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INVESTIGATION OF SOIL DEGRADATION PROCESSES IN THE MAKAT FARM IN ATYRAU REGION

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*Abstract***.** The study conducted in the Makati region includes granulometric analysis, vegetation assessment, topsoil evaluation (horizons A and B), and chemical testing to determine soil resistance to mechanical stress. The results of the soil stability analysis indicate that the upper soil layers across all sites are more vulnerable to erosion and soil exhaustion. This is primarily due to a reduction in clay content, the depletion of humus, and the accumulation of toxic salts. The decline in vegetation cover further aggravates the issue, pointing to severe pasture degradation. These findings highlight the urgent need for soil conservation measures, such as improving soil physical properties and mitigating salt exposure, to support ecosystem restoration. Field studies also identified a variety of soil profiles, with gray-brown salt marsh and brackish soils being the most prevalent. These soil types are marked by low buffering capacity, which intensifies the degradation process. The analysis classified soil degradation in the region as moderate to severe. Anthropogenic factors, including mechanical disturbances and improper land use, significantly accelerate soil degradation. This, in turn, compromises ecosystem stability by diminishing soil quality and reducing its productivity, thereby negatively impacting the broader environment of the region.

Keywords: desertification, soil degradation, the Caspian region, climatic changes, desertification, soil degradation, the Caspian region, climate change, ecosystems, soil buffering.

INTRODUCTION

Desertification is one of the most serious environmental problems of our time, affecting about 35% of the Earth's surface and affecting 32% of the world's population [1]. Desertification is the degradation of land in arid, semi-arid, and arid regions, including deterioration of vegetation, reduced soil quality, and nutrient depletion. According to various statistics, land degradation has affected more than 9 million square kilometers, and in some cases up to 7 million hectares of land are lost from productive use annually [2]. In response, the United Nations adopted the Convention to Combat Desertification [3], which aims to prevent land degradation and restore ecosystems.

According to the UN, drylands occupy about 30% of the Earth's surface and are present in more than 10 countries with more than 2 billion people [4]. At the current rate of desertification, it is projected that by 2025, one in five people on Earth will live in regions prone to drought and land degradation. Currently, more than two billion hectares of productive lands have been degraded, and another 12 million hectares continue to be degraded annually [5].

Central Asia is a prime example of a region where desertification has reached its most acute proportions, with cross-border problems having a significant impact on ecosystems and populations. A number of studies indicate that there is currently no region in the world with an area of more than four million square kilometers where the threats of desertification are as great as in the area located between the Caspian Sea and the Pamir Mountains. Currently, more than two thirds of the territory of Central Asia is arid and semi-arid lands, which makes the region extremely vulnerable to degradation processes [6]. For example, in Kazakhstan, according to the World Bank, about 66% of the territory is subject to desertification [7].

The effects of desertification in Central Asia are exacerbated by climate change and anthropogenic pressures. Climate change forecasts for the region suggest a temperature increase of 2-4°C [8]. The illegal use of land during the Soviet period, including intensive irrigation, overgrazing and deforestation of mountain forests, led to environmental consequences that are still being felt.

It is estimated that 4-10% of cultivated areas, 27-68% of pastures and 1-8% of forest resources are currently degraded in Central Asia [9]. These processes have a significant impact on the sustainability of natural systems, as well as on agricultural productivity, which leads to economic losses. In particular, since the independence of the Central Asian countries, agriculture in the region has lost about 20-30% of its productivity, resulting in annual losses of $2 billion [10].

Special attention should be paid to soil degradation, which is one of the most pressing environmental problems. The process of degradation in the Caspian region, where the factors of desertification and soil degradation are at their greatest, has both environmental and socio-economic consequences. Soil degradation is observed on these lands, manifested in erosion, salinization, desiccation and loss of fertility, which directly affects agriculture, biological diversity and the sustainability of the region's ecosystems [11-17].

MATERIALS AND METHODS

Field soil studies conducted at monitoring sites in the Makati region cover various soil conditions. Soils that have been damaged at various levels indicate low natural soil buffering rates in this area. The research was conducted on an area of 250 hectares of degraded pasture lands of a peasant farm in the Makat district. As part of the research, the gray-brown saline and salt marsh soils typical of the area, characteristic of areas with a dry climate and frequent droughts, were studied.

Makat district is located in the Atyrau region of Kazakhstan and is characterized by a sharply continental climate with hot summers and moderately cold winters. This area is characterized by significant temperature fluctuations and lack of precipitation, which significantly affects the condition of soils and their resistance to soil exhaustion.

The following chemical and physico-chemical parameters were determined in the soil samples: humus content, granulometric composition, acidity, salt composition and other parameters affecting soil quality. The field and laboratory work was carried out using generally accepted methods of soil science. The granulometric composition of soils was determined according to the Kaczynski method (GOST 12536-2014). The humus content in the soils was measured using the Tyurin method (GOST 26213-91). The mechanical composition of the soil has a decisive influence on its resistivity. In accordance with the "Scientific and methodological guidelines for monitoring lands of the Republic of Kazakhstan", soil resistance to anthropogenic mechanical stress is classified depending on the content of particles of physical clay (fraction less than 0.01 mm) as follows: more than 20% - high degree of stability, 10-20% - medium degree of stability, less than 10% - low degree of stability. The assessment of the degree of soil degradation was carried out according to the criteria specified in the "Criteria for determining the degree of degradation of soils and lands of the Republic of Kazakhstan".

RESULTS AND DISCUSSION

Soil section 1 is laid on the Makatsky district of gray-brown desert soils, under the solyanka vostochnaya- climacoptera woolly vegetation, 40-45% coverage, boiling from HCl is violent from the surface (figure 1).

0-15 cm, gray-brown (with a brownish tinge), dry, compacted, up to 5 cm lego compacted, finely porous, dusty-powdery-lumpy, large and small plant roots, medium loam,

15-34 cm, brownish-gray, dry, strongly compacted, porous, lumpy-dusty, thin plant roots, medium loam,

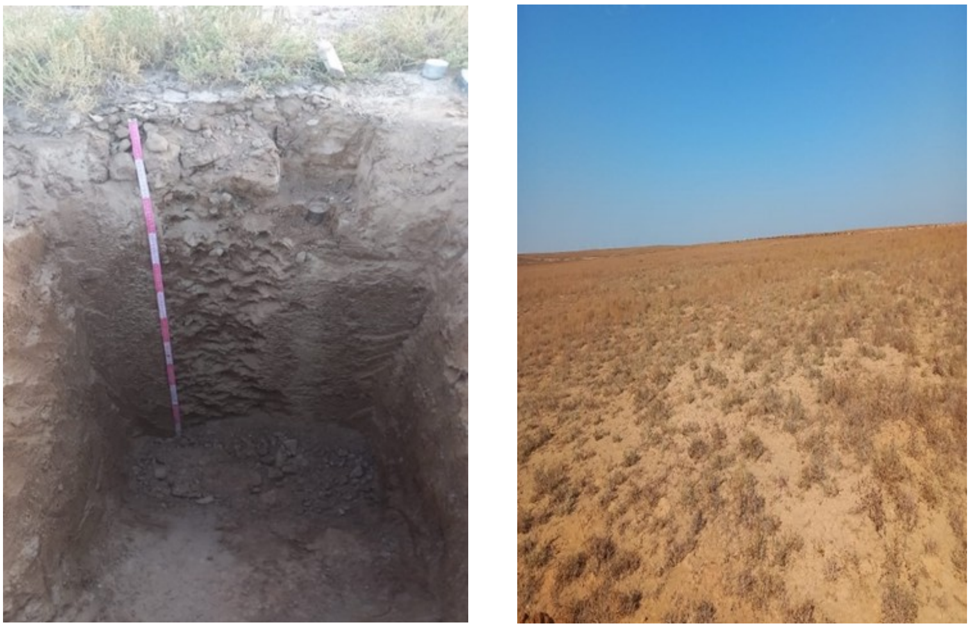


Figure 1 – Gray-brown desert soils, under Solyanka Vostochnaya (*Salsola orientalis*), soil section 1

34-59 cm, brown with spots of carbonates, moist, dense, lumpy, thin plant roots, medium loam,

59-93 cm, brown with numerous spots of carbonates, moist, fine nutty, sometimes dense, sometimes compacted, medium loam,

93-130 cm, uneven color, gray-whitish, spotted with carbonates, moist, sandy loam.

In the upper horizons, the soil is denser and inhibits root growth, which can hinder the active development of vegetation. In deeper layers, there is an increase in humidity and an increase in the content of carbonates, which may indicate more complex water-mineral characteristics of the soil. To improve conditions for plants in this area, work may be required to improve the physical properties of the soil, as well as to reduce exposure to high levels of carbonates, which may lead to improved nutrient availability for plants (figure 2).

Soil section 2 (salt marsh) is laid near Potashnikov-sarsazan vegetation, projective cover, boiling from HCl is violent from the surface (figure 3).

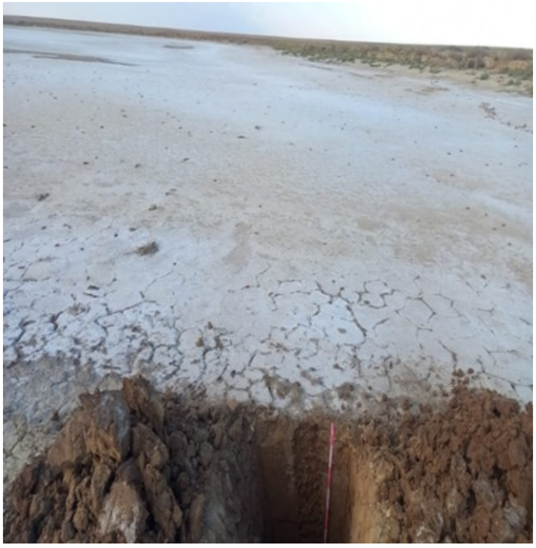
0-4 cm, dirty dark gray, moist, fractured, loam consisting of broken and whole shells,

4-23 cm, grayish-whitish with a large number of rusty and glaucous spots, dense layered loam with fragments of shell rock, 23-50 cm, irregularly colored: on a bluish background, there are abundant rusty accumulations, spots and rare humus streaks, a large number of veins and spot accumulations of salts. The horizon is moist and loamy,

50-80 cm, bluish-ochreous, moist, structureless, sandy loam. There are dirty white spots of carbonates in the lower part. There are many streaks and point accumulations of salts along the horizon, as well as broken shells,

80-100 cm, bluish-green, many spots of easily soluble salts, contains rusty and black spots of iron and manganese oxides.

In this soil section, it is a typical salt marsh soil with pronounced signs of salt formation and mineralization. It has a heterogeneous texture and color, with a large number of salt deposits, iron and manganese oxides, which indicates a high activity of the processes of leaching and accumulation of salts in the soil (figure 2).



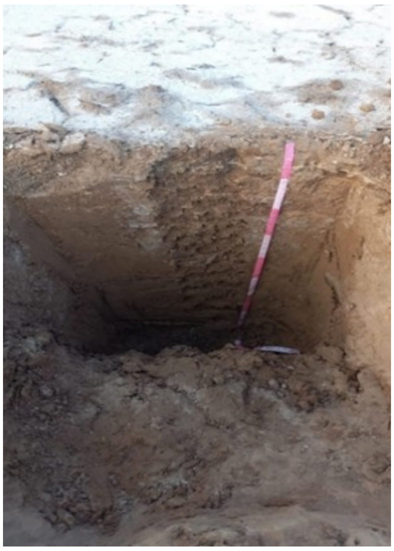


Figure 2 – Salt marsh is covered with potashnikovo-sarsazan vegetation, soil section 2

Section 3 is laid on the opposite-leaved climacopter-small-flowered worm-wood vegetation, 45-50% coverage, boiling from HCl is violent from the surface (figure 3).

0-13 cm, gray-brown, lumpy-dusty, dry, sometimes dense, sometimes loose, permeated with plant roots, light loam,

13-22 cm, light gray-brown, dry, lumpy-nutty-powdery, thin plant roots,

22-50 cm, yellowish-brown, dry, very dense, columnar-prismatic, medium loamy, streaked carbonates.

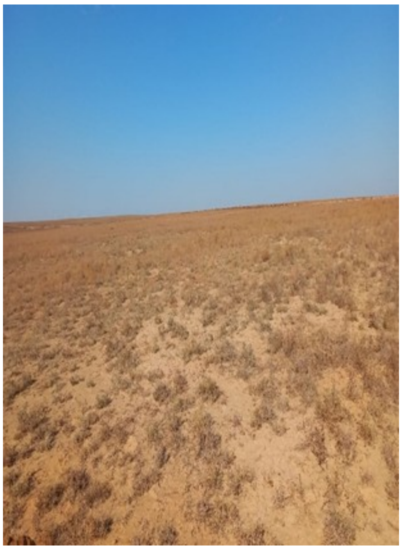
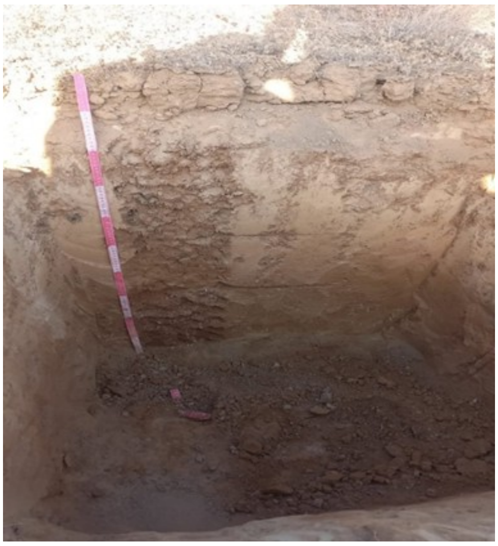



Figure 3 – Opposite-leaved wormwood is laid on a climocopter (*Climacoptera),*
soil section 3

50-71 cm, brownish-yellow, dry, compacted, slightly loamy, carbonates in the form of spots,

71-100 cm, heterogeneously colored, layered, reddish spots of iron oxides.

Based on the description, the soil has a diverse structure and composition, with noticeable changes as the depth increases. The upper layers are characterized by relatively light loam with good biological activity (presence of roots). At greater depths, the soil becomes more dense and mineralized, with carbonates and iron oxides, which may indicate the specific mineralogy of this site. Such features can have an impact on water exchange, plant nutrition, and possibly on the agronomic properties of the soil (figure 3).

Section 4 is laid on the bottom of the saltpeter wormwood-solyanka vostoch-naya-climacoptera opposite-leaved vegeta-tion, 35-45% coverage, boiling from HCl violent from the surface (figure 4).

0-10 cm, gray-brown, dry, lumpy-dusty, large and small plant roots,

10-30 cm, light brown, compacted, dry, lumpy-dusty, loam, thin plant roots,

30-41 cm, brownish-whitish, dry, strongly compacted, lumpy-nutty, carbo-nates in the form of spots,

41-90 cm, brownish yellow, dry, compacted, strong spot of carbonates,

91-130 cm, brown with separate aggregations and spots of carbonates, dry, dense, fine nutty-dusty, loam.

Based on the description of the soil, it can be concluded that the soil in question has a pronounced densification and contains a significant amount of carbonates, especially at a depth of 30-130 cm. This can limit the growth of plant roots at deeper levels and reduce the availability of water and nutrients (figure 4).

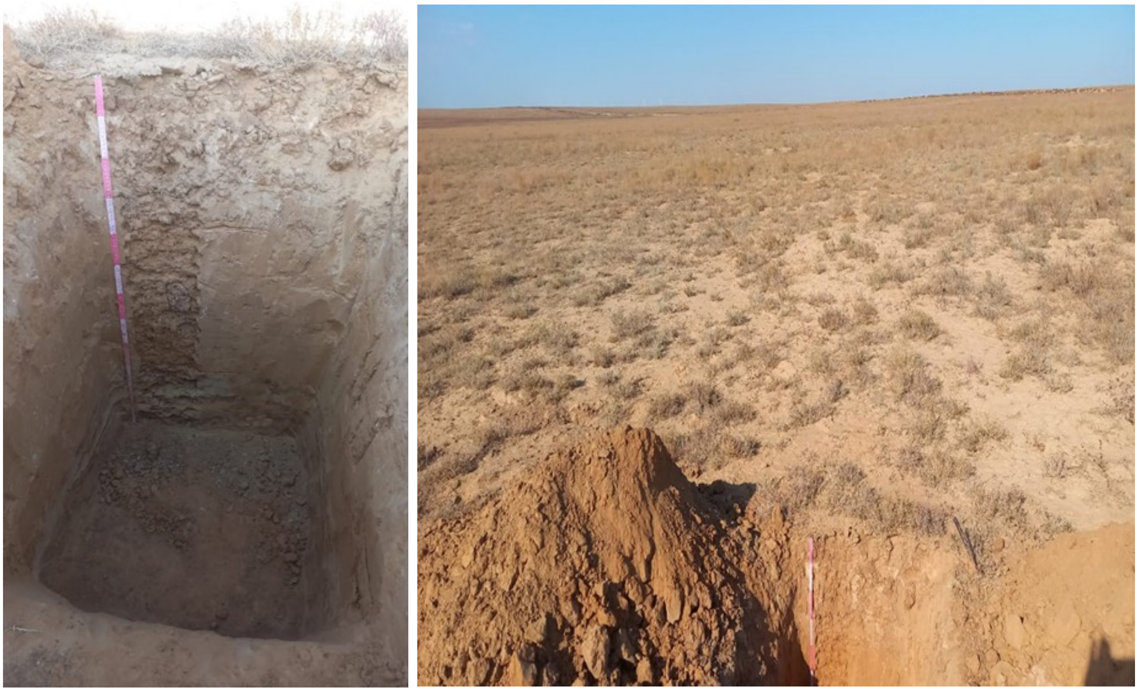


Figure 4 – Laid on the bottom of the saltpeter wormwood-oriental solyanka-Climocoptera opposite-leaved vegetation, soil section 4

The analysis of soil samples collected at the studied sites with respect to the granulometric composition demonstrates that soils have different resistance to mechanical influences. The response of ecosystems and their components, such as soils and vegetation, to anthropogenic mechanical impacts largely depends on weather conditions and the time of year. In this context, the water regime often becomes a key factor affecting soil stability.

Another important external factor influencing the nature of impacts is wind activity. Work in areas with soils of light mechanical composition in spring, during the period of the greatest Aeolian activity, can lead to a significant increase in deflation processes.

Each section has a different depth characteristic, and for each layer, soil stability is determined, which ranges from "unstable" to "high degree of stability." Depending on the mechanical composition of the soil, as well as on the mechanical impact, the degree of stability may vary at different levels of the section (table 1).

Soil section -1 demonstrates high soil stability in the deep layers (34-59 cm and below), while in the upper layers (0-34 cm) the soil is assessed as unstable or with moderate stability (table 1).

Section SS-3 has soil with a high degree of stability at almost all depths (from 23 cm to 100 cm), but in the upper layers (0-4 cm) the soil is assessed as unstable (table 2).

Section SS-0 (virgin) shows high stability at depths of 12 cm and below, with medium stability in the upper layers (table 1).

The SS-4 section is characterized by high stability at a depth of more than 22 cm, and in the upper layers (0-13 cm) soil stability is considered low (table 1).

Analysis of the resistance of gray-brown desert soil to mechanical stress shows that different sections have different degrees of stability. The soil in the upper layers (up to 20-30 cm) of virgin land is most often unstable or moderately stable, which may be due to increased susceptibility to erosion and degradation as a result of anthropogenic activity. Soil stability increases significantly in deeper layers (table 1).

Table 1 – Assessment of soil resistance to anthropogenic mechanical effects of gray-brown desert soil in 2024.

Soil sections	Depth, cm	Fraction less than 0.01	Stability
SS – 1	0-15	9,4	unstable
	15-34	8,1	unstable
	34-59	20,9	high stability
	59-93	14,59	medium degree of stability
	93-100	13,77	moderately stable
SS– 3	0-4	9,8	unstable
	4-23	19,7	medium degree of stability
	23-50	22,82	high degree of stability
	50-80	23,1	high degree of stability
	80-100	22,4	high degree of stability
SS – 0	0-12	15,0	medium degree of stability
	12-35	28,82	high degree of stability
	35-87	24,9	high degree of stability
	87-134	23,1	high degree of stability
SS – 4	0-13	9,6	unstable
	13-22	18,1	medium degree of stability
	22-50	24,20	high degree of stability
	50-71	31,64	high degree of stability
	71-100	30,91	high degree of stability

Soil section 3, there is a high degradation in the content of toxic salts, as well as an average degradation in other indicators. Section 3 can be assessed as moderately degraded (table 2).

Soil section 4, indicators of toxic salts and reduction of physical clay, the degree of degradation is high. In general, the section can be assessed as moderately degraded, but with some signs of high degradation (table 2).

Based on the presented data, it can be concluded that all three sections are at the stage of average soil degradation, which is characterized by a decrease in clay content, a decrease in the thickness of the soil profile and significant losses of humus.

The greatest threat is posed by high levels of toxic salts in arable soil layers, which leads to a high degree of degradation in this parameter. A decrease in the projective vegetation cover also indicates an increased degree of degradation of pastures (table 2).

All three soil sections show similar problems with soil degradation. The main factors influencing the deterioration of soils include:

- significant reduction of humus content,
- loss of physical clay,
- high content of toxic salts.

All sections are characterized by an average degree of soil degradation with pronounced signs of vegetation deterioration (table 2). The main problem is the loss of organic matter, which leads to a decrease in soil fertility.

Table 2 - Table assessment of the degree of soil degradation by research object

Indicators	Changing parameters, %	By points	Degree of degradation
Soil section 1			
Reduction of the physical clay content by an amount, % of the initial	15/9,0	4	High
Reduction of the thickness of the soil profile (A + B), % of the initial	29/23	2	Average
Reduction of humus reserves in the soil profile (A + B), % of the initial	94/71	2	Average
The amount of toxic salts in the humus (arable) layer (%):	0,094	4	High
Projective cover of pasture vegetation, % of the zonal	60/40	3	Increased
Soil section 3			
Reduction of the physical clay content by an amount, % of the initial		2	Average
Reduction of the thickness of the soil profile (A + B), % of the initial		2	Average
Reduction of humus reserves in the soil profile (A + B), % of the initial	105/90	2	Average
The amount of toxic salts in the humus (arable) layer (%):	0,081	4	High
Projective cover of pasture vegetation, % of the zonal	75/50	3	Increased
Soil section 4			
Reduction of the physical clay content by an amount, % of the initial	20/13,5	2	Average
Reduction of the thickness of the soil profile (A + B), % of the initial	33/27	2	Average
Reduction of humus reserves in the soil profile (A + B), % of the initial	98/89	2	Average
The amount of toxic salts in the humus (arable) layer (%):	0,079	4	High
Projective cover of pasture vegetation, % of the zonal	75/40	3	Increased

CONCLUSIONS

The soils of all sections have varying degrees of resistance to mechanical stress, with varying stability in depth. At deeper horizons, soils show higher stability, while the upper layers often turn out to be less stable. This may be due to the mechanical degradation of the upper layers, which leads to increased erosion processes and deterioration of soil quality.

Degradation problems are particularly pronounced in the upper layers of the soil, which reduces their productivity and quality for agricultural use. A decrease in the projective vegetation cover also indicates a deterioration in the condition of pastures.

All the sections studied show signs of moderate soil degradation, which requires an integrated approach to restoring and improving the condition of soil resources.

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ТҮЙІН

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АТЫРАУ ОБЛЫСЫ МАҚАТ ШАРУА ҚОЖАЛЫҒЫ ТОПЫРАҚТАРЫНЫҢ ДЕГРЕДАЦИЯҒА ҰШЫРАУ ҮРДІСТЕРІН ЗЕРТТЕУ

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Мақат ауданында жүргізілген зерттеу топырақтың механикалық әсерге төзімділігін бағалауға мүмкіндік беретін гранулометриялық, өсімдік жамылғысы, топырақтың (А + В) қабатының өзгерістері және химиялық талдауларды қамтиды. Топырақ тұрақтылығын талдау нәтижелері барлық жер телімдеріндегі топырақтың жоғарғы қабаттары эрозияға және деградацияға бейім екенін көрсетті, бұл негізінен құм-балшықты гранулометриялық құрамның азаюына, гумустың жоғалуына және утты тұздардың жиналуына байланысты. Өсімдік жамылғысының сиреуі жайылымның қатты деградациясын көрсететкіші болып табылады. Нәтижелер топырақтың физикалық қасиеттерін жақсарту және тұздардың әсерін азайту сияқты топырақты сақтау әрекеттері осы экожүйелерді қалпына келтіру үшін маңызды екенін көрсетеді. Сонымен қатар далалық зерттеулер сұр-қоңыр тұзды және тұзды топырақтар басым болатын топырақ кескіндерінің әртүрлі түрлерін анықтады. Топырақтың бұл түрлері буферлік қабілетінің төмендігімен сипатталады, бұл деградация мәселесін одан әрі күшейтеді. Талдаулар көрсеткендей, аймақтағы топырақтың деградациясы орташа және жоғары дәрежеге ие. Механикалық әсер ету және жерді дұрыс пайдаланбау сияқты антропогендік факторлар деградация процесін едәуір жылдамдатады, бұл өз кезегінде экожүйелердің тұрақтылығын төмендетеді. Бұл факторлар топырақ сапасының нашарлауына және оның өнімділігінің жоғалуына әкеледі, бұл аймақтың бүкіл экожүйесіне тікелей теріс әсер етеді.

Түйінді сөздер: шөлейттену, топырақтың деградациясы, Каспий маңы аймағы, климаттық өзгерістер, экожүйелер, топырақ буферлігі.

РЕЗЮМЕ

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ИССЛЕДОВАНИЕ ПРОЦЕССОВ ДЕГРЕДАЦИИ ПОЧВ КРЕСТЬЯНСКОГО ХОЗЯЙСТВА "МАКАТ" АТЫРАУСКОЙ ОБЛАСТИ

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Исследование, проведенное в Макатском районе, включает гранулометрический анализ, анализ растительности, изменения верхнего слоя почвы (А+В) и химические исследования, которые позволяют оценить устойчивость почвы к механическим воздействиям. Результаты анализа стабильности почвы показали, что верхние слои почвы на всех участках наиболее подвержены эрозии и деградации, в основном из-за снижения содержания глины, потери гумуса и накопления токсичных солей. Уменьшение растительного покрова усугубляет проблему, указывая на серьезную деградацию пастбищ. Полученные данные свидетельствуют о том, что усилия по сохранению почв, такие как улучшение физических свойств и снижение воздействия солей, являются решающими для восстановления этих экосистем. Полевые исследования также выявили различные типы, среди которых преобладают серо-бурые солончаковые и солонцовые почвы. Эти почвы характеризуются низкой буферной способностью, что еще больше усугубляет проблему деградации. Анализ показал, что деградация почв в регионе имеет умеренную и высокую степень. Антропогенные факторы, такие как механическое воздействие и неправильное использование земель, значительно ускоряют процесс деградации, который снижает устойчивость экосистем. Эти факторы приводят к ухудшению качества почвы и потере её продуктивности, что негативно сказывается на всей экосистеме региона.

Ключевые слова: опустынивание, деградация почв, прикаспийский регион, климатические изменения, экосистемы, буферность почв.

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