. Soil boiling is noticeable from the upper surface. The amount of humus up to 2%, contains humates (Table 1). The sum of absorbed bases is high. The low amount of total nitrogen explains the moderate supply of humus with nitrogen compounds. According to the mechanical composition, these soils are clayey and loamy. In most cases, in the upper layers of the cultivated territories, the accumulation of silt particles due to irrigation is most noticeable. Meadow-gray soils are slightly saline, the amount of dry residue in the upper layer is 0.18-0.36%. The distribution of salts along the soil profile is the same; easily soluble salts are practically absent in the lower layers (Feyziyeva, 2013).

Boggy-meadow soils. These soils are common on modern terraces of the Caspian Sea, they are formed under conditions of excessive moisture. These soils cover depression relief elements. These soils are formed in alluvial-proluvial deposits of various mechanical composition, their thickness reaches 3-5 m and gradually decreases towards the Caspian Sea. Depending on the characteristics of soil-forming rocks, the level of carbonate content and salinity of the soil is different (Mammadov et al., 2005). According to P. B. Kovalev, the absence of carbonates in the upper layers of these soils is explained by the absence of carbonate compounds in the alluvial-proluvial deposits brought from the slopes of the mountains. In the deep layers, the amount of water-soluble salts is more than 3%. These soils are rich in organic matter, humus content - 1.5-1.95%, C:N ratio - 10-16 and depend on moisture conditions (Table 2). A significant change in the amount of carbonates is observed throughout the depth of the soil profile. According to the mechanical composition, the soils are heavy loamy and loamy, the amount of physical clay in the upper layer is 50-70% (Talibli, 2018).

Alluvial-meadow soils. These soils stretch along the banks of the Kur-Araz River in the form of a narrow strip and occupy an area of 716.93 hectares or 0.15%. Typical morphological features for these soils are brown and brownish color of the upper layer, rusty and gray spots in the middle and lower parts of the profile, a high amount of carbonates and clay content. These soils were formed on young alluvial deposits with low ground moisture and no stagnant surface water. Due to the amount of physical clay, these soils are characterized by clayey, heavy loamy, and sometimes sandy mechanical composition. The amount of humus in the upper layers is 2.0-2.1%, nitrogen 0.15-0.17%. Sum of absorbed bases in these soils are 33-34 meq per 100 g of soil, calcium cations predominates among them (Table 3).

Salines. In modern times, the waters of the Kura River play an important role in the processes of salt distribution in the upper meters of the soil. Salt marches in the study area make up 44874.59 ha or 9.86% of the total area. Salt marshes are gray or steel gray to a depth of 50 cm and intensify from depth. The dry residue is more than 2%, in some places 1.7%, in the lower layers it does not exceed 3.5-4.0%. The number of absorbed bases is 30-40 meq per 100 g of soil. The influx of salts into the territory covered by these solonchaks occurs continuously, with the influx of groundwater from the Kur and Araz rivers and foothill plains.

4. Conclusion

The soils of the Mugan Plain, which is a part of the Kura-Araz lowland, the main agricultural region of Azerbaijan, are widely used for various crops (cotton, grain, beans, etc.) using intensive irrigated agriculture due to favorable soil and environmental conditions. The main irrigated soils of the region are gray-brown soils in the zone of dry steppes, gray-meadow and meadow-gray soils in the semi-desert zone. According to the results of the studies, gray-brown and meadow-gray soils have higher fertility; alluvial-meadow soils have a medium level of fertility; varieties of these soils are widespread in the plain, subjected to varying degrees of salinization and claying.

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