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Determination of the Degradation Degree of Pasture Lands in the West Kazakhstan Region Based on Monitoring Using Geoinformation Technologies

Bayan Zhumabaevna Yesmagulova[1*], Assem Yurievna Assetova[1], Zhadyra Baizhanovna Tassanova[1], Aizhan Naskenovna Zhildikbaeva[2], Dinara Kumarbekovna Molzhigitova[3]

[1] Higher School of Management of Forest, Land, and Water Resources, West Kazakhstan Agrarian and Technical University named after Zhangir Khan, 51 Zhangir Khan Str., 090009, Uralsk, Kazakhstan

[2] Department of Land Resources and Cadastre, Kazakh National Agrarian Research University, 8 Abai Ave., 050010, Almaty, Kazakhstan

[3] Department of Geography, Land Management, and Cadastre, Al-Farabi Kazakh National University, 71 Al-Farabi Ave., 050040, Almaty, Kazakhstan

* Corresponding author's e-mail: bayana_021284@mail.ru

ABSTRACT

Land degradation, including pasture lands is one of the global problems. Currently, one of the most urgent problems of the West Kazakhstan region is the preservation and restoration of the vegetation cover of pasture lands. To date, large areas of the region have been occupied by agricultural land. Several main reasons negatively affect agriculture, one of which is land degradation associated with anthropogenic impact in terms of the irrationality of land use. Thus, to preserve the biodiversity of the pastures of the West Kazakhstan region, it is necessary to fully study the projective cover of the vegetation, determine the dominant plant species, and also monitor the condition of pastures to prevent land degradation on time by conducting land and forest improvement activities. The study aimed to carry out a phyto-ecological assessment of degraded pastures of the Karatobinsky district of the West Kazakhstan region using geoinformation technologies and field study results. The paper presents the results of desktop decoding of high-resolution satellite images and ecological profiling of the studied territories. Decoding features of landscape types allowed making a preliminary map of landscape contours. The use of this technique makes it possible to monitor the condition of degraded pasture lands in a short time and justify the organization of pastures with a regulated grazing system in the study area.

Keywords: monitoring, pastures, decoding, satellite image, degradation, profile, sands, vegetation.

INTRODUCTION

Today, the problem of degraded pasture lands has become relevant for the whole world, since the annual global loss of productive pasture lands is about 55–60%. The urgency of the problem arising from this is explained by the fact that the area of degraded lands is expanding annually under the influence of anthropogenic factors [Kubenkulov et al., 2019].

According to Kucherov [2012] and Nasiev [2013], the degradation of pasture lands occurs from long-term grazing and the violation of the seasonality of their use, which results in changes or (in some places) disappearance of the species composition of vegetation.

Kulik [2004] and Nasiev [2013] have demonstrated the issues of monitoring pasture lands. The most complete studies of changes in species composition and the productivity of vegetation cover of semi-desert and desert zones of the West Kazakhstan region (WKR) were considered in the works of Vlasenko [2011], Ivanov [2007], Darbaeva [2001], whereas studies about the features of sandy lands were performed in the works of Gael [1999].

Currently, the problem of obtaining information about the state of pasture lands is solved with the use of geoinformation technologies that allow obtaining reliable and complete information about the state of pasture landscapes [Kaldybaev et al., 2022]. Satellite images make it possible to objectively assess the situation and take effective measures aimed at preserving the natural vegetation [Karynbaev, 2015]. Space information enables to assess the state of the territory and study changes in vegetation cover based on remote data [Yuferev et al., 2010; Esmagulova et al., 2015].

This is important since, with the increase in the number of livestock on private farms, the need to increase the territory of pasture lands also grows. Therefore, the problem of proper organization of activities aimed at preserving and improving pasture lands remains important and relevant [Kushnir and Konstantinov, 2008; Qnagayev et al., 2016].

The authors believe that the correct organization of measures to improve pasture lands will allow the use of pastures with the greatest effect on the development of agriculture. The use of remote geoinformation technologies and the results of ground field studies will solve the problem of degradation of pasture lands in Kazakhstan.

The purpose of the study was a phyto-ecological assessment of degraded pastures of the Karatobinsky district of the WKR using geoinformation technologies and field study results, followed by the development of the measures to improve pasture lands.

MATERIALS AND METHODS

The paper presents the results of remote monitoring and field studies of degraded pasture lands in 2019.

The study area was degraded pasture lands. Irrational methods of using pastures and anthropogenic impact accelerated the processes of their degradation and caused a decrease in fodder production. The object of the study was the pasture lands of the Karatobinsky district (Kazakhstan), located in the desert and semi-desert zone of the WKR. The paper presents the results of remote monitoring and field studies of degraded pasture lands in 2019.

Remote monitoring of pasture lands of the West Kazakhstan region is relevant due to the fragility and vulnerability of the semi-desert and desert zone. The pastures of the region occupy 73% of its entire area. Despite the huge area of pasture lands, the area of run-down and overgrown pastures with non-edible plants is steadily growing in the region. The anthropogenic impact plays a significant role in this process due to the intensive increase in the number of farm animals.

On the territory of the Karatobinsky district, the main animals grazed on pastures are sheep, goats, and cattle. As a result of prolonged excessive anthropogenic loads, degradation of pasture lands is observed on the territory of the Karatobinsky district. This requires careful analysis and some measures to preserve the natural vegetation.

The key site Alymshagyl is a sandy massif of the same name, located in the Karatobensky district of the WKR, northeast of the Karatobe village. The coordinates of the center of the key site under consideration are 49°41∍02∀ north latitude; 53°32∍33∀ east longitude. The total area of the key site is 274 hectares, of which 17.2% are occupied by the settlements of Karatobe and Shoptikol.

The following materials were used during the study:

- high-resolution satellite images from the Google Earth information and search web service;
- multi-time satellite images of Landsat 5 and 8 from the EarthExplorer portal (US Geological Survey);
- soil map of the WKR obtained at the State Research and Production Center of Land Resources and Land Management of the city of Uralsk;
- maps of the groundwater level and mineralization (GWL and GWM) obtained by the Zhaikhydrogeology Committee of the WKR;
- reports of the Department of Natural Resources and Environmental Management of the WKR.

The study was carried out based on a three-stage method, including a pre-field desktop stage, a field expeditionary study stage, and a post-field desktop stage [Kulik, 2004].

Stage 1. Pre-field desktop studies included the processing of cartographic material, as well as the selection of satellite images to determine the key site. At this stage, the route of the expeditionary field study was developed based on satellite images, and the routes for laying landscape and ecological profiles were planned.

Stage 2. During the field study, the following works were carried out at the key site:
- landscape and ecological profiling;
- establishment of geobotanical sites and sloping sites;
- determination of the degree of pasture degradation by the total projective cover and productivity of the herbage.

Landscape and ecological profiling was carried out according to the "Guidelines for landscape and ecological profiling" [Kulik et al., 2007]. Geoinformation processing was carried out based on the images of Landsat series spacecraft, from the Landsat 5 satellite, obtained from the archive of the United States Geological Survey (USGS) [Landsat Satellite Archives, 2018]. Pasture lands were decrypted in the Global Mapper software, which included the definition of pasture lands, territories of sandy lands used for pasture, territories of settlements, and roads. Decryption is the Global Mapper software included the following layers: a soil map, types of sands for vegetation colonization, and routes for laying a landscape and ecological profile to examine the main objects identified during desktop decryption at their smallest extent.

The vegetation was described on 12 geobotanical sites measuring 100 m^2. The quantitative ratio of species was characterized by the Drude scale. The productivity of pasture lands was determined by using the cutting method: plant samples were collected on geobotanical sites, that is, a cutting site with an area of about 2.5 m^2 was selected, in three-fold repetition. After cutting the plants from the cutting sites, they were immediately weighed and the results were recorded in a form. The raw mass of all plants was collected in place (if the mass exceeded 1 kg) and placed in a gauze bag for drying. The productivity of the dry mass was determined under the office conditions after the end of field studies.

The Drude scale [Stikhareva et al., 2021] has six gradations: Soc.: plants grow close to each other, joining with their aboveground parts; Cop. 3: plants occur in very large numbers; Cop. 2: plants occur in large numbers; Cop. 1: plants occur in considerable numbers; Sp.: the species is abundant, but does not form a continuous cover; Sol.: the species grows sparsely; Un.: the species occurs in single instances. To determine the degree of degradation of vegetation cover by the projective cover, the scale of V.P. Voronina [2009] was taken as a basis, where a very heavily run down pasture has a projective cover <25% (IV); a heavily run down has a cover of 25–50% (III); a medium run down one has a cover of 50–75% (II), and a slightly run down one has a projective cover.

Stage 3. For forest improvement mapping of the territory of a key site on a sandy massif, a forest improvement classification was used [Kulik et al., 2021], according to which degraded pastures are divided into 4 forest improvement categories (FIC), differing among themselves according to the state of the soil and vegetation cover. The categories identified in the FIC I include desertification foci that have arisen as a result of excessive loading of livestock at watering holes, sheep pens, and settlements, as well as pasture areas that have undergone desertification and withdrawal from economic circulation due to plowing. Depending on the area, the foci of desertification are classified as small (less than 100 ha), medium (100 to 500 ha), and large (more than 500 ha).

FIC II includes sands of different landforms in various stages of the soil-forming process slightly colonized or colonized with vegetation, often with disjointed deflation spots, as well as territories with sandy desert soils. They easily lose their soil and vegetation cover and become desertified with an increased load of livestock and even with partial plowing with wide stripes.

FIC III includes the areas with sandy loam zonal (light chestnut, brown semi-desert, gray-brown desert, takyr-like desert) soils capable of deflating with continuous plowing.

FIC IV includes loamy and clay soils that are practically not exposed to wind erosion not only during intensive grazing but also during plowing.

FICs, in turn, are divided into forest improvement types (FIT), which are distinguished by the level and mineralization of groundwater (GW).

FIT a has available GW, its depth of occurrence equals from 0 to 4 m, and mineralization up to 1 g/l; FIT b has limited available GW, its depth of occurrence equals from 4 to 8 m, with mineralization over 1 g/l; FIT c has redistributed precipitation (snow accumulation, surface runoff); FIT d has inaccessible GW and is devoid of the specified sources of moisture.

The combination of FIC and FIT gives forest improvement divisions (FID) designated by the double category and type index [Kulik, 2004].

The degree of colonization of the sandy massif with grassy and woody vegetation was estimated from satellite images and isolinear maps based on them. An isolinear map was created based on the data obtained by dividing the area of grassy and woody vegetation by the total area of a regular grid square (translated into %), which was superimposed on the satellite image:

$$C = \frac{S1}{S2} \times 100\% \quad (1)$$

where: C – the degree of colonization of the sandy massif with vegetation, %;
S_1 – the area of herbaceous or woody vegetation (ha or km^2);
S_2 – the square area (ha or km^2).

Using these points in the Surfer software, using the kriging interpolation method [Silkin, 2008], isolinear maps of the GWL and GWM for the key site were constructed. To work in Surfer, spreadsheets must contain at least three columns of data: the first two columns of data are the coordinates X and Y, and the third column is the value Z assigned to the X, Y point. In the considered case, X and Y are the coordinates of the center of the cell of the regular grid, which is superimposed on the satellite image, and Z represents either GWL or GWM data.

Similarly, isolinear maps were constructed according to the degree of colonization of the sands with herbaceous and woody vegetation.

RESULTS

According to decoding signs, the surface of the key area is flat. The soils around the sandy massif are sandy loam brown semi-desert solonized soils (Figure 1).

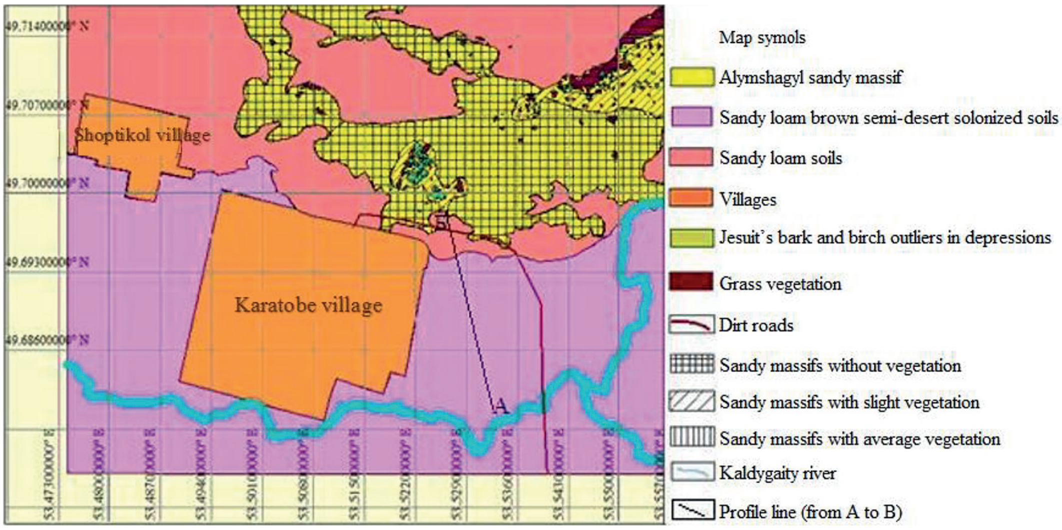

Figure 1. Landscape and ecological scheme of the Alymshagyl key site (Scale 1: 100,000)

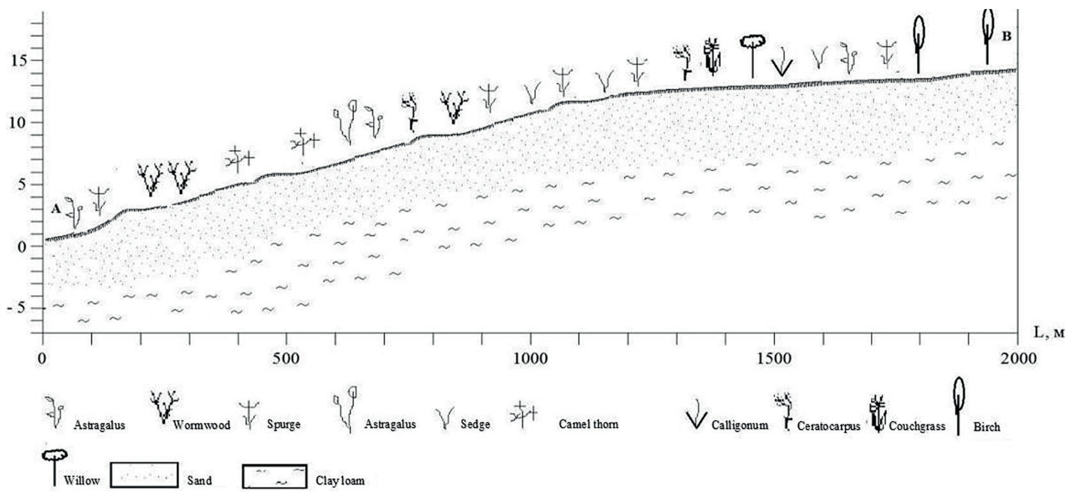

Figure 2. Landscape and ecological profile (AB) of the Alymshagyl key site

The landscape and ecological profile begins on the bank of the Kaldygaity River and is located in the direction from south to north. The length of the profile is 2 km. The landscape and ecological profile (Figure 2) and the geobotanical description (Table 1) allow performing the most expressive and complete assessment of the features of the key site.

Plant communities change frequently throughout the profile. The profile begins with the astragalus and spurge community. Downy brome, milfoil, and sand oats are found only occasionally.

On the 3rd site, an open area is observed, the projective cover on which does not exceed 1%, and camel thorn is found only once. At 500 m from the Kaldygaity River, the projective cover reaches 20% and the plant community changes to bluegrass and astragalus.

Table 1. Geobotanical description of the landscape and ecological profile at the Alymshagyl key site

Number of geobotanical sites	1	2	3	4	5	6	7	8	9	10	11	12
Projective cover, %	10	8	1	20	10	10	10	10	25	10	10	10
Number of species	5	5	1	4	3	2	3	2	5	3	5	3
Species	Abundance on the Drude scale											
Astragalus	Sp.			Sp.						Sol.		
Camel thorn			Sol.									
Calligonum aphyllum									Sol.			
Limonium suffruticosum		Un.										
Awnless brome		Sol.					Un.					
Grey saltbush				Un.								
Bulbous bluegrass		Sol.		Sp.						Un.		
Field spurge	Sp.				Sol.	Sol.			Sp.		Sp.	Sp.
Sand oats	Un.						Sp.					
Sedge	Un.	Un.			Sol.	Sol.			Sp.	Sol.	Sol.	Sol.
Austrian wormwood					Sol.				Sol.		Sol.	
White wormwood		Sp.		Un.			Un.					
Field wormwood											Sol.	
Couchgrass								Sp.				
Goose grass											Un.	Un.
Wild rye									Un.			
Pamirian winterfat								Un.				
Milfoil	Un.											

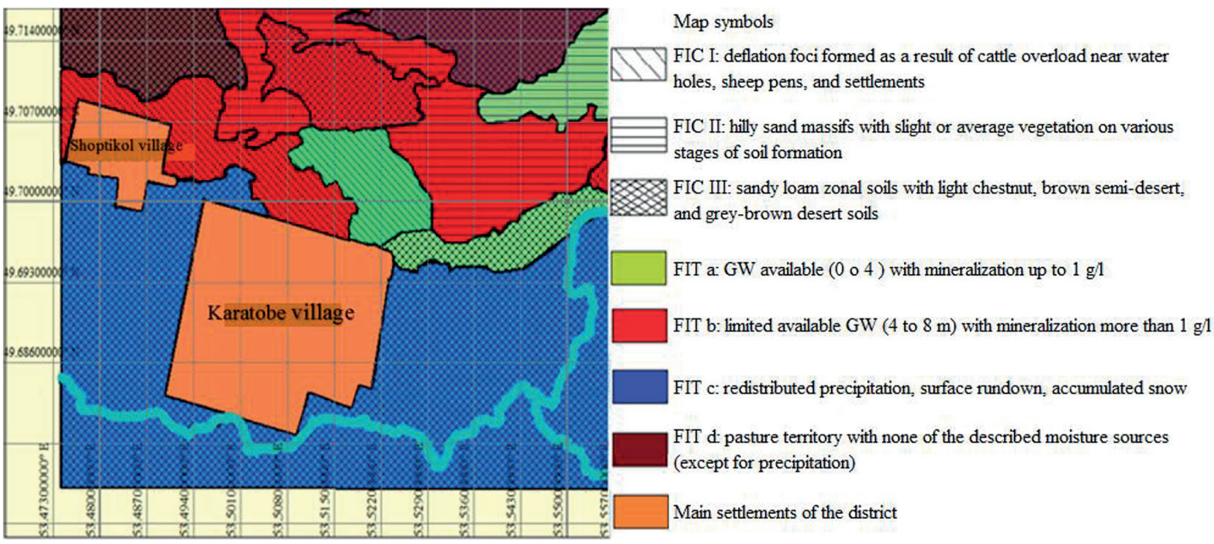

Figure 3. Forest improvement map of the Alymshagyl key site (Scale 1: 100,000)

After 1,500 m from the beginning of the profile, calligonum bushes grow and wild rye and spurge are found. The profile ends at the top of a sandy hillock with a height of 7 m. Here, in the depressions between the hillocks, forest outliers of Jesuit's bark and birch grow, up to 3–5 m high. From the herbaceous vegetation, goose grass is found in some places. It should be noted that throughout the entire profile, the species composition of vegetation is no more than 5 and the territory of the key site is a very heavily run down pasture.

On the basis of soil and landscape and ecological maps, a forest improvement map of the key site was compiled (Figure 3). All forest improvement categories are present on this site. Over 50% of the land is under sandy loam brown semi-desert solonized soils (FIC III). The land of FIC I occupies 9.8% of the total area and is confined to the villages of Karatobe and Shoptikol, where pockets of deflation have arisen as a result of overgrazing.

The lands of FIC II are completely located within the Alymshagyl sandy massif and occupy 15.3% of the total area of the key site, according to inter-hillock depressions, the projective cover increases to 25% (Table 2).

To determine the FIT, isolinear maps of sand colonization with vegetation were constructed (Figure 4). The analysis of Figure 4 showed that the main tree stands are concentrated in the central part of the sandy massif and represent birch outliers along inter-hillock depressions. The main

Table 2. Distribution of land by FIC in the Alymshagyl key area

Area	FIC and other sites				Total by key site
	I	II	III	Settlement	
ha	27.0	42.0	158.0	47.0	274.0
%	9.8	15.3	57.7	17.2	100.0

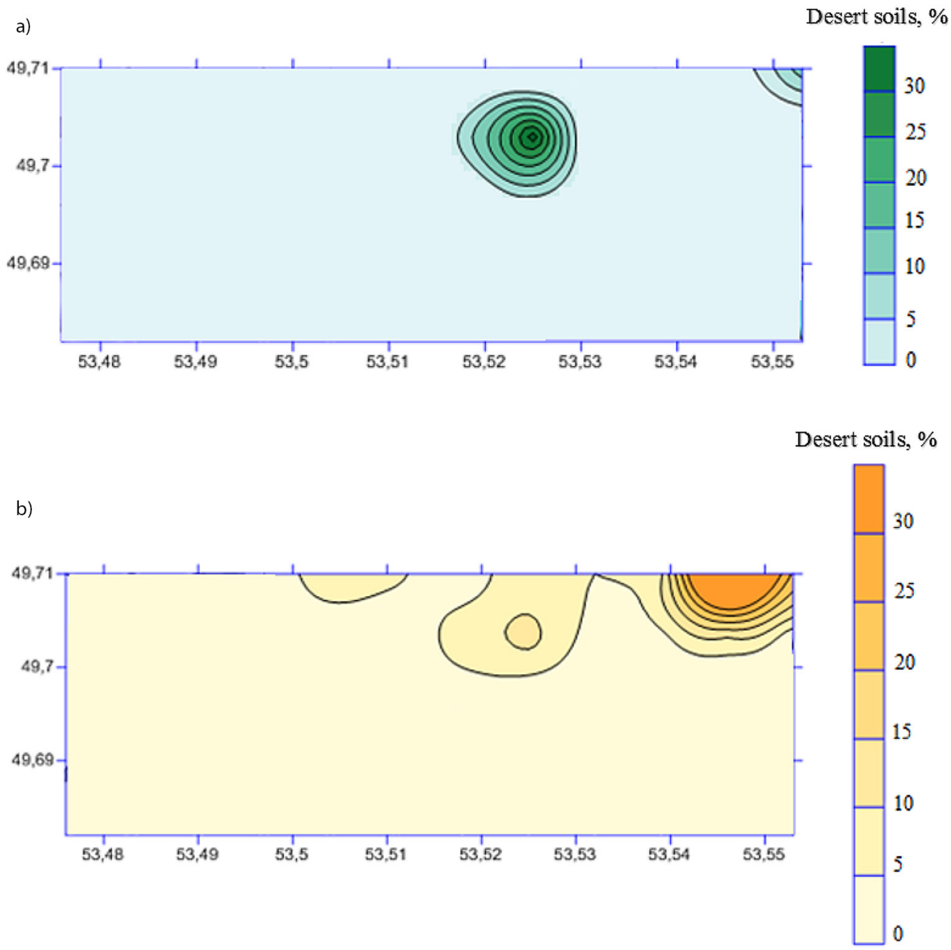

Figure 4. Isolinear map of colonization by tree stands (A) and herbaceous vegetation (B) of the Alymshagyl sandy massif, in %

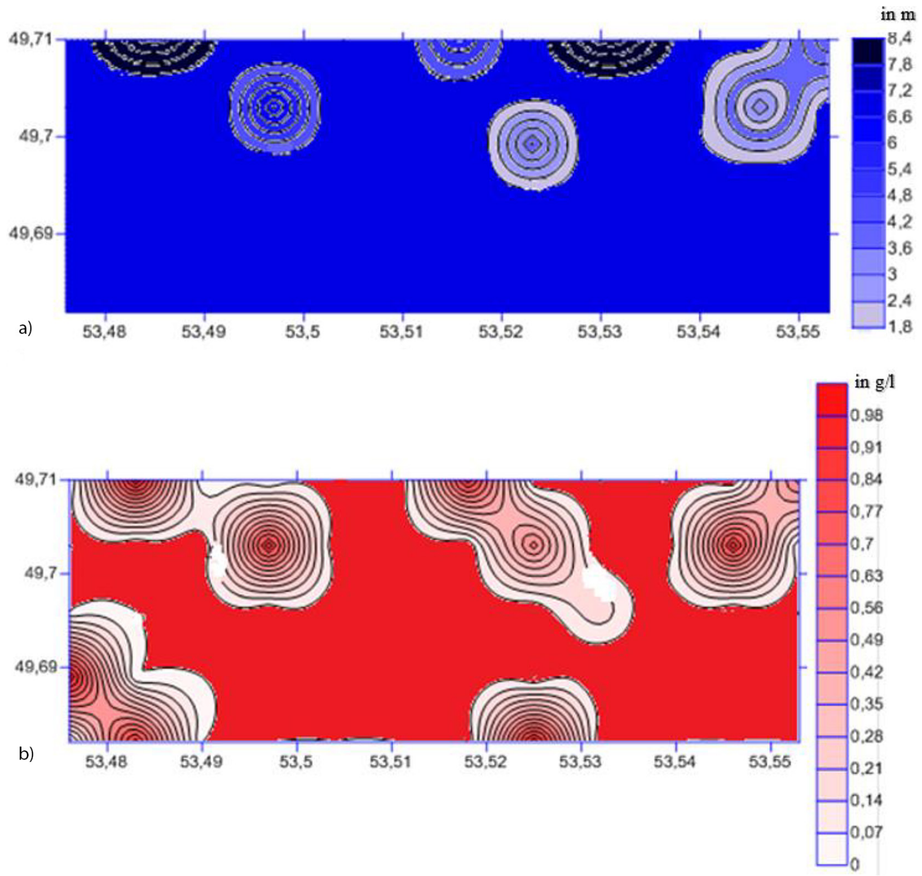

Figure 5. Isolinear map of GWL (A, m) and GWM (B, g/l) of the Alymshagyl sand massif

Table 3. Distribution of land by FIT in the Alymshagyl key site

Area	FIT					Total by key site
	a	b	c	d	Settlement	
ha	26.0	63.0	112.0	26.0	47.0	274.0
%	9.5	23.0	40.8	9.5	17.2	100.0

part of the sandy massif does not have a continuous grass cover, i.e. it has a weak and medium degree of colonization with herbaceous vegetation.

According to the isolinear maps of the GWL and GWM (Figure 5), it can be seen that most of the key site has limited available GW (4–6 m), while its mineralization does not exceed 1 g/l.

The distribution of areas by FIT is shown in Table 3, from which it can be seen that the largest area is occupied by the land of the FIT b (40.8%), and they are located in the contour of the FIC III, where the Kaldygaity River passes through the territory of the key site. The lands with accessible and limited available GW (FIT a and b) occupy 32.5%.

Thus, eight FID were identified at the key site (Table 4). The analysis of the data in Table 4 shows that the Alymshagyl key site is dominated by the lands of the FID III (40.9%). The plots with available GW at the FIC Ia, FIC IIa, and FIC IIIa equal 9.4%. The sites with limited available GW at the FIC Ib, FIC IIb, and FIC IIB occupy 23%.

Table 4. FID at the Alymshagyl key site

FID	Area of FID, ha	Share of the total area of the key site, %
I a	10.0	3.6
I b	17.0	6.2
II a	8.0	2.9
II b	34.0	12.4
III a	8.0	2.9
III b	12.0	4.4
III c	112.0	40.9
III d	26.0	9.5
Settlement, 0	47.0	17.2
Total	274.0	100.0

On the key site, FIT d is present, located on the site of FIC III d and occupying 9.5% of the total area of the site.

DISCUSSION

Improving the microclimate of the territory and creating productive fodder base on the pastures of the Karatobinsky district remains an urgent problem. An exceptional role in the preservation of pastures from wind erosion and increasing their productivity on degraded pastures of the Karatobinsky district, as a rule, belongs to pasture-protective forest strips, and shade clumps, which are the most powerful means of protecting pastures. The issues of proper use of pastures are important.

The most important task in processing remote monitoring data is to determine the condition of pasture lands. According to Bekmukhamedov [2019], the pasture lands of Kazakhstan are characterized by three degradation factors: overgrazing, cutting of shrubs, and abandonment. According to the conducted study, among the important remote indicators of the ecological state of phytocenoses, one can name the run down vegetation cover, which was formed due to overgrazing.

As one can see in the key area, due to intensive grazing of livestock, natural grains have disappeared. The areas with excessive grazing are mostly adjacent to settlements and wells, where animals cross the territory several times during one day. In such areas, the vegetation is almost completely run down. Therefore, a detailed analysis of satellite images and landscape and ecological profiling makes it possible to conduct monitoring of pasture lands in a remote mode without specialists visiting the site. Remote monitoring enables to justify the transformation of degraded pasture lands into other types of land, organize pastures with a regulated grazing system, fix the sands with psammophytes, and plant woody plants such as tamarix, marsh elder, and calligonum along inter-hillock depressions.

According to studies [Nasiyev and Bekkaliyev, 2019; Nasiyev et al., 2022], when organizing pastures with a regulated grazing system, the fodder base improves, and productivity increases. Therefore, to maintain pastures in good natural condition in the study area, based on the instructions [Yunusbaev, 2001], the creation of a pasture rotation with alternating spring season with winter and summer with autumn is recommended.

CONCLUSIONS

The use of this study method and the interpretation of satellite images in the territory of the WKR will ensure constant monitoring of the condition of objects, high quality, and efficiency of creating thematic maps for agroforestry activities, as well as high reliability of information about the state of pasture landscapes.

The results of the conducted study showed that the concentration of animals along livestock centers, watering holes, settlements, and overgrazing on pastures leads to complete desertification of the territory. The recommended measures should be comprehensive, taking into account both natural and climatic and anthropogenic factors.

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