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SOIL INDICATORS IN DEGRADED PASTURES OF FOOTHILL SEMI-DESERT AND DESERT ZONES OF KAZAKHSTAN

ANNOTATION

In this article, the authors have developed and used in the course of field work indicators of physico-biological indicators to determine the degree of degradation of pastures in the foothill-semi-desert and desert zones of the Almaty region of Kazakhstan. There are no scientific and practical provisions on the management and monitoring of degraded pastures based on digital technologies in Kazakhstan. This development will make it possible to determine the location of such lands depending on the degree of degradation in the foothill semi-desert and desert zones. In addition, the development of a cartographic model of degraded pasture lands, taking into account the degree of degradation, allows (taking into account soil and climatic conditions) to develop optimal options for their restoration (improvement) with subsequent preservation of productive longevity. Studies conducted on gray-brown soils, gray soils and sandy desert soils of the studied region allowed us to obtain 240 soil indicators and 280 indicators of biological indicators. These indicators and materials were used to develop digital cartographic material on the stages of degradation of pasture lands on the territory of the foothill semi-desert and desert, according to the results of which a digital map of pastures (September) was formed on a scale of 1:1,000,000 meters in accordance with the strong, medium and weak degradation of the foothill semi-desert and desert zones of Kazakhstan.

Key words: *Degradation, pastures, monitoring, cartographic model, digital technology*.

Introduction. Soil degradation of grassland by grazing livestock, through defoliation, trampling, and excretion, is a crucial problem in many countries. The negative impact of trampling on soil physical properties is of special interest, as intensive livestock farming systems continue to increase worldwide (Andreas Roesch et al. 2009) [1]. Soil erosion and land use type have long been viewed as being particularly important drivers of soil degradation (Nosrati, K., et al. 2019) [2]. This feature of herbal mixtures derived from perennial cereals and legumes allows you to control the structure and fertility of the soil. At the same time, the study of biohumus and biostimulators from natural organic substances opens a new direction in soil fertility in agricultural systems (Bukenova E.A., et al. 2019; Ydyrys Alibek, et al. 2020) [3, 4]. The Republic of Kazakhstan has enormous potential for the effective development of animal husbandry. Kazakhstan's pasture resources are very extensive, but far from being fully utilized. Recently, overgrazing of pastures near rural settlements has been a problem, together with a sharp depletion of natural pastures in densely populated areas, especially in the southeastern part of the country.

They are a clear indicator of the state of the environment, a source of nutrients and nutrients for all living organisms on the plane. The research and preservation of biological diversity is a global task nowadays (Ydyrys A., et al. 2020) [5]. One of the main reasons for the fall of species into the category of rare and endangered is the destruction or complete destruction of the habitats of these species (Akhmetova A.B., et al. 2018) [6]. The negative consequences of human impact on rare and endangered species, depending on a diverse combination of impact factors and specific territorial conditions, are different (Begenov A., et al. 2014) [7]. The specifics and size of construction change, some species disappear individually. And in agricultural areas (artificial biogeocenoses) the main role in the composition of biodiversity and the preservation of biological and ecological balance are played by their components that do not directly affect agricultural production (Seilkhan A.S., et al. 2016) [8].

Natural pastures in Kazakhstan occupy 186.4 million hectares. The annually renewable feedstock on them in terms of nutritional value reaches 23.0 and more million tons of fodder units. Pastures are the national treasure of the republic, the foundation of the population's life support in all historical periods. It should not be forgotten that in the conditions of Kazakhstan, natural forage lands, occupying vast areas, act not only as a source of cheap and nutritious feed, but also as an environment. Therefore, not only the economic, but also the ecological well-being of the country depends on their condition. Today, according to official statistics, there are 27.1 million hectares of knocked down pastures on the territory of the republic (failure is the last stage of degradation). At the same time, the productivity of pastures has decreased by almost 50% [9]. Due to the sparseness of herbage, a decrease in the share of the most valuable and productive species of grasses, the value of the pasture territory is being lost, the equilibrium of the pasture - animal changes, with the provision of self-renewal and self-regulation of the natural environment. There is no material on the areas of degraded (except for knocked down) pastures either in official or other sources. However, the failure rates (10% of the entire territory of the country) indicate a very alarming situation in the pasturelands. And here the priority task becomes systematic work to identify degraded massifs and take radical measures to restore them.

Many domestic and foreign researchers and analysts Petr Tsymbarovich et al 2020 [10], Orr et al., 2017 [11], Solomun et al., 2018 [12], Kaldybayev S., 2019 [13], Yertayeva, Z., 2018 [14] and others agree on the idea that pasture degradation is an anthropogenic factor, and the cause of degradation is overgrazing.

Research methodology. The methodology of pasture research was based on the systemic, natural-historical, landscape-ecological and natural-aesthetic approaches, made it possible to consid er pasture resources as open dynamic systems that ensure sustainable functioning and ecological well-being of human life, the economic and natural component of natural-agricultural systems. The project is interdisciplinary in nature. In the course of its implementation, the methods and methodology of agricultural science and space science were used. The main forms of scientific research are empirical and theoretical forms of research, which involve: statement of the problem; development of an action program for the implementation of the assigned tasks, with the definition of the main hypotheses and priorities; selection and substantiation of a theoretical and methodological basis, adapted to fulfill the assigned tasks; factual and experimental collection of materials on the retrospective and current state of the territory of degraded pastures; creation of real cartographic models; obtaining results, their approbation and popularization.

Field studies. At each base site (selected from satellite images), studies were carried out on indicators of physical (soil) and biological (plants) indicators. Data acquisition is carried out on base plots for 4 stages of pasture degradation: 1-weak, 2-medium, 3-strong and 4-failure.

List of indicators for biological indicators: - the name of the plant community (background) - species composition (per 1m2x4); - botanical composition (%); - poisonous and non-edible plant species (% in the yield), - projective coverage of soil by plants (%); - yield (c / ha at natural moisture content); - quality of feed (feed units); - presence of grazing (yes, no).

As a result of the study, forms were drawn up for the geobotanical description and anthropogenic modification of the background community, in which the digital indicators of biological indicators were indicated. Measured and recorded the distance between the boundaries of plant contours (km) of varying degrees of pasture degradation.

Research work related to biological indicators was carried out according to the following approved methodological guidelines: - Amenov M.Sh. Geoecological monitoring of the territory of Kazakhstan in the interests of sustainable development // Bulletin of KazNU. Biological series. Almaty, 2014 [15] (rus) - Medeu A.R., Plokhikh R.V. Methodological foundations of environmental assessments and mapping. // Questions of geography and geoecology. Almaty, 2012 [16] (rus) -

Instructions and methods for conducting a botanical and fodder survey of hay and pasture lands on the territory of Kazakhstan. Alma-Ata, 1969 [17] (rus) - Instructions for the production of agrometeorological and zoometeorological observations in pasture areas. Leningrad, 1978 [18] (rus) - Methodology of experiments on hayfields and pastures, part 1, part 2, Moscow, VIC, 1971 [19] (rus) - Methods of field experience, Moscow, Kolos, 1968 [20] (rus).

Research on physical indicators is based on traditional methods. At the stage of the route field studies, morphological methods were carried out. Laboratory and analytical studies of soils were carried out according to generally accepted methods. The compilation of the soil map was carried out by the method of mapping using GIS technologies of remote sensing materials. The following indicators were used:

- determination of the thickness of the humus horizon;
- humus content in humus horizons;
- determination of the amount and composition of exchangeable cations;
- determination of the granulometric composition of the soil along the soil horizons;
- determination of soil pH;
- determination of mobile soil nutrients (N, P, K).

In the course of field studies, full-profile soil sections were laid, their profiles were described, and soil samples were taken from genetic horizons. In areas of varying degrees of degradation, samples were taken from depths of 0-10, 10-20 and 20-30 cm. Soil analyzes and nutritional assessment of feed were carried out in licensed specialized laboratories with appropriate certificates.

Research based on data from RSE. Determination of Degradation Using Earth Remote Sensing Data.

a) *Input data.* The GIS of the project is created with the involvement of all available cartographic material on the study area and replenishing it with thematic maps obtained as a result of processing satellite data.

Cartographic material. Raster data includes cartographic material and satellite imagery. So, the database will include topographic maps of scales 1: 200000, 1: 100000 and 1: 50000. Thematic maps: soil map, hydrogeological map, forage map. As a basis, a map of forage lands at a scale of 1: 1000,000 will be used. A geobotanical map is used as a clarifying basis for the vegetation cover. When interpreting medium-resolution satellite images, small-scale geobotanical maps are the most acceptable for practical use. The territory of the demonstration plots should be covered with large-scale forage maps. All data are reduced to a single geographic projection.

Earth remote sensing data. Space images are selected from the catalog for the growing season. Data from satellites of medium resolution (Landsat 8 and Sentinel 2) - for the purpose of subsatellite research (determining the degree of degradation and carrying out a detailed classification of landfills, with subsequent verification of ground and space information).

Vector data. Thematic layers contain the thematic map digitization data with the necessary attributive information. Field research data is entered in the form of polygon objects from a GPS receiver and is replenished with attributive information from field notebooks and forms.

в) Earth remote sensing methods. Technique for processing satellite images to identify and assess foci of soil degradation (knock-down).

The calculation method is based on the use of two spectral indices (LDI-NDVI, LDI-TCW) developed to assess soil degradation. Considered separately, these indices are not very informative in the conditions of Kazakhstani deserts. The method developed on their basis for calculating degradation centers using satellite images takes into account such parameters as the nature and dynamics of vegetation cover (via NDVI), surface moisture (TCW) and surface brightness in the red channel of a satellite image, where open soils have the highest brightness characteristics.

The study of this calculation method in various territories shows that for the Landsat 8 and Sentinel 2 satellite data, there is a certain range of index values, which determines the areas with constantly knocked down soil cover, which are found on the images, regardless of the time or year of the survey. At the same time, a range of index values was identified that describes seasonal changes in the soil cover, for example, the drying up of the coast and bottom of temporary water bodies.

Degradation of soil and vegetation cover - a decrease in plant biomass and total projective cover (TPC), exposure of the soil cover occurs as a result of natural or anthropogenic factors.

The degradation index consists of three components, each of which is associated with a specific parameter of land cover change: derivative of surface moisture (NDTCW), derivative of vegetation condition (NDNDVI), and the red channel of the satellite image, in which soils without vegetation have the strongest signal. The general equation of the index is:

$$NDLDI\_RED = \frac{LDITCW - LDINDVI}{LDITCW + LDINDVI} * TM3$$

Verification of this index using ground-based data showed a high correlation of calculations made using Landsat data with ground-based measurements.
The expression used to calculate the degree of disturbance (degradation) for Landsat OLI has the form:

*Land Degradation (%) = 687,99*NDLDI – 388,6,*
with a standard deviation coefficient $R^2 = 0,8565$.

This index can be used independently, to identify foci of disturbance of the soil and vegetation cover, as well as to quantitatively assess the degree of disturbance.

Results and discussion. The study of physical and biological indicators in the foothill-semi-desert and desert zones was conducted at base points along the route: Lepsy-Koksu-Koskuduk-Aydarly-Zhambyl-Moinkum-Akkol

Below are the data of the point of study №1 - Lepsy.

Research spot №1- Lepsy. The research was conducted on 06.10.2018. On Sarkand district territory of Almaty region. The site relief is a hilly plain. Landscape aspect is greyish yellow. Below are chemical composition indicators of gray-brown low carbonate light loamy soils, depending on their degradation level (table 1).

Table 1 – Soil indicators on degraded pasture plots of Lepsy, Almaty region.

Indicators	Depth, cm	Degradation stage			
		very strong (failure) IV stage	strong III stage	moderate II stage	weak I stage (background)
1	2	3	4	5	6
Humus horizon ($A+B_1$), cm		-	18	24	27
Humus content, %	0-10 10-20 20-30 0-30	- - - -	0,39 0,61 0,52 0,51	0,45 0,86 0,50 0,60	0,66 0,91 0,50 0,69
Amount of absorbed bases (mEq per 100g of soil) and their composition (Ca, Mg, Na, % of the amount)	0-10 10-20 20-30 0-30	- - - -	4,8 8,9 6,0 -	5.0; 78; 14.8 9.8; 93; 3.4 7.8; 78; 9.13 -	5.1; 75.16; 9 11.4; 93.3; 4 7.2; 82.6; 12 -
Content of physical mud (%)	0-10 10-20 20-30 0-30	- - - -	10,2 17,8 18,0 15,3	12,1 18,3 16,6 15,7	14,2 18,5 16,0 15,2
Content of water-soluble salts (%)	0-10 10-20 20-30 0-30	- - - -	0,08 0,09 0,22 0,13	0,08 0,08 0,21 0,12	0,06 0,07 0,19 0,11
pH of water suspension	0-10 10-20 20-30 0-30	- - - -	8,2 8,2 8,3 8,2	8,0 8,0 8,2 8,1	8,0 8,0 8,2 8,1
Content of mobile nutrients (mg per kg of soil): $N_{hydr.}$	0-10 10-20 20-30 0-30	- - - -	4,1 5,6 6,1 5,3	8,5 8,5 8,6 8,5	8,9 8,3 8,9 -
Content of mobile nutrients (mg per kg of soil): P_2O_5	0-10 10-20 20-30 0-30	- - - -	2,0 1,6 1,4 1,7	2,3 1,5 1,4 1,7	2,1 1,4 1,3 1,6

Analyzing table 1 data, we can say that humus content in humus horizon (A + B_1) of gray-brown low-carbonate light loamy soils is insignificant - 0.75%, with its thickness of 27 cm, which decreases as degradation level increases to 0.5% and 18 cm respectively. These changes affect, albeit weakly, facilitation of particle size distribution, decrease in the absorption capacity and content of easily hydrolyzed nitrogen, but do not affect content of salts, mobile phosphorus and pH of environmental soil.

When studying biological indicators on a degraded pasture of Lepsy site at Sarkand district of Almaty region, attention is drawn to an increase in projective cover of soil with vegetation (from 6% to 55%) in areas with 1^{st} stage of degradation (Table 2).

Table 2 – Indices of biological indicators on degraded pasture at Lepsy site in the autumn period.

Indicators	Degradation stage			
	very strong (failure) IV stage	strong III stage	moderate II stage	weak I stage (background)
Projective cover, %	6-8	35-40	40-45	55-60
Name of plant community	Sagebrush, Ceratocarpus,	Sagebrush, Ceratocarpus, Feather grass	Sagebrush, Ceratocarpus, Feather grass	Sagebrush, Ceratocarpus, Feather grass with ephemeras
Species composition, dominants	Ceratocarpus, bluegrass, sagebrush	Sagebrush, Ceratocarpus, Feather grass	Sagebrush, Ceratocarpus, Feather grass	Sagebrush, Kochia Ceratocarpus, Feather grass,
Botanical composition, %	Ceratocarpus-45, Sagebrush-20, Bluegrass-15 others -20	Sagebrush-50, Feather grass-20, Ceratocarpus-30	Sagebrush-50, Feather grass-40, Ceratocarpus-10	Sagebrush-30, Feather grass-40, Ceratocarpus-30
Poisonous and unconsumable kinds	Peganum harmala, single shrubs	Peganum harmala, single shrubs	Peganum harmala, single shrubs	Peganum harmala, single shrubs
Yield of pasture feed, t / ha	0,40	0,48	0,53	0,89
Presence of grazing	Strong	Strong	Present	Present

The name and structure of a plant community yield clearly varies depending on degradation stage. Ceratocarpus and Sagebrush type in case of natural pastures' failure and Sagebrush-Ceratocarpus- Feather grass on area with 1^{st} stage of degradation. The boundaries of degradation contours: with a very strong degradation- -N: $46^{0}14^{1}58{,}1_{1}$and E: $0{,}78^{0}56^{1}61{,}5_{1}$; with strong degradation –N:$46^{0}15^{1}16{,}9_{1}$and E: $078^{0}56^{1}43{,}9_{1}$; with medium degradation –N:$46^{0}15^{1}34{,}0_{1}$ and E:$078^{0}57^{1}05{,}9_{1}$ and with weak degradation- N: $46^{0}15^{1}52{,}7_{1}$ and E:$078^{0}57^{1}06{,}2_{1}$.

The spectral characteristics of vegetation's reflection are influenced by the following factors: reflectivity and "transparency" (permeability) of individual leaves of vegetation; the order of dimension of the leaf surface, assessed as a whole in connection with this interaction; location of leaves in relation to total surface of plant cover and verticality, the ability and nature of reflection and transparency of radiation flux in different parts - leaves, stem; at different levels of height (shrubs, grasses, leaf cover of the soil, its type, composition, moisture, thickness, substrate rocks, and finally, total moisture of soil surface); standing of Sun (height and azimuth that change during the day and year), as well as direction and height of survey. All these factors can vary not only from one survey area to another, but also within the same contour. It hinders study and classification of objects, first of all the existence of different types of shadows, which is observed even in the same shooting conditions, and even more so in different periods of observation. When studying vegetation, when vegetation cover is not uniform, it is very difficult to make the right spectrographic characterization of the community.

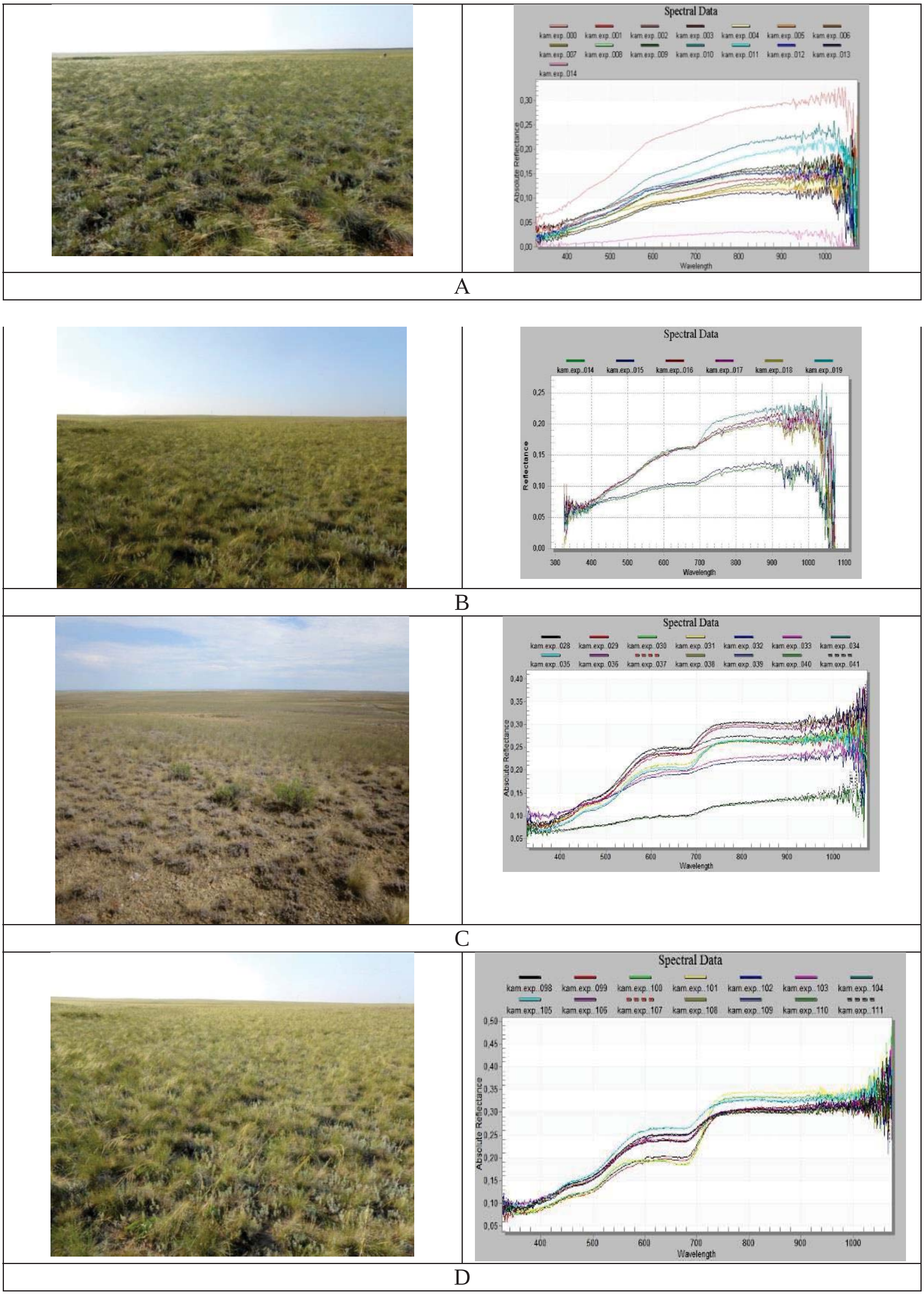

Figure 1 – Spectral characteristics of the study point № 1 - Lepsy
A - very strong IV-degree (failure), B - strong degradation III-degree, C - average degradation II-degree, D - weak degradation I-degree (background).

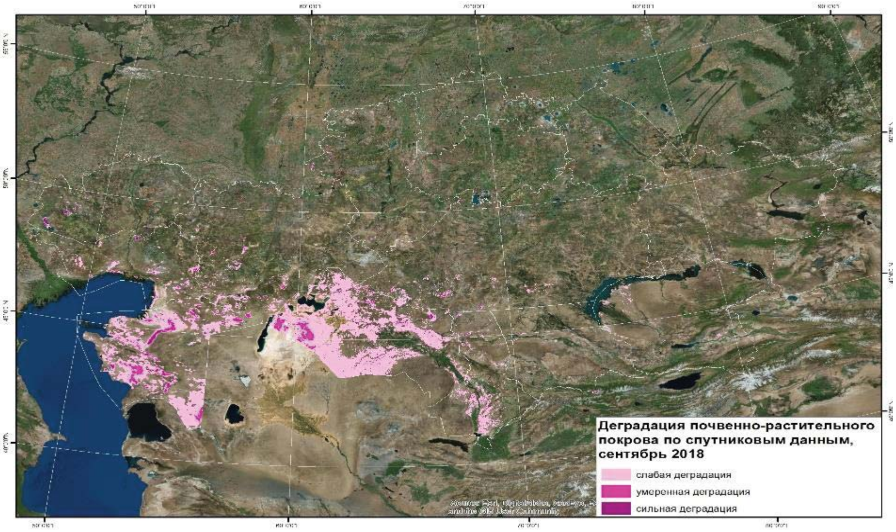

Figure 2 – The degradation stage of soil and vegetation cover of natural desert and semi-desert pastures for September 2018

The change in spectral images of vegetation in desert zone, is expressed quite strongly depending on degradation stage (Figure 1). Thus, in our studies, strongly degraded areas are similar by spectral reflection to bare soil graphs. Open soil and remnants of vegetation are mainly involved in spectrum. The average and weak degradation in autumn period also has the character of a bare plot.

Only a small jump was noted in red region of the spectrum at a wavelength of λ = 625-740 nm. It is quite difficult to assess the state of vegetation from autumn photos.

If we take into account the reflectivity in near infrared range, then good state of plant community is marked on contours with weak degradation. But most plant communities do not have changes in red spectrum. This means that most of the plants have finished their growing season. Thus, based on spectral characteristics, according to degradation stage of soil-plant communities, four degradation stages were identified: failure, strong degradation stage, medium and weak.

The same studies were conducted on other 6 points.

As a result of ground-and- space based research, maps of degradation of desert and semi-desert zones of the Republic of Kazakhstan were constructed (Figure 2).

Conclusion. Indicators of physical biological indicators for determining degradation stages for pastures in foothill-semi-desert and desert zones of the republic were developed and used during field work.

Routing studies conducted on gray-brown soils, gray soils and sandy desert soils of studied region allowed us to obtain 240 indicators of soil and 280 indicators of biological indicators.

These indicators and fond material were used to develop digital cartographic material on degradation stages of pasture land in territory of foothill semi-desert (vertical zoning) and desert (latitudinal zonality) of natural areas.

One digital map of pastures with strong, medium and weak degradation of the foothill semi-desert and desert zones of Kazakhstan on a scale of 1:1000000 was formed.

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ТҮЙІН

Бұл мақалада авторлар Қазақстанның Алматы облысының тау бөктері-шөлейт және шөл аймақтарындағы жайылымдардың тозу дәрежесін анықтау үшін далалық жұмыстар барысында физикалық-биологиялық көрсеткіштерін әзірледі және пайдаланды. Қазақстанда цифрлық технологиялар негізінде тозған жайылымдарды басқару және мониторингтеу бойынша ғылыми және практикалық ережелер жоқ. Бұл әзірлеме тау бөктеріндегі шөлейт және шөл аймақтардағы деградация дәрежесіне байланысты осындай жерлердің орналасқан жерін анықтауға мүмкіндік

береді. Бұдан басқа, тозу дәрежесін ескере отырып, тозған жайылымдық жерлердің картографиялық моделін әзірлеу (топырақтық-климаттық жағдайларды ескере отырып) өнімді ұзақ өмір сүруді сақтай отырып, оларды қалпына келтірудің (жақсартудың) оңтайлы нұсқаларын әзірлеуге мүмкіндік береді. Сұр-қоңыр топырақтарда, сұр топырақтарда және зерттелетін аймақтың құмды шөлді топырақтарында жүргізілген зерттеулер бізге 240 топырақ пен 280 биологиялық көрсеткіштерді алуға мүмкіндік берді. Бұл көрсеткіштер мен материалдар Қазақстанның тау бөктеріндегі жартылай шөлейт және шөл аймақтарының күшті, орташа және әлсіз тозуына сәйкес 1:1000 000 масштабтағы жайылымдардың цифрлық картасы (қыркүйек) тау етегіндегі шөлейт және шөл аймақтар аумағындағы жайылымдық жерлердің тозу сатылары бойынша цифрлық картографиялық материалды әзірлеу үшін пайдаланылды.

РЕЗЮМЕ

В данной статье авторами разработаны и использованы в ходе полевых работ показатели физико-биологических показателей для определения степени деградации пастбищ в предгорно-полупустынной и пустынной зонах Алматинской области Казахстана. В Казахстане отсутствуют научные и практические положения по управлению и мониторингу деградированных пастбищ на основе цифровых технологий. Эта разработка позволит определить местоположение таких земель в зависимости от степени деградации в предгорной полупустынной и пустынной зонах. Кроме того, разработка картографической модели деградированных пастбищных угодий с учетом степени деградации позволяет (с учетом почвенно-климатических условий) разработать оптимальные варианты их восстановления (улучшения) с последующим сохранением продуктивного долголетия. Исследования, проведенные на серо-бурых почвах, серых почвах и песчаных пустынных почвах исследуемого региона, позволили нам получить 240 показателей почвы и 280 показателей биологических показателей. Эти показатели и материалы были использованы для разработки цифрового картографического материала по стадиям деградации пастбищных угодий на территории предгорной полупустыни и пустыни, по результатам которых была сформирована цифровая карта пастбищ (сентябрь) в масштабе 1:1 000 000 метров в соответствии с сильной, средней и слабой деградацией предгорных полупустынных и пустынных зон Казахстана.

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