ISSN 2079-0961, Arid Ecosystems, 2022, Vol. 12, No. 4, pp. 473–480. © Pleiades Publishing, Ltd., 2022.
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INDUSTRIAL PROBLEMS OF THE STUDY OF ARID TERRITORIES

Mapping the Rangelands of Wild Ungulates in the Barsakelmes Nature Reserve (Kazakhstan)

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Received May 2, 2022; revised July 1, 2022; accepted July 1, 2022

Abstract—This article presents a medium-scale map of the forage areas of the Kaskakulan cluster area of the Barsakelmes Nature Reserve, where wild ungulates, kulans, saigas, and goitered gazelles, live. The map was designed using data from ground surveys and remote sensing. The author's technique and a set of spectral indices were used for processing satellite data. Maps of seasonal rangeland yields, which were considered when calculating the total yield, were designed based on the interpretation of space images. The legend to the Rangeland map is a system of headings that take into account zonality, ecological and physiognomic types of vegetation, and soil conditions. Types of rangelands are reflected in the legend by 15 numbers; for each the total yield for the seasons of the year is given. The map can be used to assess the grazing capacity of the territory and calculate the allowable number of wild ungulates to maintain ecosystems in a balanced state.

Keywords: Aral Sea, feed resources, remote sensing, productivity, medium scale map

DOI: 10.1134/S2079096122040047

The Barsakelmes Nature Reserve was organized on the island of the same name in the Aral Sea in 1939 to preserve wild ungulates of the saiga (*Saiga tatarica*, Linnaeus, 1766) and goitered gazelle (*Gazella subgutturoza* Güldendtaedt, 1780). In 1953, the Turkmen kulan (*Equus hemionus onager* Boddaort, 1785) was introduced to the island. All these species are included in the Red List of the International Union for Conservation of Nature and Natural Resources (IUCN SSC, 2017, 2018; Kaczensky et al., 2020).

The territory of the island merged with the mainland during the drying of the sea in the late 1990s. Animals migrated in search of water sources. The territory of the compact habitat of wild asses, the former island of Kaskakulan and the adjacent drained strip of the sea, was included into the reserve in 2006. The total area of the reserve increased by 10 times. There are three artesian wells on Kaskakulan, which are an important resource for watering animals.

Wild ungulates: saigas, gazelles, and kulans are well adapted to the harsh desert conditions of the reserve, they are the main components of its ecosystems. Desert plant resources are a natural source of food for wild animals living in the reserve.

The flora of vascular plants of the reserve includes 293 species, 134 of which have been found on Kaskakulan (Dimeyeva and Alimbetova, 2007). The spectrum of leading families is dominated by representatives of Amaranthaceae, Asteraceae, Poaceae, Brassicaceae, Polygonaceae, Fabaceae. Valuable fodder plants include *Artemisia terrae-albae, Salsola orientalis, Kochia prostrata, Agropyron fragile, A. desertorum, Stipa lessingiana,* and *S. richteriana*. The vegetation of Kaskakulan Island is represented by communities with the participation of sagebrush *Artemisia terrae-albae* with *Tulipa biflora, T. borszczovii, Takhtajaniantha pusilla, Poa bulbosa, Anabasis salsa, Haloxylon ammoderndron*, and *Halocnemum strobilaceum*. Meadow vegetation (*Phragmites australis, Saussurea salsa,* and *Atriplex littoralis*) is formed near the wells. The phytocoenotic diversity of the dry seabed is characterized by a unique combination of plant communities and aggregations representing the stages of primary successions. Communities of *Anabasis aphylla, Kalidium caspicum, Nitraria schoberi, Haloxylon ammodendron, Climacoptera aralensis,* and *C. ferganica* formed near the former eastern coast on takyr-like soils. The coastal solonchaks are overgrown with *Suaeda microphylla* and *Halogeton glomeratus*. Haloxylon stands, in which perennial and annual saltworts (*Halocnemum strobilaceum, Salsola nitraria,* and *Halostachys belangeriana*) are subdominants, are widespread on takyr-like soils

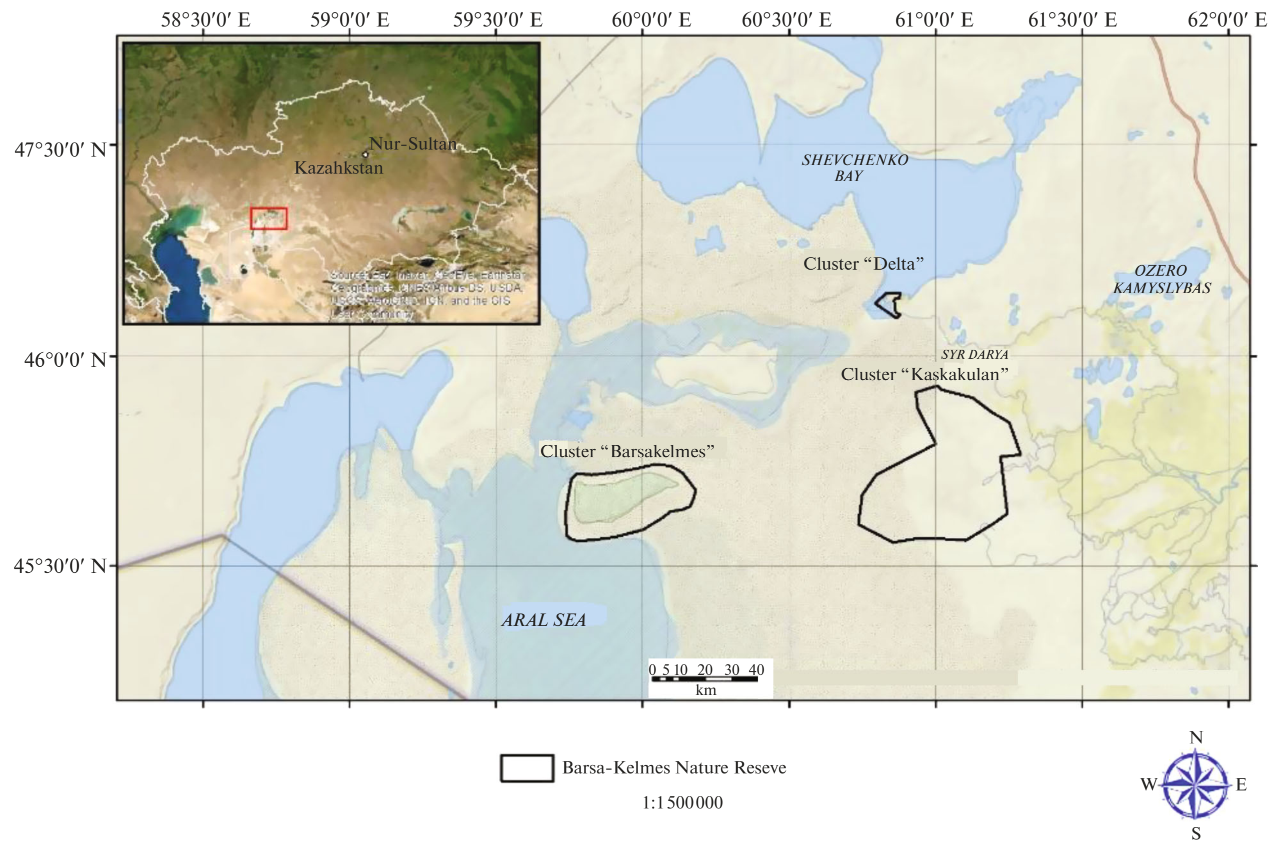

Fig. 1. The location of the Barsakelmes Reserve.

with a wind-blown sandy cover. Psammophytic communities (*Coryspermum aralo-caspicum, Eremosparton aphyllum, Atriplex pratovii, Stipagrostis pennata*; Dimeyeva, 2007) are grow on hummocky sands.

The number of saigas in the Barsakelmes reserve when it was still an island on an area of 186 sq. km changed dramatically over the years from 50 to 2000 individuals. The number of gazelles in the 1970s ranged from 120 to 400. In 1980, more than 200 kulans lived on the island (Eliseev, 2007). Since then, the specially protected area has increased by 10 times. Based on the 2021 census, it was found that there are 690 kulans, 47 saigas, and 171 goitered gazelles in the reserve. The lands of the Kaskakulan cluster site, which is newly included in the reserve, are subjected to pasture load, and there is practically no grazing on the territory of the former island Barsakelmes.

Before the catastrophic decline of the sea, the staff of the reserve studied the food base of wild ungulates (Vasenko, 1950; Demchenko, 1950; Rashek, 1977; Zhevnerov, 1984). Based on these studies, we found that 105 plant species are eaten by ungulates, of which 35 species are eaten by saigas, 78 by goitered gazelles, and 71 by kulans. The preferences of ungulates are similar. The first place is occupied by species Poaceae family Amaranthaceae are in the second place, Asteraceae, Brassicaceae, and Fabaceae are in the third place. Seasonal food preferences also coincide. In spring, animals feed on ephemers and ephemeroids, especially grasses, including green shoots of feather grass. In summer, *Kraschenınnikovia ceratoides*, fruits of *Nitraria schoberi* and *Ephedra distachya* appear in the diet. In autumn, saltwort and sagebrush are most often eaten, in winter they eat annual shoots of Haloxylon, perennial saltwort and sagebrush. The seasonal productivity of pastures was studied during the complex expedition of the Leningrad State Pedagogical University in the 1970s–1980s (Romanova et al., 1979). After the migration of animals to the adjacent territory, the food supply was not studied. The purpose of our research was to determine the productivity of the main plant communities and map the forage lands of the Kaskakulan cluster site to study the current state of rangelands of wild ungulates.

OBJECTS AND METHODS OF RESEARCH

The Barsakelmes Reserve is located in the northern part of the eastern coast of the Aral Sea and consists of three cluster areas: Barsakelmes, Kaskakulan, and Delta (Fig. 1).

The objects of study included plant communities, which are natural fodder lands. Field research was

Table 1. The productivity of fodder mass of plant communities

Coordinates	Plant community	TPC, %	Number, plant/ha	Species	Raw mass, c/ha	Dried mass, c/ha
45°39′30.0″ N 60°57′45.1″ E	Reed (*Phragmites australis*)			Reed	**146.3**	**53.6**
45°39′36.7″ N 60°57′48.4″ E	Saltwort-ephemeral-camel's thorn (*Alhagi pseudalhagi, Tulipa buhseana, Koelpinia linearis, Climacoptera brachiata*, *Ceratocarpus arenarius*)	80		Camel's thorn Climacoptera Ceratocarpus Ephemers Harmala **Total:**	16.9 3.3 0.9 5.2 5.2 **31.5**	2.4 1.3 0.4 3.3 1.4 **8.8**
45°39′28.0″ N 60°57′45.1″ E	Anabasis (*Anabasis salsa*)	35–40		Anabasis Saltworts Ephemers **Total:**	13.8 1.8 1.8 **17.4**	5.8 1.2 0.8 **7.8**
45°39′35.7″ N 60°57′41.0″ E	Aggregations of tamarix with halophytic forbs and ephemers (*Tamarix elonagata, Artemisia scopiformis, Aeluropus littoralis, Eremopyrum orientale, Climacoptera aralensis, Lycium ruthenicum, Alhagi pseudalhagi*)	80	600	Tamarix Sagebrush Aeluropus Ephemers Climacoptera Box-thorn Camel's thorn **Total:**	21.9 8.3 3.7 1.7 1.3 2.3 3.3 **42.5**	5.7 4.0 1.5 1.7 0.5 0.3 1.1 **14.8**
45°38′53.5″ N 60°58′54.1″ E	Aggregations of nitrebush (*Nitraria schoberi*)	60	2400 m^2/ha	Nitraria	**26.3**	**4.8**
45°39′02.2″ N 60°58′40.7″ E	Psammophytic shrub (*Astragalus brachypus, Calligonum* spp., *Convolvulus subsericeus*)	60–70	300 4000 4000	Calligonum Astragalus Convolvulus **Total:**	2.0 3.6 2.4 **8.0**	0.6 1.1 1.1 **2.8**
45°39′25.2″ N 60°59′13.5″ E	Ephemeral–Haloxylon (*Haloxylon ammodendron, Senecio noeanus*)	70–80	700	Haloxylon	**5.9**	**1.9**
45°39′28.5″ N 60°59′49.4″ E	Halocnemum (*Halocnemum strobilaceum*)	40–50		Halocnemum	**44.0**	**15.0**
45°39′26.8″ N 61°01′04.6″ E	Halostachys (*Halostachys belangeriana*)	25	600	Halostachys	**9.1**	**1.8**
45°39′24.3″ N 61°01′43.1″ E	Haloxylon (depressed) *Haloxylon ammodendron*)	40	800	Haloxylon	**6.5**	**1.8**
45°39′35.0″ N 61°04′06.0″ E	Haloxylon (undersized) with kalidium (*Haloxylon ammodendron, Kalidium capsicum*)	30	1200 h. 700 k.	Haloxylon Kalidium **Total:**	1.6 2.6 **4.2**	0.7 0.6 **1.3**
45°40′17.6″ N 61°06′16.7″ E	Halocnemum (*Halocnemum strobilaceum*)	40		Halocnemum	**54.7**	**21.9**
45°42′49.7″ N 61°12′02.3″ E	Aggregations of saltworts (*Suaeda microphylla, Climacoptera lanata, C. brachiata*)	35		Saltworts	**32.3**	**8.2**
45°44′56.7″ N 61°13′19.8″ E	Ephemeral–Haloxylon (*Haloxylon ammodendron, Senecio noeanus*)	60–70	1500	Haloxylon	**12.2**	**4.1**

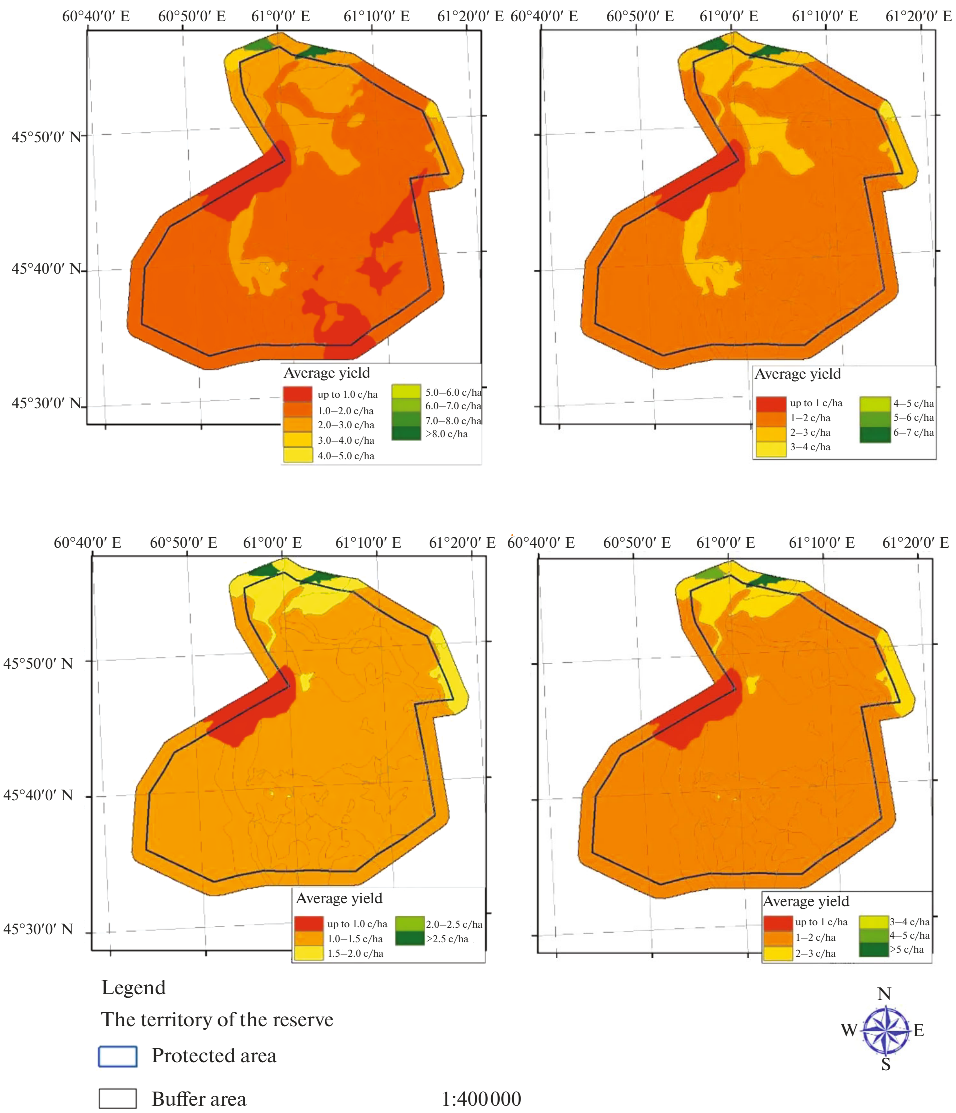

Fig. 2. Maps of rangeland productivity for the seasons of the year.

organized at the beginning of June 2019 with the participation of the reserve staff. Descriptions of plant communities were carried out at 29 points. On plots with a typical vegetation cover for the studied area, 14 plots were laid to account for the yield. The survey routes were tied to existing roads, and the interpretation of the vegetation cover of the entire territory was carried out on the basis of satellite images and ground data. In addition, 27 geobotanical descriptions of past years (2003–2015) were used to identify the contours of the rangeland map.

The research methods were geobotanical, floristic, pasture, cartographic, GIS technologies and remote sensing (Bykov, 1978; Sochava, 1979; Kurochkina et al., 1986; Berlyant, 1997).

Rangeland vegetation was studied using traditional methods of field geobotanical research. For each plant community, the following parameters were established: coordinates, landscape, soils, water regime, total projective coverage (TPC), layering, degree of transformation, complete floristic composition, phenophases, vigour (a 5-point scale), abundance (the Drude scale), spreading (according to the scale of B.A. Bykov), height, and habitus. The *Illyustrirovannyi opredelitel' rastenii Kazakhstana* in 2 volumes (1969–1972) and *Flora Kazakhstana* in 9 volumes (1956–1966) were used, identifying the species of plants. The nomenclature of species is given taking into account the Internet resource “The World Flora Online” (2022).

The forage mass yield was calculated by cutting methods and model bushes (Ramensky et al., 1956; Brown, 1957; Nechaeva, 1957; *Instruktsiya* ..., 1996).

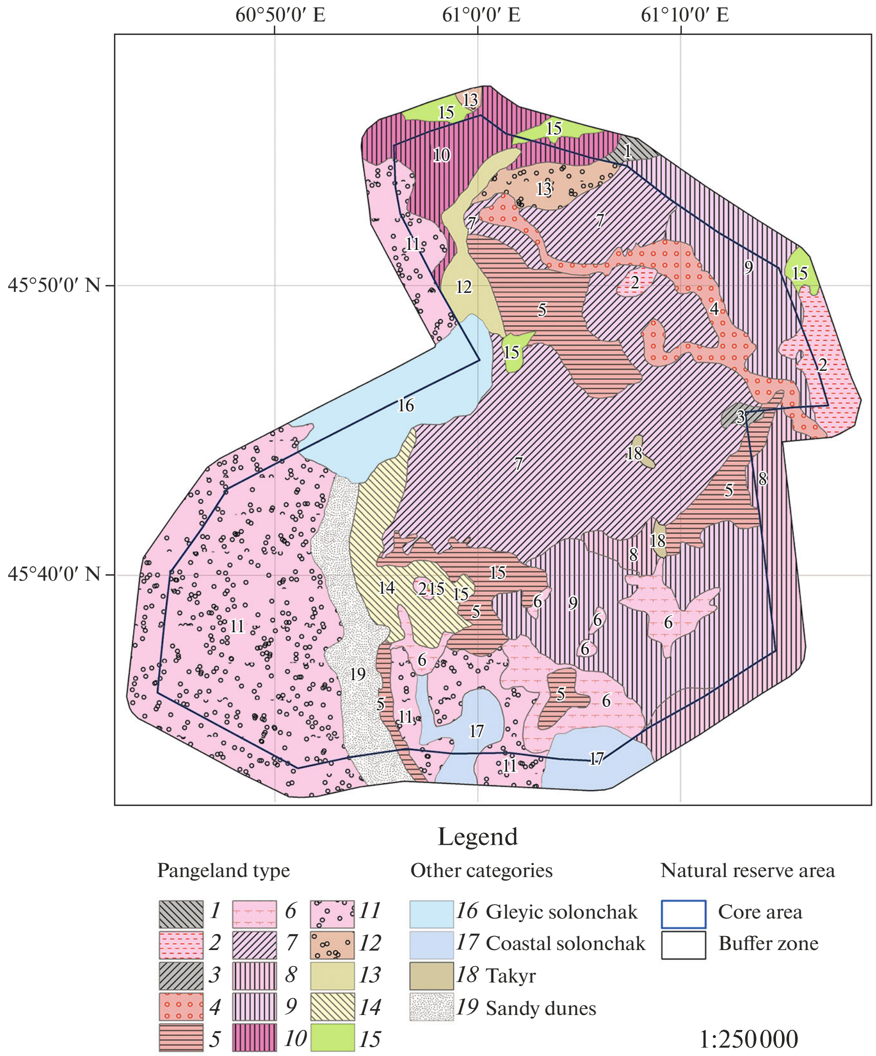

Fig. 3. Rangeland map of the Kaskakulan cluster area.

Field mapping of vegetation was carried out by a combination of detailed route studies and the landscape-ecological profiling using a topographic base and satellite images. The author's technique was used for processing satellite data (Malakhov, Islamgulova, 2014, 2015). A set of spectral indices: Salinity Index, Water Index, Top Soil Grain Size, Water Concentration in Green Biomass (NDWI), and Bare Soil Index, was used to calculate and analyze the main pasture indicators (Penuelas et al., 1993; Yilmaz et al., 2008; Gao, 1995).

RESULTS AND DISCUSSION

Determination of the forage mass in the field. The accumulation of forage mass was studied in the first 10 days of June 2019. The sequence for determining the reserves of forage mass included the following steps: laying standard sites or choosing model bushes; cutting the fodder mass; weighing raw phytomass, drying, weighing dried phytomass; and converting the obtained data into centners per hectare.

Table 1 shows the yield data of the main plant communities of the Kaskakulan cluster area.

Evaluation of forage mass accumulation by remote sensing. Landsat OLI images (USGS, 2022) were used to calculate seasonal yields. The author's methodology (Malakhov, Islamgulova, 2014, 2015) and seasonal correction factors (Lebed, 1989) made it possible to compile pasture yield maps for different seasons (Fig. 2).

The results of yield calculations obtained from satellite data are averaged. For each vegetation contour, the yield was recalculated from the original rasters containing the actual yield using the Zonal Statistics function of the ArcGIS software package. This approach makes it possible to level fluctuations in yield values that are not typical for the contour as a whole, for example, an increase in yield values near wells, or, conversely, their decrease in certain areas devoid of vegetation due to human activity.

Table 2. The legend to the Rangeland map of the Kaskakulan cluster area

No.	Rangeland types	Total yield, c/ha			
		spring	summer	autumn	winter
DESERT RANGELANDS					
Dwarf semi-shrub rangelands on brown, gray-brown desert soils, and desert solonetzes					
1	Sagebrush (*Artemisia terrae-albae, Stipa sareptana, Peganum harmala*)	3.1	3.3	2.9	1.5
2	Anabasis (*Anabasis salsa, Climacoptera brachiata, Tulipa biflora*)	2.0	3.7	3.2	2.7
3	Complex of sagebrush-anabasis (*Artemisia terrae-albae, Anabasis salsa, Climacoptera brachiata*)	2.5	3.3	3.0	1.8
Haloxylon rangelands on takyr-like soils					
4	Haloxylon, annual saltwort-haloxylon, anabasis-haloxylon with halostachys and kalidium (*Haloxylon ammodendron, Suaeda microphylla, Climacoptera lanata, C. brachiata, Salsola foliosa, Anabasis aphylla, Halostachys belangeriana, Kalidium capsicum*)	1.1	3.8	3.1	1.9
Haloxylon pastures on the sands of desert plains and saline seaside					
5	Ephemeral-haloxylon, annual saltwort-haloxylon (*Haloxylon ammodendron, Eremopyrum orientale, E. triticeum, Lepidium perfoliatum, Suaeda acuminata, Atriplex ornata*)	2.8	7.1	5.7	3.6
Saltwort rangelands on takyr-like soils and takyr-like soils with wind-blown sandy cover, coastal solonchaks					
6	Halocnemum (*Halocnemum strobilaceum, Girgensohnia oppositiflora, Climacoptera aralensis, C. lanata*)	5.4	18.0	16.2	10.8
7	Halostachys-halocnemum, halocnemum-halostachys with kalidium and annual saltworts (*Halocnemum strobilaceum, Halostachys belangeriana, Kalidium capsicum, Climacoptera aralensis, C. ferganica*)	1.9	4.7	3.7	3.3
8	Kalidium-halostachys (*Kalidium capsicum, Halostachys belangeriana, Climacoptera aralensis*)	1.0	2.4	1.9	1.7
9	Kalidium-halostachys and halocnemum with haloxylon and ephemers (*Kalidium capsicum, Halostachys belangeriana, Haloxylon ammodendron, Salsola nitraria, Eremopyrum orientale, Strigosella circinata*)	1.0	2.6	2.2	1.7
10	Annual saltworts (*Suaeda acuminata, Bassia hyssopifolia, Atriplex pratovii, Clemacoptera aralensis*)	4.1	8.2	7.4	5.7
11	Sparse aggregations of annual saltworts (*Suaeda acuminata, Atriplex pratovii*)	<1	<1	<1	<1
Halophytic shrub rangelands on saline coastal sands					
12	Nitrebush and tamarisk with ephemers (*Nitraria schoberi, Tamarix laxa, Eremopyrum orientale, E. triticeum, Hyalea pulchella, Anisantha tectorum*)	1.9	4.8	3.8	2.4
Halophytic shrub rangelands on meadow solonchaks and meadow-marsh drying soils					
13	Nitrebush, tamarisk, kalidium with annual saltworts (*Nitraria schoberi, Tamarix hispida, T. laxa, Halostachys belangeriana, Suaeda acuminata, Climacoptera aralensis, C. brachiata*)	1.4	3.2	2.5	1.7
Psammophytic shrub rangelands on the sands of desert plains and coasts					
14	Psammophyte shrubs with haloxylon and tamarisk (*Astragalus brachypus, Calligonum* spp., *Convolvulus subsericeus, Eremosparton aphyllum, Haloxylon ammodendron, Tamarix hispida*)	1.9	2.8	2.3	1.4
MEADOW RANGELANDS					
Grass rangelands on meadow-marsh saline soils and meadow solonchaks					
15	Reed, halophytic forbs with tamarisk (*Phragmites australis, Karelinia caspia, Alhagi pseudalhagi, Artemisia scopiformis, Tamarix elongata, Saussurea salsa*)	12.4	25.1	14.0	12.2

Rangeland map. The development of a map of the forage lands of the Kaskakulan cluster area (Fig. 3) included the following stages: systematization of geobotanical descriptions, expert interpretation of a satellite image, drawing up a contour map, and development of a map legend. The available cartographic materials were analyzed: Map of forage lands of Kazakhstan M 1 : 2000000 (1978), Map of vegetation of Kazakhstan and Central Asia (within the desert zone) M 1 : 2500000 (1995), Map of soils (Erokhina, 2016), Map of vegetation M 1: 350000 (Rachkovskaya, Egemberdieva, 2016), Map of vegetation of the Kyzylorda region M 1 : 1500000 (Dimeyeva, 2019). The structure of the legend to the map (Table 2) is based on the principles of the Map of the forage lands of Kazakhstan (1978), in which for each section of the map the yield for the seasons (spring, summer, autumn, winter) is shown. Seasonal productivity was calculated on the basis of coefficients (*Instruktsiya*..., 1996), published data (Dimeyeva, 1990, 1994), and satellite data calculations (Fig. 2). The total yield, which is the sum of the phytomass of the community species, is given for each mapping unit. The legend for the rangeland map is a system of headings; it consists of 15 numbers. Each legend number corresponds to a rangeland type. The largest sections of the legend correspond to zonal (Desert rangelands) or intrazonal (Meadow rangelands) conditions for the formation of fodder lands. Headings of the second level correspond to ecological and physiognomic types of vegetation corresponding to certain soil conditions.

CONCLUSIONS

The research in the Barsakelmes reserve resulted in the Rangeland map of the Kaskakulan cluster site, which is a habitat for wild ungulates: kulans, saigas, and goitered gazelles. Field studies assessing rangeland productivity and remote sensing data were used to develop the map. Maps of the seasonal yield of rangelands, which became the basis for calculating the gross yield of each type of forage land, were developed based on the interpretation of satellite images.

Forage resource assessment is essential for successful pasture management to balance the number of animals grazing with the pasture's ability to sustainably provide forage. The optimal load of livestock on pastures, which is defined as the pasture area required for grazing one animal per month or for the entire pasture period, is one of the important characteristics of pastures, in addition to their productivity (Baisholanov et al., 2020). In addition, it is important to assess the topographic characteristics of the territory, the distance to water sources, food preferences, and daily feed intake of each animal species for pasture management. The future research may include an assessment of the grazing capacity and stocking rates of the territory of the reserve, which will allow calculating the allowable number of wild ungulates to maintain ecosystems in a balanced state.

FUNDING

The research was financially supported by the Succow Foundation/Greifswald, Germany through the Association for the Conservation of Biodiversity of Kazakhstan and the International Fund for Saving the Aral Sea in the Republic of Kazakhstan.

COMPLIANCE WITH ETHICAL STANDARDS

Conflict of interests. The authors declare that they have no conflict of interest.

Statement on the welfare of animals. All applicable international, national, and/or institutional guidelines for the care and use of animals were followed.

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Translated by M. Shulskaya