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PASTURE ECOSYSTEMS OF THE ARID ZONE OF SOUTHERN KAZAKHSTAN: CURRENT STATE, PROBLEMS AND WAYS TO RESTORATION (REVIEW)

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Abstract. The article presents an overview of modern studies of pasture ecosystems in the arid zone of Southern Kazakhstan using the example of the Otyrar district of the Turkestan region. The article examines the region's natural and climatic features, and the influence of aridization and climate change on the structure of pasture phytocenoses, their productivity, and biodiversity. The main factors of sustainability of pasture ecosystems were analyzed, including water regime, soil salinity, organic carbon content, the state of the soil microbiome, and anthropogenic load. The purpose of this review article is to analyze and summarize recent scientific research on the state, functioning, assessment methods, and prospects for the restoration of pasture ecosystems in the arid zone of Southern Kazakhstan, using the example of the Otyrar district of the Turkestan region. Particular attention is paid to modern methods of geobotanical assessment of vegetation, determination of projective cover, productivity, and biodiversity indicators, as well as to the use of geographic information systems, remote sensing, and satellite monitoring to assess the condition of pastures. The data on the prospects for the restoration of degraded pastures through the use of organomineral fertilizers based on natural aluminosilicates, humic substances, protein hydrolysate, and microalgae *Chlorella vulgaris* are summarized. It has been shown that an integrated approach combining geobotanical, soil-ecological, and digital research methods contributes to increasing the sustainability of pasture ecosystems, preserving biodiversity, and rational use of natural forage resources in arid territories.

Keywords: arid zone, Otyrar district, pasture vegetation, phytocenoses, biodiversity, pasture productivity, organomineral fertilizers, vermiculite, humic substances, Chlorella vulgaris.

Pasture ecosystems of the arid territories of Southern Kazakhstan are the most important natural resource, ensuring the conservation of biodiversity and the development of pasture livestock farming. In recent decades, under the influence of climate change, accompanied by rising air temperatures, longer droughts and moisture deficits, changes in the structure of vegetation cover, a decrease in pasture productivity, and an increase in land degradation processes have been observed [1, 2]. These problems are especially relevant for the pastures of the Otyrar district of the Turkestan region, located in a zone of desert landscapes with limited water resources and widespread saline soils.

The condition and productivity of pasture vegetation are determined by a complex of natural, climatic, and soil-ecological factors. Temperature, moisture availability, salinity, soil physicochemical properties, organic carbon content, and soil microbiota activity have a significant impact. The interaction of these components shapes the species composition, biodiversity, and productivity of pasture phytocenoses [3]. This increases the need for a comprehensive assessment of pasture eco-

systems, including geobotanical studies of vegetation, biodiversity analysis, determination of phytocenoses productivity, and investigation of soil properties, organic carbon reserves, and soil microbiome composition. This approach allows for an objective assessment of the current state of pastures and the identification of the main factors driving their transformation. A promising direction for the restoration of degraded pastures is the use of organo-mineral fertilizers that help improve soil fertility, activate microbiological processes, and increase the productivity of plant communities.

The scientific novelty of this study lies in its comprehensive examination of the relationships between climate conditions, the state of pasture phytocenoses, biodiversity, vegetation productivity, soil properties, organic carbon content, and the soil microbiome in the Otyrar district. The impact of organomineral fertilizers on the restoration of degraded pastures is also assessed. The practical significance of this review lies in its ability to provide a scientific basis for selecting monitoring methods and restoration measures depending on the type and degree of pasture degradation. The summarized materials can be used in developing sustainable grazing programs, restoring vegetation cover, reclaiming saline and alkaline soils, and organizing regional monitoring of pasture resources.

The review aims to conduct a comprehensive assessment of the condition, biodiversity, and productivity of pasture vegetation in the arid zone of Southern Kazakhstan, to identify the relationship between vegetation cover and soil-ecological factors, and to determine the effectiveness of the use of organo-mineral fertilizers to increase the sustainability and restore degraded pasture ecosystems.

Natural and climatic characteristics of the arid zone

Current climate change is significantly impacting the functioning of natural and agricultural ecosystems in many regions of the world. Rising average annual temperatures are accompanied by changes in precipitation patterns, more frequent dry periods, and an increase in the frequency of extreme weather events. These processes impact the state of vegetation, land productivity, and ecosystem resilience.

Arid and semi-arid regions, which occupy a significant portion of the planet's landmass, are the most sensitive to climate change. They are characterized by insufficient moisture, high evaporation rates, sharp seasonal temperature fluctuations, and limited surface water resources. In such conditions, even small deviations in climate parameters can cause significant changes in the composition of plant communities, soil properties, and biodiversity.

Central Asia is considered a region with a high degree of climate risk. The observed increase in air temperature, changes in precipitation distribution, and increased duration of rainless periods are intensifying desertification and land degradation processes [4]. As a result, the productivity of natural forage lands is declining, the condition of the soil cover is deteriorating, and the vulnerability of natural ecosystems to anthropogenic impacts is increasing.

The Otyrar district of the Turkestan region is among the driest areas in the region. Average annual precipitation is low and distributed extremely unevenly throughout the year. Most precipitation falls in the winter and spring, while the summer months are characterized by prolonged periods of dry spells and high temperatures. In some years, summer temperatures exceed 40°C, significantly increasing soil moisture evaporation and creating unfavorable conditions for vegetation growth. Even short periods of wet weather can trigger the active growth of ephemerals and ephemeroids, while prolonged droughts lead to a reduction in the protective cover and degradation of the vegetation.

Climate conditions affect not only vegetation but also soil properties. In arid regions, organic matter accumulation slows, humus content decreases, and the biological activity of soil microorganisms declines. This leads to deterioration of soil fertility and a reduced ability to supply plants with nutrients and moisture [5].

The integration of data on climatic conditions, soil properties and the state of pasture ecosystems contributes to a more objective assessment of degradation factors and serves as a scientific basis for developing strategies for their conservation, restoration and rational use in the arid zone of Southern Kazakhstan.

Theoretical and methodological foundations of geobotanical and agroecological assessment

Pasture vegetation is a collection of plant communities (phytocenoses) formed under the influence of climatic, soil, and biotic factors. Studying the structure and functioning of phytocenoses is an important task in geobotany, as vegetation serves as an indicator of the ecological state of an area and the level of anthropogenic pressure [6].

The main characteristics of phytocenoses are species composition, dominant species, spatial structure, and productivity. The arid territories of Southern Kazakhstan are most characterized by communities dominated by species of the genera *Artemisia, Limonium, Salsola, Kochia*, and *Tamarix*, which play an important role in the formation of forage resources and maintaining the stability of pasture ecosystems [7, 8]. Changes in the composition of dominant species and a decrease in their contribution to the vegetation cover often indicate pasture degradation processes [9].

One of the most common methods of geobotanical research is the Braun-Blanquet ecofloristic method, based on determining the species composition, abundance, and occurrence of plants in sample plots. This method is widely used to classify and monitor plant communities [10]. An important indicator of pasture condition is the projective cover, which reflects the proportion of the soil surface occupied by vegetation. A decrease in this indicator is usually associated with degradation of the vegetation cover, a decrease in forage reserves, and increased erosion processes [11]. Pasture productivity is assessed by the amount of aboveground phytomass, which depends on climatic conditions, moisture availability, and soil fertility.

Biodiversity indicators, including the Shannon and Simpson indices, are used to assess the sustainability of phytocenoses. High species diversity contributes to increased resilience of plant communities to drought and other stress factors [12]. A comprehensive analysis of floristic composition, projective cover, productivity, and biodiversity allows for an objective assessment of the state of pasture ecosystems and the development of scientifically based measures for their conservation, restoration, and sustainable use [13].

Biological characteristics of pasture vegetation in the arid zone

Vegetation in arid areas develops under conditions of moisture deficiency, high temperatures, intense solar radiation, and soil salinity. As a result of long-term adaptation, xerophytic and halophytic species predominate here, ensuring the stability and productivity of the vegetation cover in extreme environmental conditions [14]. One of the most important adaptations is the efficient use of limited water resources. Many plants have deep root systems, allowing them to utilize moisture from the lower soil horizons. Reduced leaf surface area, a waxy coating, and a thickened cuticle contribute to reduced water loss [15].

A significant number of arid zone species are highly salt-tolerant. Thanks to physiological mechanisms regulating water and salt balance, halophytes can survive in saline soils where most plants cannot develop. Desert and semi-desert plants also have specific life strategies. Annual

ephemerals quickly complete their development cycle during the spring wet season, while perennial subshrubs and shrubs are distinguished by their longevity and high ability to recover after grazing. In the pasture ecosystems of Southern Kazakhstan, wormwood-saltwort and limonium-zhyngyl (*tamarix*) communities are widespread, with species of the genera *Artemisia, Salsola, Limonium, Kochia*, and *Tamarix* dominating. These plants form the basis of the forage base and determine the ecological stability of pastures [16]. The condition of arid phytocenoses is assessed based on species composition, projective cover, and biodiversity level. High species diversity contributes to the resilience of communities to drought and other stress factors, while its decline is considered a sign of degradation of pasture ecosystems [17].

Modern methods of monitoring pasture ecosystems

Assessing the condition of pasture ecosystems is based on a combination of geobotanical, soil-ecological, and geoinformation methods. Modern monitoring combines field studies, laboratory soil analysis, and remote sensing technologies, allowing for the assessment of vegetation, soil, and the degree of pasture degradation [18].

Field research is based on geobotanical descriptions using the Braun-Blanquet ecofloristic method. These surveys determine species composition, phytocenoses structure, dominant species, vegetation cover, and productivity. The Shannon and Simpson indices are used to assess biodiversity [19] (table 1).

One of the main indicators of the condition of pastures is the projective cover (PP), which reflects the proportion of the surface occupied by vegetation:

$$PP = \frac{Sp}{\text{Stotal}} * 100\%$$

where S_p is the area covered by vegetation; S_{total} is the total area of the survey plot.

Productivity is determined by mowing, followed by the recalculation of air-dry mass per unit area. The structure of plant communities is characterized by Shannon indices

$$H' = -\sum p_i \ln p_i$$

and Simpson

$$D = \Sigma(pi^2)$$

where p_i is the relative proportion of the i-th species. High values of the Shannon index and low values of the Simpson index indicate higher biodiversity and community stability [20].

Additionally, pastures are classified by dominant species, life forms, and ecological groups of plants, which allows for the assessment of degradation stages, forage value, and vegetation dynamics [21].

An important part of soil monitoring is the analysis of soil properties. Typically, soil particle size distribution, pH, electrical conductivity (EC), organic carbon (SOC), humus, nitrogen, available phosphorus, exchangeable potassium, and cation exchange capacity are determined. These parameters reflect the level of salinity, soil fertility, and plant nutrient availability [22–24]. Furthermore, soil microbiome analysis allows for an assessment of soil biological activity and its role in the functioning of pasture ecosystems.

Spatial monitoring is carried out using GPS and geographic information systems (GIS), which provide mapping of vegetation, soil cover, and the degree of degradation. Sentinel-2 and Landsat satellite data are widely used for regional assessments [25].

The most common indicator of vegetation condition is the normalized vegetation index:

$$NDVI = \frac{NIR - RED}{NIR + RED}$$

where NIR is the reflectivity in the near infrared range, RED is the reflectivity in the red range of the spectrum.

High NDVI values correspond to well-developed vegetation cover, while low values are typical of degraded and saline areas. To improve the accuracy of assess-

ments in sparse vegetation conditions, the EVI, SAVI, and MSAVI indices are additionally used [26].

Consequently, modern methods for monitoring pasture ecosystems are based on the integration of geobotanical, soil-ecological, and geoinformation approaches. The combined use of field observations, laboratory soil analyses, soil microbiome assessment, and remote sensing data provides a comprehensive evaluation of pasture condition, biodiversity, productivity, degradation level, and restoration potential. Such an integrated approach forms the scientific basis for sustainable pasture management and the development of effective restoration strategies in arid regions.

Table 1 – Modern methods of assessment, monitoring and restoration of pasture ecosystems in the arid zone

Approach	Main assessment object	Advantages	Limitations	Application in arid rangelands
Geobotanical survey (Braun–Blanquet method)	Species composition, vegetation structure, projective cover	Reliable field assessment of vegetation communities; biodiversity evaluation	Time-consuming; requires botanical expertise	Assessment of vegetation condition and degradation level
Productivity assessment (harvest method)	Aboveground biomass and forage productivity	Direct estimation of forage yield	Labor-intensive; seasonal dependence	Evaluation of pasture productivity
Biodiversity indices (Shannon, Simpson)	Species diversity and community stability	Quantitative comparison of plant communities	Sensitive to sampling intensity	Monitoring ecosystem stability
Soil physicochemical analysis	Salinity, pH, organic carbon, nutrients	Explains vegetation–soil relationships	Requires laboratory analyses	Assessment of soil fertility and degradation
Soil microbiome analysis	Microbial diversity and activity	Indicates biological soil quality and ecosystem functioning	High analytical cost; specialized equipment	Evaluation of soil restoration processes
GPS and GIS technologies	Spatial distribution of vegetation and soils	Accurate mapping; long-term monitoring	Depends on data quality	Mapping degraded pasture areas
Remote sensing (Sentinel-2, Landsat)	Vegetation dynamics, land degradation	Large-area coverage; repeated observations	Lower accuracy without field validation	Regional pasture monitoring
NDVI and vegetation indices	Vegetation cover and productivity	Rapid assessment; suitable for long-term monitoring	Influenced by soil background and seasonality	Estimation of pasture condition and biomass

Approaches to restoration of degraded pastures in arid zones

One of the main reasons for the decline in pasture productivity in arid areas is soil degradation caused by drought, salinization, wind erosion, and long-term intensive land use. This results in deterioration of the soil's physical and chemical properties, a decrease in organic matter content, and a decline in biological activity, which negatively impacts the development of pasture vegetation. In recent years, considerable attention has been paid to developing technologies for restoring soil fertility and enhancing the resilience of pasture ecosystems in arid climates. According to numerous studies, the use of organic fertilizers promotes the accumulation of organic carbon, improves soil structure, increases water-holding capacity, and activates soil microbiota. The addition of manure, compost, and other organic materials increases humus content, improves the hydrophysical properties of the soil, and creates favorable conditions for plant growth [27].

Mineral fertilizers play a key role in increasing pasture productivity by compensating for nutrient deficiencies. Nitrogen fertilizers stimulate the growth of aboveground biomass, phosphorus fertilizers promote root development and increase plant resistance to drought, and potassium regulates water balance and improves plant tolerance to salinity and high temperatures. In recent years, particular attention has been paid to organomineral fertilizers, which combine organic and mineral components. According to various authors, such compositions not only provide nutrients but also improve the agrophysical properties of the soil, increase the buffering capacity of the environment, reduce the negative impact of salinity, and promote more efficient water use by plants [28].

To restore saline soils, land reclamation measures are widely used alongside fertilizer application. Research shows that chemical reclamation, primarily gypsum application to solonetz soils, promotes the replacement of exchangeable sodium with calcium, improves soil structure, increases its permeability, and reduces salinity. In soils with unfavorable environmental conditions, liming is an effective technique, increasing the availability of nutrients and soil biological activity [29]. In conditions of limited water resources, water-saving technologies are important. According to published data, the use of drip irrigation, mulching, minimum tillage, and other techniques can reduce moisture loss, increase the efficiency of its use, and maintain vegetation productivity in arid conditions.

Available scientific evidence indicates a close relationship between fertilizer use, organic carbon content, and the health of the soil microbiome. Increasing organic matter content has been shown to promote the development of beneficial microorganisms, activate mineralization processes, and improve nutrient cycling, all of which positively impact soil fertility and ecosystem resilience [29]. The use of organomineral preparations based on natural aluminosilicates, including vermiculite, zeolites, and other minerals, is considered a promising approach. Due to their high sorption capacity, such materials can retain moisture and nutrients, improve the hydrophysical properties of the soil, and reduce the stress effects of drought and salinity on plants.

Several studies have shown that the inclusion of humic substances, amino acids, protein hydrolysates, and microalgae, including Chlorella vulgaris, in organomineral compositions promotes root system development, activates soil microbiota, and increases plant resistance to abiotic stress. However, the effectiveness of such preparations depends on soil and climatic conditions and requires further experimental evaluation for various types of pasture ecosystems. Based on the above, an analysis of published studies shows that the most effective systems technologies are

those that combine the use of organo-mineral fertilizers, land reclamation measures, and water conservation techniques. Their use improves the physical and chemical properties of soils, increases organic carbon content, activates the soil microbiome, and enhances the productivity of degraded pastures in arid areas [30].

An analysis of published studies shows that most authors agree that pasture degradation in arid areas is caused by the combined effects of climatic and anthropogenic factors. The most common of these are soil salinization, precipitation deficits, high temperatures, wind erosion, and long-term grazing pressure. Regardless of the study region, these processes are accompanied by a decrease in projective cover, reduced productivity, and a gradual simplification of plant community structure. At the same time, the proportion of valuable forage species decreases, while the proportion of xerophytic and halophytic plants adapted to extreme environmental conditions increases.

The general conclusion of most studies is that the assessment of pasture condition should be based not only on the analysis of floristic composition, but also takes into account soil characteristics, the level of biodiversity, the content of organic carbon, the state of the soil microbiome, and the spatial distribution of vegetation. In recent years, the integration of geobotanical research with geoinformation technologies and remote sensing of the Earth has become increasingly widespread, which allows for an objective assessment of the degree of pasture degradation and monitoring changes in their productivity over long-term dynamics.

At the same time, a literature review reveals certain differences in the approaches of various authors. Some researchers view salinization as the main factor in the degradation of pasture ecosystems, while others attribute the determining factors to overgrazing or climate change. Similar discrepancies are observed in assessing the effectiveness of measures to restore degraded lands. Some studies focus on grazing pressure management and sustainable grazing, while other studies demonstrate the high effectiveness of organo-mineral fertilizers, soil reclamation measures, and water-saving technologies. These differences are likely due to the specific natural and climatic conditions, soil types, salinity levels, and plant community composition of the study areas.

Despite the available scientific data, a number of scientific issues remain understudied. In particular, the number of studies devoted to a comprehensive analysis of the relationships between soil salinity, organic carbon content, soil microbiome structure, and changes in the floristic composition of pasture communities is limited. The impact of modern organomineral fertilizers on the restoration of degraded pastures under conditions of severe salinization and chronic moisture deficit has also been insufficiently studied. Furthermore, most published studies examine individual ecosystem components, while comprehensive studies integrating geobotanical, soil, and geoinformation data are much rarer.

The findings are consistent with research conducted in other arid regions of the world, including Central Asia, Mongolia, northern China, Australia, and North Africa. Despite differences in floristic composition and climatic conditions, most authors note similar patterns of pasture degradation: decreased biodiversity, reduced projective cover, deterioration of soil properties, and an increased role of drought- and salt-tolerant species. This indicates that the fundamental mechanisms underlying arid pasture functioning are universal, while the effectiveness of restoration measures must account for regional environmental characteristics. The Otyrar district of the Turkestan region is located in the desert (arid) zone of southern Kazakhstan and is one of the largest pasture areas in the region. The

total area of agricultural land is 611.8 thousand hectares, of which 565.9 thousand hectares are natural pastures, and the area of irrigated arable land reaches 44.3 thousand hectares. The climate of the region is sharply continental, with an annual precipitation of 100–200 mm, hot, long summers (up to +40…+45°C), high evaporation, and an aridity coefficient of less than 0.20. The soil cover is predominantly composed of sierozem soils of varying degrees of salinity, sierozem-salt soils, solonchaks, solonetz soils, and sandy-loamy deposits. The most common types of salinity are chloride, sulfate, and chloride-sulfate, which determine the development of xerophytic and halophytic vegetation. The main pasture communities are wormwood-kermek, wormwood-saltwort, saltwort-anabasis and tamarisk phytocenoses with the dominance of *Artemisia terrae-albae var. aralensis, Anabasis aphylla, Salsola tragus, Limonium caspium, Tamarix ramosissima* and *Alhagi pseudalhagi*. Pastures are used primarily for year-round grazing of sheep, goats, cattle, horses and camels, with the highest grazing pressure observed near settlements, livestock camps and watering places, usually within the first 3–5 km. The main forms of pasture degradation include overgrazing, secondary salinization, wind erosion, reduced protective cover, changes in species composition, and desertification processes, making the area representative for studying the functioning and restoration of arid zone pasture ecosystems. In recent years, the condition of natural pastures has been deteriorating under the influence of climate change and increasing anthropogenic pressure. In modern conditions, the restoration of pasture ecosystems requires a comprehensive approach, including regulation of grazing pressure, the use of organomineral fertilizers, soil reclamation measures and the use of geoinformation monitoring technologies and remote sensing of the Earth to assess the state of vegetation and identify degraded areas. This approach will increase pasture productivity, preserve biodiversity and ensure sustainable use of natural forage lands in the Otyrar district.

The main factors of degradation are climate aridization, overgrazing, soil salinization, land use change and irrational nature management, leading to deterioration of the physical, chemical and biological properties of the soil, a decrease in projective cover, biodiversity and vegetation productivity (figure 1).

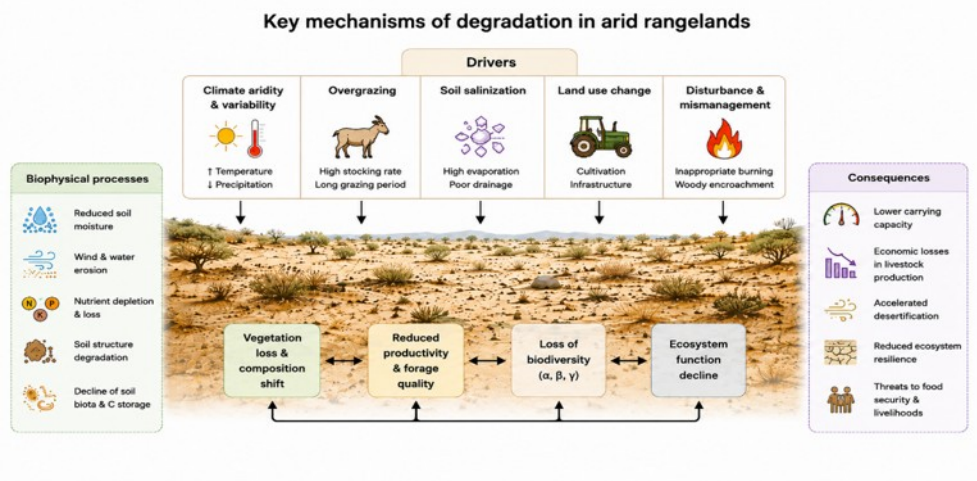


Figure 1 - Conceptual diagram of degradation mechanisms of pasture ecosystems in the arid zone

CONCLUSION

Pasture ecosystems in arid areas are an important component of natural resources, providing forage for livestock, preserving biodiversity, and supporting ecosystem resilience. An analysis of published studies shows that their condition is largely determined by climate conditions, soil salinity, moisture deficit, and the intensity of anthropogenic pressure, which lead to reduced productivity and changes in the structure of plant communities.

An analysis of published studies shows that the most reliable assessment of pasture conditions is achieved by integrating geobotanical, soil-ecological, and geoinformation methods. The combined use of field observations, laboratory soil analysis, and remote sensing data allows for an objective assessment of the floristic composition, productivity, biodiversity, and degree of degradation of pasture ecosystems. An analysis of published studies shows that the relationships between soil salinity, organic carbon content, soil microbiome status, and vegetation changes in arid ecosystems remain insufficiently studied. Research devoted to a comprehensive assessment of the effectiveness of organomineral fertilizers in restoring degraded pastures is also limited.

Promising areas for further research include the development of scientifically based technologies for the restoration of degraded pastures using organomineral fertilizers, the improvement of geoinformation monitoring based on Earth remote sensing data, and the integration of soil, geobotanical and microbiological studies to predict long-term changes in pasture ecosystems and improve the efficiency of their rational use.

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ТҮЙІН

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ОҢТҮСТІК ҚАЗАҚСТАННЫҢ ҚҰРҒАҚ АЙМАҒЫНЫҢ ЖАЙЫЛЫМ ЭКОЖҮЙЕЛЕРІ: ҚАЗІРГІ ЖАҒДАЙЫ, МӘСЕЛЕЛЕРІ ЖӘНЕ ҚАЛПЫНА КЕЛТІРУ ЖОЛДАРЫ (ШОЛУ)

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Бұл мақалада Түркістан облысының Отырар ауданы мысал ретінде Оңтүстік Қазақстанның құрғақ аймағындағы жайылым экожүйелерінің жағдайы мен жұмыс істеуі бойынша қазіргі зерттеулерге шолу жасалған. Онда аймақтың табиғи-климаттық сипаттамалары, құрғақшылық пен климаттың өзгеруінің жайылым фитоценоздарының құрылымына, олардың өнімділігіне және биоәртүрлілігіне әсері қарастырылды. Жайылым экожүйелерінің тұрақтылығына әсер ететін негізгі факторлар, соның ішінде су режимі, топырақтың тұздылығы, органикалық көміртегі мөлшері, топырақ микробиомының жағдайы және антропогендік жүктеме талданды. Өсімдіктерді геоботаникалық бағалаудың заманауи әдістеріне, проекциялық жамылғыны, өнімділікті және биоәртүрлілік көрсеткіштерін анықтауға, сондай-ақ жайылым жағдайын бағалау үшін геоақпараттық жүйелерді, қашықтықтан зондтауды және спутниктік мониторингті пайдалануға ерекше назар аударылды. Табиғи алюмосиликаттар, гуминді заттар, ақуыз гидролизаты және микробалдырлар *Chlorella vulgaris* негізіндегі органоминералды тыңайтқыштарды пайдалану арқылы деградацияланған жайылымдарды қалпына келтіру перспективалары туралы деректер қорытындыланды. Геоботаникалық, топырақ-экологиялық және цифр-

лық зерттеу әдістерін біріктіретін кешенді тәсіл жайылым экожүйелерінің тұрақтылығын арттыруға, биоәртүрлілікті сақтауға және құрғақ аумақтарда табиғи жемшөп ресурстарын ұтымды пайдалануға ықпал ететіні көрсетілді.

Түйінді сөздер: құрғақ аймақ, Отырар ауданы, жайылым өсімдіктері, фитоценоздар, биоәртүрлілік, жайылым өнімділігі, органоминералды тыңайтқыштар, вермикулит, гуминді заттар, Chlorella vulgaris.

РЕЗЮМЕ

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ПАСТБИЩНЫЕ ЭКОСИСТЕМЫ ЗАСУШЛИВОЙ ЗОНЫ ЮЖНОГО КАЗАХСТАНА: СОВРЕМЕННОЕ СОСТОЯНИЕ, ПРОБЛЕМЫ И ПУТИ ВОССТАНОВЛЕНИЯ (ОБЗОР)

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В статье представлен обзор современных исследований текущего состояния и функционирования пастбищных экосистем в засушливой зоне Южного Казахстана на примере Отрарского района Туркестанской области. Рассмотрены природно-климатические особенности региона, влияние аридизации и изменения климата на структуру фитоценозов пастбищ, их продуктивность и биоразнообразие. Проанализированы основные факторы, влияющие на стабильность пастбищных экосистем, такие как водный режим, засоленность почвы, содержание органического углерода, состояние почвенного микробиома и антропогенная нагрузка. Особое внимание уделено современным методам геоботанической оценки растительного покрова, определению проективного покрытия, показателей продуктивности и биоразнообразия, а также использованию геоинформационных систем, технологий дистанционного зондирования и спутникового мониторинга для оценки состояния пастбищ. Собраны данные о перспективах восстановления деградированных пастбищ с использованием органоминеральных удобрений на основе природных алюмосиликатов, гуминовых веществ, гидролизата белка и микроводорослей Chlorella vulgaris. Показано, что комплексный подход, сочетающий геоботанические, почвенно-экологические и цифровые методы исследования, способствует повышению стабильности пастбищных экосистем, сохранению биоразнообразия и рациональному использованию природных земельных ресурсов засушливых районов.

Ключевые слова: аридная зона, Отырарский район, пастбищная растительность, фитоценозы, биоразнообразие, продуктивность пастбищ, органоминеральные удобрения, вермикулит, гуминовые вещества, Chlorella vulgaris.

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