ISSN 2079-0961, Arid Ecosystems, 2023, Vol. 13, No. 4, pp. 507–517. © Pleiades Publishing, Ltd., 2023.
Russian Text © The Author(s), 2023, published in Aridnye Ekosistemy, 2023, Vol. 29, No. 4(97), pp. 154–165.

INDUSTRY PROBLEMS
OF DRY LANDS DEVELOPMENT

The Ecological–Phytocenotic Characteristics of *Halocnemum strobilaceum* (Pall.) Bieb. Grasslands on the Ustyurt Plateau in Karakalpakstan

Kh. F. Shomurodov[a], *, N. K. Rakhimova[a], U. Sh. Saitjanova[a], and Zhao Zhenyong[b]

[a] *Institute of Botany, Academy of Sciences of the Republic of Uzbekistan, Tashkent, 100125 Uzbekistan*
[b] *Xinjiang Institute of Ecology and Geography, Chinese Academy of Sciences, 818 South Beijing Road, Urumqi, Xinjiang, 830011 China*
**e-mail: spring_girl93@mail.ru*

Received January 24, 2023; revised June 30, 2023; accepted July 1, 2023

Abstract—The ecological–phytocenotic characteristic of the *Halocnemum strobilaceum* (Pall.) Bieb. grasslands is given on the basis of observation data obtained by the authors in 2020–2021 on the Ustyurt Plateau in Karakalpakstan (Uzbekistan). The biotopes, the total projective cover, the species composition, the yield of pasture varieties, and the change in the eaten phytomass during the growing season are characterized, and the seasonality of pasture use is recommended. The *Halocnemum strobilaceum* type of grassland is located in the Barsakel'mes, Sarykamysh, and Churuk regions of the Karakalpakstan Ustyurt and occupies 76492 ha. This type of pasture consists of three varieties: *Halocnemum strobilaceum*, *Halocnemum strobilaceum–Kalidium capsicum,* and *Halocnemum strobilaceum–Haloxylon ammodendron* as wet and puff solonchaks with highly mineralized groundwater very close to the surface, as well as to loamy and sandy loamy solonchakous soils. The plant cover is thin and predominated by shrubs and semi-shrubs, its species composition is poor, and the communities are monodominant and are assigned to the *Halocnemum* pasture variety. This is explained by the high salt content in the soil, which can be tolerated by a limited number of species. The seasonal yield of the forage mass ranges from 90 to 430 kg/ha. The eaten mass becomes reaches its maximum on all pasture varieties at the end of the growing season, thus, it is recommended to use pastures in the autumn–winter period.

Keywords: the Ustyurt Plateau, pastures, pasture varieties, salinization, plant communities, species composition, seasonal productivity, eaten phytomass, pasture load

DOI: 10.1134/S2079096123040145

INTRODUCTION

Vegetation of desert pastures is the main food for sheep and camels; it provides year-round free-range animal husbandry. The improvement of the fodder base of desert–pasture animal husbandry is one of the most difficult and urgent problems today. When solving some of them related to the use and improvement of pastures, livestock workers still face insufficient data on natural desert pastures and on their typical vegetation (Gaevskaya et al., 1958).

Pastures of Central Asia have been studied by many researchers: L.S. Gaevskaya et al. (1958), N.T. Nechaeva and S.Ya. Prikhod'ko (1966), H. Zaripov et al. (1972), O.Kh. Khasanov et al. (2000), N.A. Bobokulov et al. (2014), Z.Sh. Shamsutdinov and E.Z. Shamsutdinova (2015), Kh.F. Shomurodov (2018), V. Adilov et al. (2021), and N.K. Rakhimova and T. Rakhimova (2022), Sharipova V.K. et al. (2022), N.K. Rakhimova et al. (2023).

The natural pastures of Central Asia occupy 200 million hectares. They represent the main fodder base for the development of animal husbandry on a very large scale. The plant cover is thin; however, deserts provide fodder for livestock throughout the year (Shamsutdinov, 2015).

In recent years, the mean productivity of desert pastures of the Republic of Karakalpakstan has decreased by 21%, because about 40% of them have been degraded at various rates. This is related to unstable grazing in large areas (Bobokulov et al., 2014). The elaboration of the correct technology for the restoration and an increase in the forage productivity of degraded pastures is the main task of the use of pasture–forage resources of deserts.

The Ustyurt is an elevated plateau in the north of the Aral–Caspian watershed. It is bordered from almost all sides by steep cliffs towards the sea (chinks). The Ustyurt chink in the east is formed by the former western shore of the Aral Sea. It sharply drops to the

Kunya-Darya ancient alluvial plain and the Uzboi River Valley in the south, to the Karynyaryk Depression and to the sands of the North Caspian Karakum in the west, and to the Caspian Sea Lowland in the northwest (Bykova et al., 2017).

The position of the Ustyurt in the central part of the Eurasian continent determines two main features of its climate: sharp continentality and aridity (Zaripov et al., 1972). This area is characterized by a rather severe winter, strong winds, low precipitation, and unstable snow cover. The soil freezes to a depth of 5–15 cm in winter. The growing season lasts 200–210 days on average (Rachkovskaya, 2003; Shomurodov et al., 2015).

Gray-brown, takyr, and desert sandy soils, as well as desert solonetzes, solonchaks, and gypsozems are represented on the Ustyurt. Salinity and low humus content are typical for these soils (Kleimenova, 2010).

The floristic composition of vegetation on the Ustyurt includes up to 326 species of wild higher plants assigned to 192 genera and 42 families (Aimuratov et al., 2017). The plant cover is dominated by semishrubs and shrubs. There are no other tree species besides saxaul (Viktorov, 1971). Formations of wormwood (*Artemisia terrae-albae* Krasch.) on relatively more leached and desalinated varieties of gray–brown soils, of *Anabasis salsa* (Ledeb.) Benth. ex Volkens on solonetzic and solonchakous varieties of the same soils, of *Salsola arbuscula* Pall. on transitional soils between the two above-mentioned groups, of *Haloxylon aphyllum* on gypsum soils, and of *Halocnemum strobilaceum* (Pall.) Bieb on solonchaks are the most widespread.

The plant cover of the Ustyurt usually seems simple and monotonous, but closer examination shows that it is complicated due to the small areas and diversity of the spatial pattern of plant communities. The close location of different associations in small areas is a distinctive feature of the plant cover of the Ustyurt. Its complexity is determined by the relief and is typical for areas with a more dissected surface (Korovin, 1949).

Halophilous vegetation is widespread due to the domination of saline soils. Vast areas of solonchaks are allocated to depressions in the topography. The Barsakel'mes Depression in the largest on the Ustyurt and is a huge solonchakous plain mainly covered by *Halocnemum*. Small mounds of silt and salt particles are often accumulated near each bush, creating a specific terrain type: the hummocky *Halocnemum* community (Viktorov, 1971).

Halocnemum strobilaceum, the dominant of plant communities of the studied pastures, is a low semishrub with fleshy articulate leafless shoots. It is widespread on solonchaks with sodium–chloride salinization. This is a salt-accumulating hyperhalophyte that is able to concentrate up to 38% of mineral substances, including 25% of the chlorine (Vasina et al., 1972). *Halocnemum* is a reliable indicator of saline soils, and is an obligate halophyte, whose development optimum with respect to soil salinity is higher than 0.6–1.0% (Turovtsev and Krasnov, 2004). The plant contains up to 23% of Glauber salt, which is toxic for plant pests. Dwarf and depressed *Halocnemum* may be an indicator of gas and oil deposits (Kaplin, 2001).

The *Halocnemum* type of pasture is often detected on wet and puff solonchaks with strongly mineralized groundwater very close to the surface, on loamy and sandy loam solonchakous soils around sors, in depressions with hummocks, on puff solonchaks and pseudo-sands, and on solonetzic-solonchakous soils and takyrs. Salinization of the soil profile of biotopes in conditions of close mineralized groundwater under the effect of evaporation is at its maximum, and mainly single-species and monodominant plant communities are formed here. When groundwater is deeper, other species penetrate into *Halocnemum* communities, their phytocenotic role increases, and communities become polydominant with great species richness.

There are different opinions on the digestibility of *Halocnemum*. Some scientists believe that the fresh plant is not eaten by animals, others consider that it is not eaten in spring and summer and is satisfactorily eaten in autumn and winter only by camels and is slightly eaten by small cattle. For camels, *Halocnemum* is a fattening feed (Agababyan et al., 1934; Larin et al., 1951).

The Ustyurt Plateau in the Karakalpakstan could become an economically very promising area. A large number of livestock could be kept there in spring, summer, and autumn. Unfortunately, pastures of the Ustyurt of Karakalpakstan are not adequately used due to the lack of water supply. Winds, snow, and the lack of usable forage prevent animals from occupying the Ustyurt in winter.

One of the urgent problems related to a sharp change in climatic conditions towards warming, to soil degradation, and to the development of industrial facilities that violate the soil–plant cover is the involvement of desert little-used grasslands in economic use. The *Halocnemum* type of pastures is assigned to such ones. For this purpose, target research is performed in order to obtain the ecological–phytocenotic, and economic characteristics of the plant communities of these pastures.

OBJECTS AND METHODS

The objects of this study are three pasture varieties assigned to the type of *Halocnemum* pastures of the Ustyurt of Karakalpakstan: of *Halocnemum strobilaceum* formed on wet solonchaks in combination with sors without vegetation; of *Halocnemum strobilaceum–Kalidium caspicum* on wet and puff solonchaks; and of *Halocnemum strobilaceum–Haloxylon ammodendron* on solonchaks with phytogenic mounds

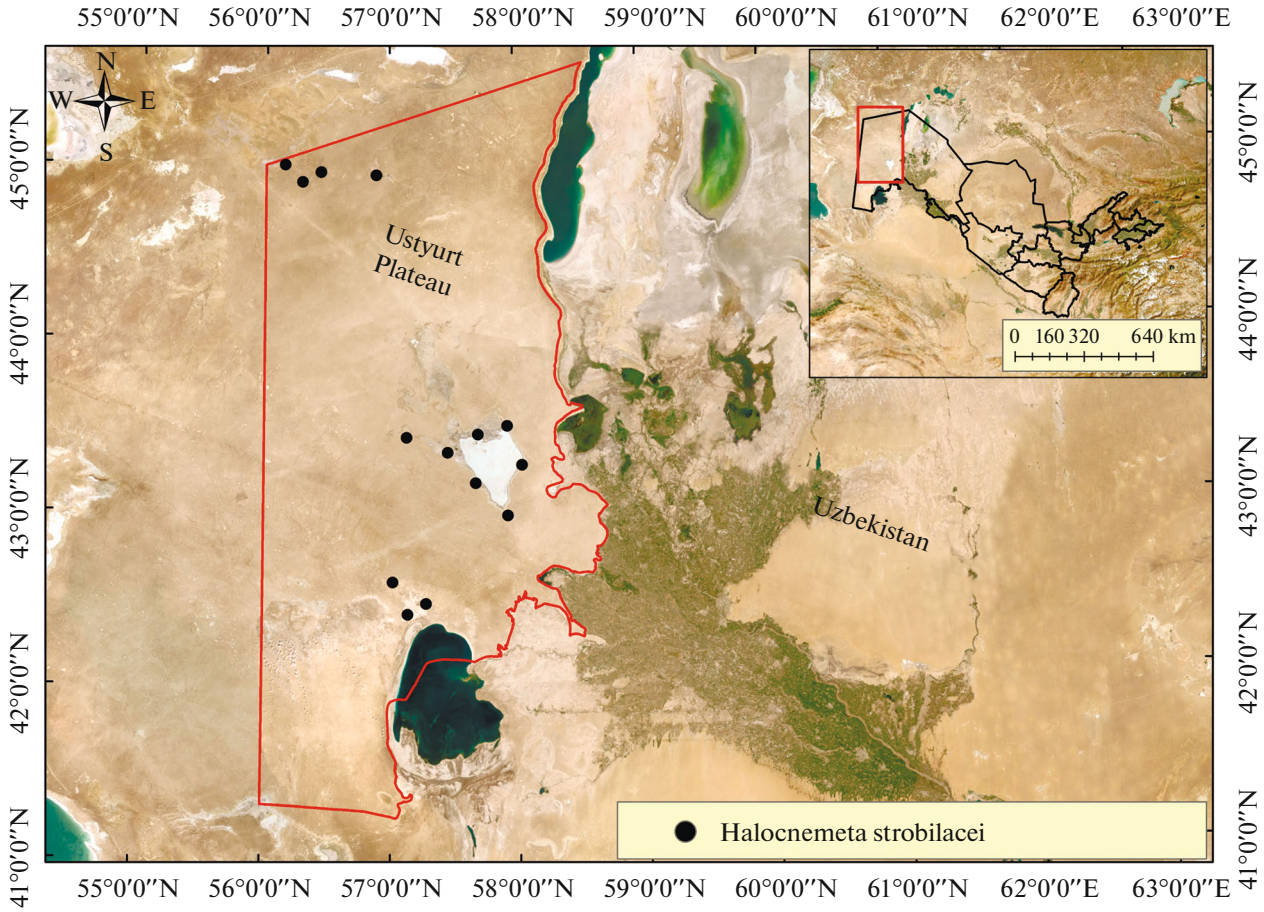


Fig. 1. The location of *Halocnemum* pastures on the Ustyurt Plateau.

formed by gypsum pseudo-sands, with the participation of *Reaumuria songarica* (Pall.) Maxim and *Kalidium caspicum* (L.) Ung.-Sternb. on puff solonchaks and in combination with *Anabasis salsa* on fans of temporary watercourses.

Salt-tolerant species mainly participate in the formation of vegetation of pasture varieties. These are woody *Haloxylon ammodendron* (C.A. Mey.) Bunge ex Fenzl.; shrubs *Tamarix hispida* Willd., *Atraphaxis spinosa* L., *Lycium ruthenicum* Murray, *Nitraria schoberi* L., *Halostachys belangeriana* (Moq.) Botsch., and *Reaumuria songarica;* semi-shrub *Halocnemum strobilaceum;* dwarf shrub *Kalidium capsicum;* and dwarf semi-shrubs *Anabasis salsa* and *Artemisia terrae-albae*. This type of pastures is poor in herbs. Perennials include *Zosima orientalis* Hoffm. and *Cistanche salsa* (C.A. Mey.) Beck., and annuals are represented by *Ceratocarpus arenarius* L.

The *Halocnemum* type of pastures occupies a relatively small area in the Karakalpak part of the Ustyurt (76492 ha). Its main massifs are located in the center and north of the Karakalpak Ustyurt in the Barsakel'mes, Sarykamysh, and Churuk regions (Fig. 1). The materials for this article were obtained during an expedition in 2020–2021 during the survey of ecological–cenotic and forage features of *Halocnemum* communities located in these areas.

The Vegetation Map of the Karakalpak Ustyurt (Adilov et al., 2020) was used during the preparation for terrain works to clarify the locations of plant communities of the *Halocnemum strobilaceum* formation. After the terrain works, the data were processed on the basis of this map and schematic maps of the distribution of varieties of *Halocnemum* pastures on the Ustyurt Plateau were compiled and their areas were quantified.

Pasture vegetation was studied during terrain works by conventional methods (*Polevaya geobotanika,* 1964). Geobotanical descriptions of plant communities, determination of names, and evaluation of yield of pasture varieties were performed according to the handbook (*Metodicheskie ukazaniya...*, 1980). The total projective cover of plant communities was determined by visual estimation (Ramenskii, 1971). Latin names of plant species were given by the Plants of the World Online database (2023).

Table 1. The species composition of plant communities on the surveyed pasture varieties

No.	Community characteristics	*Halocnemum strobilaceum*	*Halocnemum strobilaceum–Kalidium caspicum*	*Halocnemum strobilaceum–Haloxylon ammodendron*
	Total projective cover, %	20	15	17
	Species number	4	9	11
	Trees			
1	*Haloxylon ammodendron* (C.A. Mey.) Bunge ex Fenzl	–*	+	+
	Shrubs			
2	*Atraphaxis spinosa* L.	–	–	+
3	*Halostachys belangeriana* (Moq.) Botsch.	–	+	–
4	*Lycium ruthenicum* Murray	–	+	–
5	*Reaumuria songarica* (Pall.) Maxim.	–	+	–
6	*Salsola arbuscula* Pall.	–	–	+
7	*Tamarix hispida* Willd.	+	–	–
	Semi-shrubs			
8	*Halocnemum strobilaceum* (Pall.) M.Bieb.	+	+	+
9	*Kraschenninnikovia ceratoides* (L.) Gueldenst.	–	–	+
	Dwarf shrubs			
10	*Kalidium caspicum* (L.) Ung.-Sternb.	+	+	+
	Dwarf semi-shrubs			
11	*Anabasis salsa* (Ledeb.) Benth. ex Volkens	–	1	–
12	*Artemisia terrae-albae* Krasch.	–	–	+
13	*Limonium suffruticosum* (L.) Kuntze	+	+	–
14	*Salsola gemmascens* Pall.	–	–	+
15	*Salsola orientalis* S.G. Gmel.	–	+	–
	Perennials			
16	*Cistanche salsa* (C.A. Mey.) Beck	–	–	+
17	*Zosima orientalis* Hoffm.	–	–	+
	Annuals			
18	*Ceratocarpus arenarius* L.	–	–	+

* Minus, the species is absent and plus, the species is present.

RESULTS AND DISCUSSION

Data on the species composition, forage characteristics, and dynamics of the plant phytomass consumed during the growing season were obtained during terrain work in 2020–2021 and arranged in tables, which enabled the comparison of pasture varieties by these characteristics.

The total list of species found in plant communities of pasture varieties (Table 1) shows that their species richness is low, 18 species. The number of species is highest in *Halocnemum–Haloxylon* communities and is the lowest in monodominant *Halocnemum* communities. The total projective cover is the largest in *Halocnemum* communities and is the lowest in *Halocnemum–Haloxylon* communities. Only two of 18 species are common for all communities: *Halocnemum strobilaceum* and *Kalidium caspicum*. There are three common species for the pairs of communities: *Halocnemum and Halocnemum–Kalidium, as well as Haloc-*

Table 2. The characteristics of the forage properties of the studied pasture varieties

No.	Forage characteristics of pasture varieties	*Halocnemum strobilaceum*	*Halocnemum strobilaceum–Kalidium caspicum*	*Halocnemum strobilaceum–Haloxylon ammodendron*
1	Eaten part of forage mass, kg/ha	90–360	190–420	190–430
2	Content of forage units	85	180	182
3	Pasture load, ha/year:			
	— for one camel	11	8	8
	— for one sheep	2	1.5	1.5
4	The area of the pasture variety on the Ustyurt, ha	31495	36075	8922
4	Cost of 1 ha of pasture, thousand soms	545.0	1155.0	1168.0

Table 3. The seasonal productivity of forage mass on varieties of *Halocnemum* pastures

Pasture variety	Seasonal productivity, kg/ha			
	spring	summer	autumn	winter
Halocnemum strobilaceum in combination with sors without vegetation	90	90	270	360
Halocnemum strobilaceum–Kalidium caspicum with participation of *Haloxylon ammodendron*, *Reaumuria songarica*, and *Kalidium caspicum*	190	190	410	420
Halocnemum strobilaceum–Haloxylon ammodendron with participation of *Kalidium caspicum*	190	190	420	430

nemum–Kalidium and Halocnemum–Haloxylon. More ecologically distant *Halocnemum* and *Halocnemum–Haloxylon* communities have only two common species. The studied communities may be arranged in a sequence by a gradient of a decrease in soil salinity and moisture: *Halocnemum* → *Halocnemum–Kalidium* → *Halocnemum–Haloxylon*.

The analysis of the characteristics of forage properties of plant communities of pasture varieties of the *Halocnemum* type (Table 2) shows that *Halocnemum* communities form the lowest eaten mass in the ecological sequence and the mass of *Halocnemum–Kalidium* and *Halocnemum–Haloxylon*_communities is approximately the same. The forage value of these two pastures is also similar and is more than two times higher than that of *Halocnemum* pastures. Larger areas of *Halocnemum* pastures should be used to feed one cattle animal, as compared to the other two varieties. The cost of 1 ha of *Halocnemum* pastures is about two times lower than that of *Halocnemum–Kalidium*-and *Halocnemum-Haloxylon* varieties. The area of *Halocnemum–Haloxylon* pastures of higher quality on the Karakalpak Ustyurt is about four times lower compared to other two varieties.

The characteristic of changes in reserves of eaten phytomass during a year is important for determining the seasonality of pasture use. The obtained characteristics (Table 3) testify that the yield increases from spring to winter, which is a reason to recommend their use in the autumn–winter period and mainly for camels.

The compiled Tables 1–3 enable more systematic description of the ecological–phytocenotic and forage features of the three pasture varieties of the *Halocnemum* type located on the Karakalpak Ustyurt.

The ***Halocnemum strobilaceum*** pasture variety is spread on wet solonchaks in combination with sors without vegetation. On the Ustyurt Plateau, it occurs on solonchaks of Barsakel'mes and the Sarykamysh Depression (Fig. 2b). The total area of pastures of the *Halocnemum* variety on the plateau is 31495 ha.

The vegetation is represented by communities of the *Halocnemum* association. The projective cover of plant communities is 20%. There are only four species in their composition: *Halocnemum strobilaceum* (Pall.) M. Bieb., *Tamarix hispida* Willd., *Kalidium caspicum* (L.) Ung.-Sternb., and *Limonium suffruticosum* (L.) Kuntze. The last three species are spectators of this plant community and are single. Their role in the formation of the projective cover of the community is small.

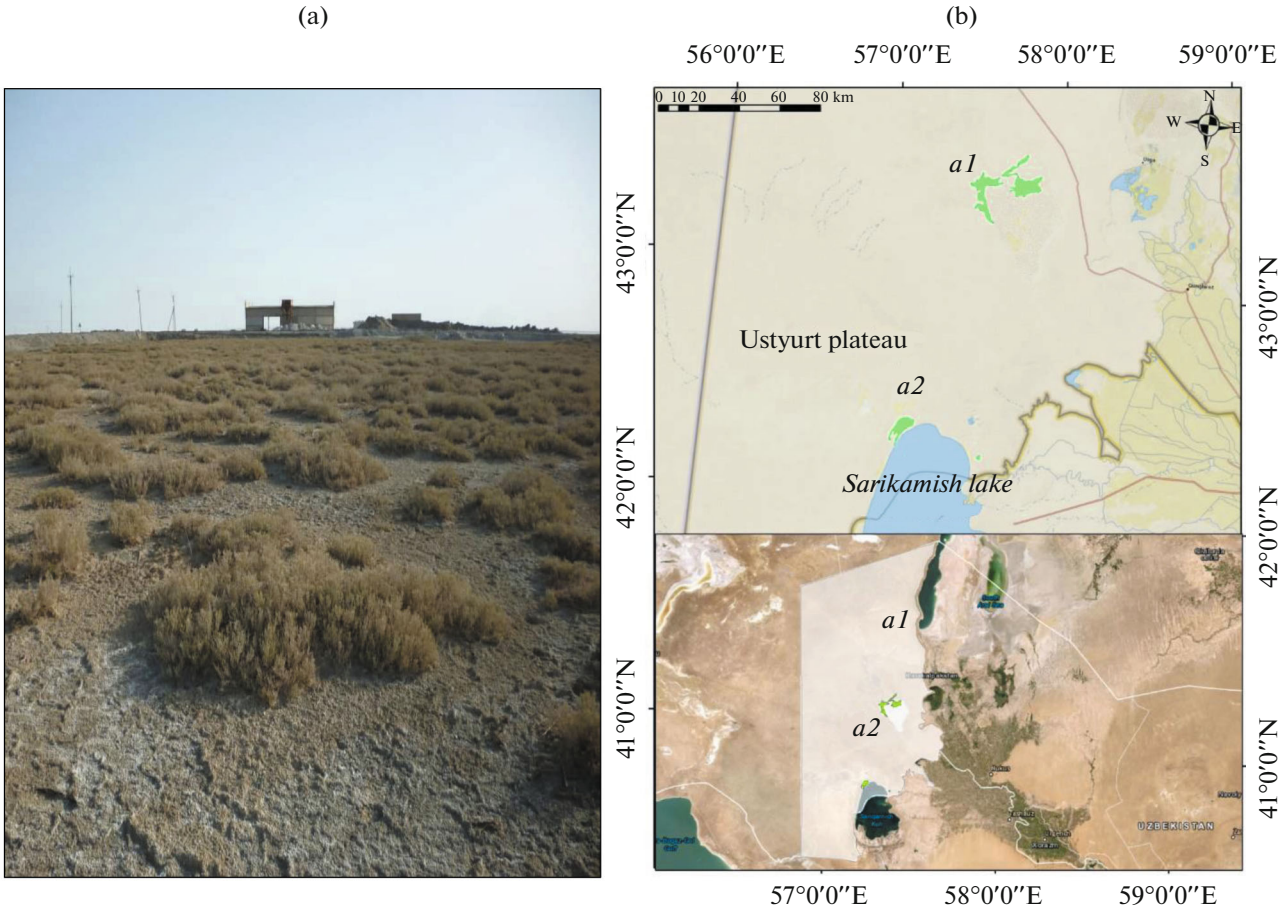


Fig. 2. A photograph of vegetation of the *Halocnemum* pasture variety (a) and its location (b: *a1*, *a2*) on the schematic map and satellite image.

Halocnemum in the center of sors (solonchaks) occurs singly and is depressed. With the distance from the sors, its thickets become denser. The basis of the structure of the communities is formed by *Halocnemum* communities with the participation of *Kalidium* shrubs. The distribution pattern of *Tamarix hispida* and *Limonium suffruticosum* in the community is sparse and mosaic (Fig. 2a).

According to the handbook of forage production of the Federal Scientific Center of All-Russian Williams Fodder Research Institute (2018), the yield of lowland halophytic pastures on solonchaks and saline takyr soils with insufficient surface and ground-surface moisture (*Halocnemum*, *Anabasis*, etc.) is 600–800 kg/ha.

According to the results of the expedition of 2021, the part of the eaten forage mass in *Halocnemum* communities is low: from 90 to 360 kg/ha (Table 2). The yield of this type of pasture in spring and summer is 90 kg/ha due to the small portion of formed eaten green mass of forage species (5%). It is at its maximum in autumn and winter due to the growth of annual shoots of *Halocnemum strobilaceum* by autumn. This species forms 15% of the eaten mass of the annual yield both in the autumn and in the winter periods.

According to calculations, the mean pasture load on this type of pasture for sheep and camels is very low. It takes 11 ha of pasture a year to graze one camel and 2 ha for a sheep. According to the regional quality scale (Nikolaev, 1977) and taking low values of the fodder unit into account (85), this pasture variety may be assigned to the group of the poorest pastures.

According to the economic assessment, the standard price of 1 ha of the *Halocnemum* pasture variety is 545000 soms (Uzbek national currency).

The ***Halocnemum strobilaceum–Kalidium caspicum*** pasture variety is allocated to wet and puff solonchaks. *Haloxylon ammodendron* appears on gypsum puff solonchaks, and *Reaumuria songarica* and *Kalidium caspicum* participate in the communities on fans of temporary watercourses. This pasture variety is located in the vicinity of solonchaks of Barsakel'mes and Shordzha (Fig. 3b). The area of the pasture variety is 36075 ha.

Halocnemum is an indicator of groundwater in desert: it evaporates in the zone of discharge of groundwa-

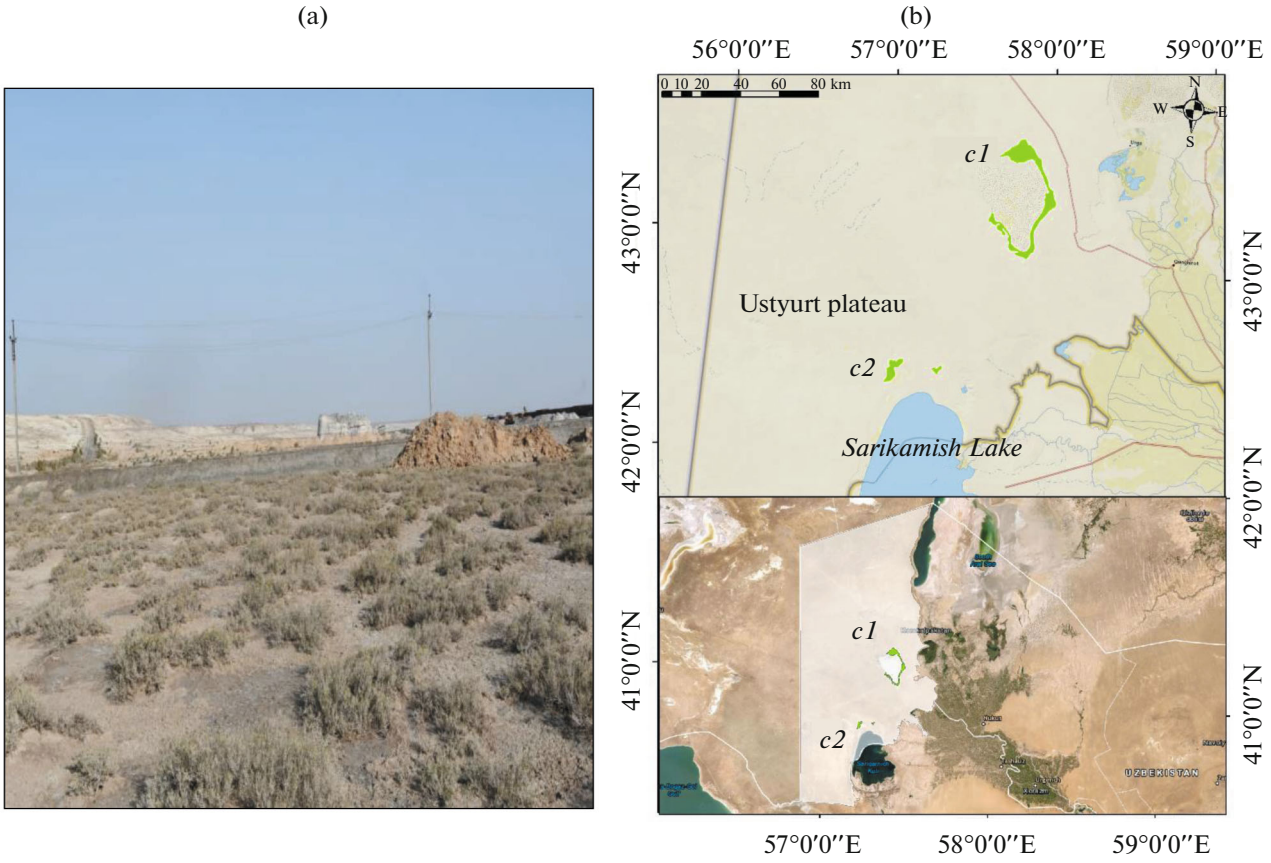


Fig. 3. A photograph of vegetation of the *Halocnemum–Kalidium* pasture variety (a) and its location on the Ustyurt Plateau on wet and puff solonchaks on the map and satellite image (b: *c1*, *c2*).

ter lenses, and salts are accumulated in soils. Such plots are covered by Halocnemum thickets. The total projective cover of plant communities of this pasture variety is 15%. The highest portion in the structure of plant communities is comprised by halophytes: 40% by *Halocnemum*, slightly lower (33%) by *Kalidium*, and 20% by *Haloxylon ammodendron*.

Plant communities of the *Halocnemum–Kalidium* pasture variety occur on saline soils with the groundwater level of 2 m and deeper. They are characterized by a two-layer vertical structure. *Kalidium* at the height of 70 cm forms the first layer. Its abundance is significantly lower compared to Halocnemum, which forms the second layer 35–40-cm high. In the third layer 10–15-cm high, annual saltwort sometimes occurs. Shrubs and dwarf shrubs (*Reaumuria songarica* and *Kalidium caspicum*) are only located on fans of temporary watercourses. There are 5–7 large *Haloxylon* bushes, 10–20 medium-size bushes of *Lycium ruthenicum* Murray, and 20–30 medium-size bushes of *Halostachys belangeriana* per 1 ha of the area.

According to our calculations, the eaten part of the forage mass of the Kalidium–Halocnemum pasture variety is low and ranges from 190 to 420 kg/ha (Table 2). The advantage of this pasture variety consists in the presence of three species: *Halocnemum strobilaceum, Kalidium capsicum*, and *Haloxylon ammodendron*. The eaten phytomass is the greatest in autumn and winter due to the maximal growth of annual shoots of these three species. In autumn, 63% of the yield is comprised by *Haloxylon ammodendron* and the portion of *Halocnemum strobilaceum* is lower: 20%.

In spring and summer, the two main plants *Halocnemum* and *Kalidium* are not eaten, so cattle may be grazed in these periods, using small branches of *Haloxylon ammodendron* and *Lycium ruthenicum*. To provide standard feed units per year, 8 ha of these pastures are needed for one camel and 1.5 ha are required for one sheep.

According to the quality scale, low forage value (180) enables us to assign this pasture variety to the group of the poorest pastures. The standard cost of 1 ha of the *Halocnemum–Kalidium* pasture variety is 1 155 000 soms.

The ***Halocnemum strobilaceum–Haloxylon ammodendron*** pasture variety consists of phytogenic mounds formed by gypsum saline pseudo-sand. It is located in the Saigachii Landscape Reserve in the vicinity of the Churuk Well (in the north of the Karakalpak Ustyurt, Fig. 4).

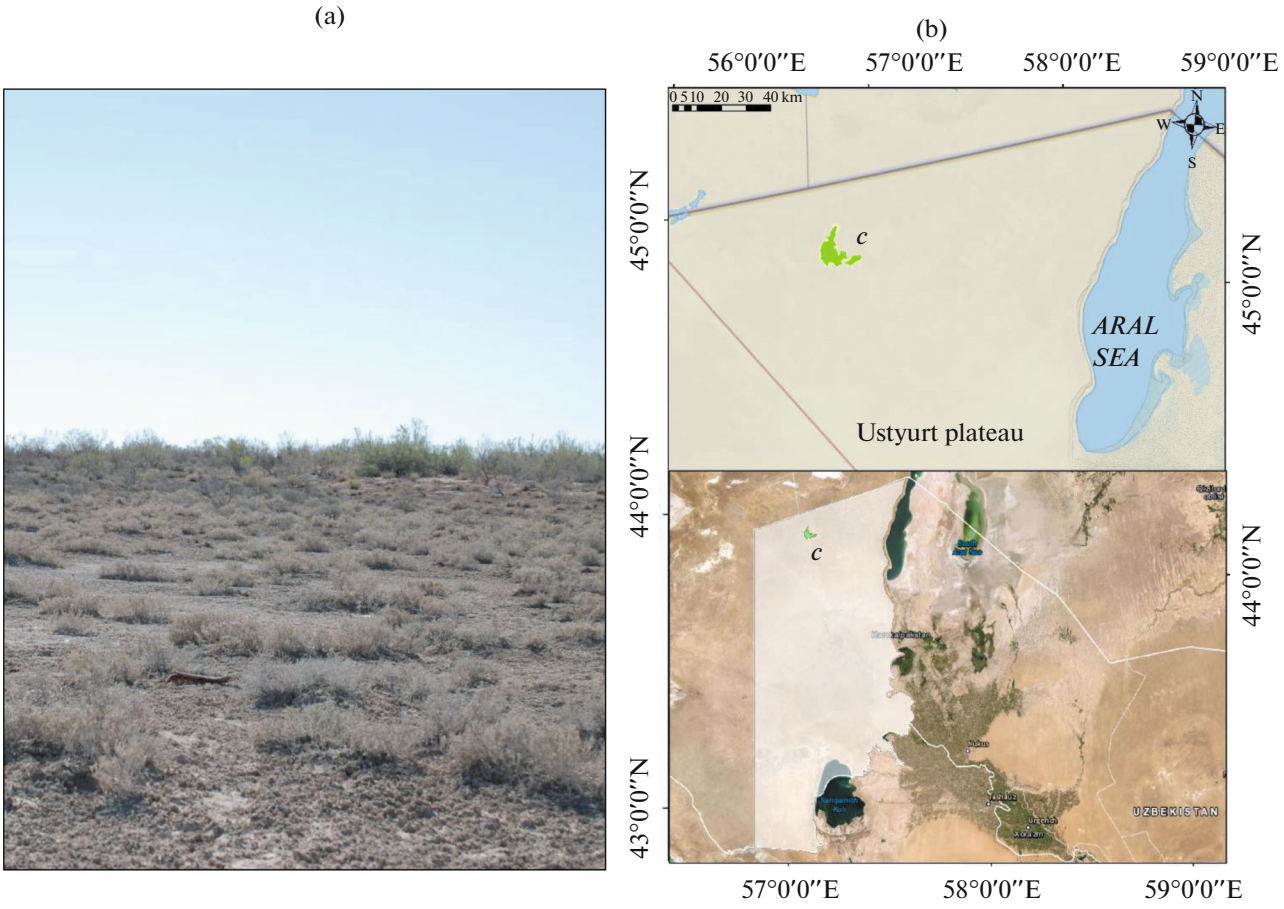


Fig. 4. A photograph of vegetation of the *Halocnemum–Haloxylon* pasture variety (a) and its location on the Ustyurt Plateau in the area of the Churuk well on map and satellite image (b: *c*).

The area of the pasture variety is small: 8922 ha. The projective cover is 17%. The *Halocnemum–Haloxylon* pasture variety consists of 11 species of vascular plants. Their participation in the projective cover is different: the main portion belongs to *Halocnemum strobilaceum* (10%), *Haloxylon ammodendron* (3%), *Kalidium capsicum* (2%), and *Atraphaxis spinosa* (2%). The share of other species does not exceed 1% (Table 1).

There is an opinion (Korovin, 1961) that the Central Asian deserts are one of the centers of formation of the halophilous vegetation type. It is characterized by monotonous and comparatively poor species composition. The species composition of *Halocnemum strobilaceum* communities on phytogenic mounds is richer, and the dominant is accompanied by the shrub *Atraphaxis spinosa*, semi-shrub *Kalidium caspicum*, and dwarf semi-shrubs *Artemisia terrae-albae* and *Salsola gemmascens*.

The basis of the community structure is composed of bushes of *Halocnemum*. There are two–five large *Haloxylon* bushes on gypsum pseudo-sands per 1 ha of the area. *Kalidium* accompanies *Halocnemum* in almost all associations. *Atraphaxis spinosa* is spread only in areas of soil subsidence and along watercourses. The portion of herbaceous species in the composition of this association is the largest in comparison with other communities (three species in contrast to one–two). The eaten part of the forage mass of the *Halocnemum–Haloxylon* pasture variety is low and ranges from 190 to 430 kg/ha (Table 2).

The yield of this type of pasture in spring and summer is 190 kg/ha (Table 3). It is at its maximum in autumn and winter due to the greatest growth of annual shoots of *Halocnemum strobilaceum*, *Haloxylon ammodendron*, *Kalidium capsicum*, and other shrubs.

Despite the fact that *Haloxylon* is sparse in the communities, it comprises 61% of the yield in autumn, and the share of *Halocnemum strobilaceum* is 32%. The participation of *Kalidium capsicum* is the lowest: the formation rate of its eaten mass is low in almost all seasons.

According to the results of the study, the mean pasture load for sheep and camels is very low. Grazing of one camel requires 8 ha per year, and 1.5 ha of pasture area is required for one sheep. Taking into account the low values of the forage unit (182), the pasture variety

may be assigned to the group of the poorest pastures. The standard price of 1 ha of *Halocnemum–Haloxylon* pasture is 1 168 000 soms.

CONCLUSIONS

There are three varieties of pastures of the Halocnemum type on the Karakalpak part of the Ustyurt: *Halocnemum strobilaceum*, *Halocnemum strobilaceum–Kalidium capsicum*, and *Halocnemum strobilaceum–Haloxylon ammodendron*. They occupy 76492 ha, and the area of more productive *Halocnemum–Haloxylon* pasture varieties is about four times smaller compared to pastures of the other two varieties.

According to the ecological conditions of biotopes, pasture varieties may be arranged in the sequence according to the gradient of salinization and soil moisture. The most severe conditions (wet solonchaks with the maximum concentration of salts in soil solutions) are typical for the *Halocnemum* variety. The *Halocnemum–Kalidium* pasture variety occurs on dry solonchaks with a lower salt concentration, and the *Halocnemum–Haloxylon* variety is formed in the most favorable conditions of the least saline solonchakous soils, on mounds, and takyrs. Various habitat conditions determine the difference between the main characteristics and the productivity of plant communities of pasture varieties.

The sparse plant cover and extremely poor species composition are typical for all pasture varieties. Communities of the *Halocnemum* pastures located in the most severe environmental conditions of wet solonchaks are monodominant. The species richness of plant communities is low, 18 species. The species number is the largest in *Halocnemum–Haloxylon* communities (11 species) and is the lowest in *Halocnemum* communities (four species).

The formed eaten mass is the lowest in *Halocnemum* communities (90–360 kg/ha) and is similar in *Halocnemum–Kalidium* and *Halocnemum–Haloxylon* communities (190–420 and 19–430 kg/ha, respectively). The forage values of the last two pastures are also similar, and their quality is more than two times higher than that of pastures of *Halocnemum* varieties. In order to feed one head of cattle, it is necessary to use larger areas of pastures of *Halocnemum* varieties than of the other two ones. The cost of 1 ha of *Halocnemum* pastures is about two times less compared to *Halocnemum–Kalidium* and *Halocnemum–Haloxylon* pastures. The yield of the eaten mass increases from spring to winter. This is the reason to recommend the use of the pastures in the autumn–winter period and mainly for camels. These pastures may also be additionally used in low-yield years.

The survey of the overgrowing of disturbed areas of solonchaks shows a sufficiently strong resistance of *Halocnemum* communities to the effect of anthropogenic factors and their ability for self-regulation and self-maintenance (Zenkina, 2012). This also confirms the possibility of the use of *Halocnemum* pastures.

Further study of various types, productivity, and seasonal use of pastures on the Ustyurt and identification of forage properties of particular plants is the basis for the rational development of the plateau.

Water supply remains an important problem in the arid conditions of the Ustyurt, largely determining the possibility of pasture use. The Sarakamysh Lake with a low water level is located in this area. Its role in providing livestock with water is small, because a huge level of harmful substances from agricultural plantations penetrates into it. In the last 10–15-year period, collector water from Tashauz and Khorezm oblasts enters the Sarykamysh basin through the old Dar'yalyk channels. The water level in the lake decreased due to the smaller volume of collector waters. There is only one operating well Davetkuduk at a distance of 8–9 km from the filled-up Churuk well, and there are the Karakudyk and Agyin salt wells not far from it. There are no data on the suitability of these wells for stock watering. It is necessary to dig new wells outside the salt depressions of the Barsakel'mes Lake for the rational use of pastures.

FUNDING

This work was performed within the framework of the State Program (PFI-5) Assessment of the Modern Status of the Plant Cover and Pasture Resources of the Republic of Karakalpakstan.

COMPLIANCE WITH ETHICAL STANDARDS

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

REFERENCES

Adilov, B.A., Shomurodov, Kh.F., Rakhimova, T., and Polvonov, F.I., *Karta rastitel'nosti Karakalpakskogo Ustyurta. Masshtab 1 : 200000* (Vegetation Map of Karakalpak Ustyurt. Scale 1 : 200000), Tashkent: Inst. Bot. Akad. Nauk Respubliki Uzbekistan, 2020.

Adilov, B., Shomurodov, H., Lianlian, F.A.N., Kaihui, L.I., Xuexi, M.A., in Yaoming, L.I., Transformation of vegetative cover on the Ustyurt Plateau of Central Asia as a consequence of the Aral Sea shrinkage, *Journal of Arid Land*, 2021, vol. 13, no. 1, pp. 71–87.

Agababyan, Sh.M., Granitov, I.I., and Kasimenko, M.A., *Kormovaya kharakteristika naibolee rasprostranennykh dikorastushchikh rastenii Uzbekskoi SSR* (Feeding

Characteristics of the Most Common Wild Plants of the Uzbek SSR), Tashkent: Gosizdat Uzbeksk. SSR, 1934.

Aimuratov, R.P. and Pirzhanova, R.K., Dynamics of the flora of Karakalpakstan, in *Dinamika I potentsial prirodnoi sredy Karakalpakstan* (Dynamics and Potential of the Natural Environment of Karakalpakstan), Nukus: Karakalpakstan, 2017, pp. 78–90.

Bobokulov, N.A., Mukimov, T.Kh., Rafiev, B.Kh., and Rasulov, A., *Pustynno-pastbishchnoe zhivotnovodstvo Uzbekistana i ratsional'noe ispol'zovanie kormovykh resursov* (Desert-Pasture Animal Husbandry in Uzbekistan and Rational Use of Forage Resources), Tashkent: IKARDA, 2014.

Bykova, E.A., Esipov, A.V.,Golovtsov, D.E., and Nuridzhanov, D.A., Fauna of terrestrial vertebrates of the eastern escarpment of Ustyurt Plateau, *Vestnik Tyumen'skogo Gosudarstvennogo Universiteta: Ekologiya i Prirodopol'zovanie*, 2017, vol. 3, no. 4, pp. 74–88.

Gaevskaya, L.S., Shamsutdinov, Z.Sh., and Shtefan, M.K., *Rasteniya karakulevodcheskikh pastbishch Srednei Azii* (Plants of Karakul Pastures of Central Asia), Samarkand: Uzbeksk. Akad. Sel'skokhoz. Nauk; Nauchno-Issled. Inst. Karakulevodstva, 1958.

Handbook on fodder production of the Federal Scientific Center "All-Russian Research Institute of Feeds. V.R. Williams". www.vniikormov.ru/spravochnik-po-kormoproizvodstvy/spravochnik-po-kormoproizvodstvy-92.php. Cited November 2, 2018.

Kaplin, V.G., *Bioindikatsiya sostoyaniya ekosistem: Uchebnoe posobie dlya studentov biologicheskikh spetsial'nostei universitetov i s/kh vuzov* (Bioindication of the State of Ecosystems: Textbook for Students of Biological Specialties of Universities and Agricultural Universities), Samara: Samarsk. Gos. Sel'skokhoz. Akad., 2001.

Khasanov, O.Kh., Rakhimova, T., and Shomurodov, Kh.F., On the classification of pastures, *Ekol. Vestn. Mosk. Gos. Univ.*, 2000, no. 1, pp. 43–44.

Kleimenova, I.E., The ecological-geographical division into districts of Karakalpak Ustyurt, *Vestn. Orenburgsk. Gos. Univ.*, 2010, no. 10 (116), pp. 106–111.

Korovin, E.P., *Ust'-Urt Karakalpakskii: ego priroda i khozyaistvo* (Ust-Urt Karakalpaksky: Its Nature and Economy), Tashkent: Akad. Nauk SSR, 1949.

Korovin, E.P., *Rastitel'nost' Srednei Azii i Yuzhnogo Kazakhstana. Kniga 1* (Vegetation of Central Asia and South Kazakhstan. Book 1), Tashkent: Akad. Nauk Uzbeksk. SSR, 1961.

Larin, I.V., Agababyan, Sh.M., Rabotnov, T.A., Larina, V.K., Kasimenko, M.A., and Lyubskaya, A.F., *Kormovye rasteniya senokosov i pastbishch SSSR* (Forage Plants of Hayfields and Pastures of the USSR), Moscow: Sel'khozgiz, 1950, vol. 1.

Larin, I.V., Agababyan, Sh.M., Rabotnov, T.A., Larina, V.K., Kasimenko, M.A., and Lyubskaya, A.F., *Kormovye rasteniya senokosov i pastbishch SSSR* (Forage Plants of Hayfields and Pastures of the USSR), Moscow: Sel'khozgiz, 1951, vol. 2.

Metodicheskie ukazaniya po geobotanicheskomu obsledovaniyu estestvennykh kormovykh ugodii Uzbekistana (Guidelines for Geobotanical Survey of Natural Fodder Lands in Uzbekistan), Tashkent: Uzgiprozem, 1980.

Nechaeva, N.T. and Prikhod'ko, S.Ya., *Iskusstvennye zimnie pastbishcha v predgornykh pustynyakh Srednei Azii* (Artificial Winter Pastures in the Foothill Deserts of Central Asia), Ashkhabad: Akad. Nauk Turkmensk. SSR, 1966, pp. 106–107.

Nikolaev, V.N., Amangel'diev, A.A., and Smetankina, V.A., *Pustynnye pastbishcha, ikh kormovaya otsenka i bonitirovka* (Desert Pastures, Their Fodder Evaluation and Appraisal), Moscow: Nauka, 1977.

Plants of the World Online, 2023. https://powo.science.kew.org/. Cited November 2, 2018.

Polevaya geobotanika (Field Geobotany), Lavrenko, E.M. and Korchagin, A.A., Eds., Moscow: Nauka, 1964, vol. 3.

Rachkovskaya, E.I., Volkova, E.A., and Khramtsova, V.N., *Botanicheskaya geografiya Kazakhstana i Srednei Azii (v predelakh pustynnoi oblasti)* (Botanical Geography of Kazakhstan and Central Asia (Within the Desert Region)), St. Petersburg: Boston-Spektr, 2003.

Rakhimova, N.K. and Rakhimova, T., The status of *Salsola arbusculiformis* and *Anabasis salsa* shrub grasslands on the Ustyurt Plateau in Karakalpakstan (Uzbekistan), *Arid Ecosyst.*, 2022, vol. 12, no. 3, pp. 286–295.

Rakhimova, N.K., Rakhimova T., Shomurodov Kh.F., Adilov B.A., Sharipova V.K., Saitjanova U.Sh., Khabibullaev B.Sh., Sadinov J.S., Polvonov F.I., Sultamuratov A.T. Assessment of the current state of rangelands in Karakalpak Ustyurt, Uzbekistan. Biodiversitas. 2023, vol. 24, no. 7, pp. 3835–3843.

Ramenskii, L.G., *Izbrannye raboty. Problemy i metody izucheniya rastitel'nogo pokrova* (Selected works. Problems and Methods of Studying the Vegetation Cover), Leningrad: Nauka, 1971.

Shamsutdinov, N.Z. and Shamsutdinova, E.Z., Natural fodder resources of the arid regions of Central Asia: prospects for their use in phytomelioration and breeding (In connection with the 65th anniversary of the publication of the three-volume monograph "Forage plants of hayfields and pastures of the USSR"), in *Nauchno-Prakticheskie puti povysheniya ekologicheskoi ustoichivosti i sotsial'no-ekonomicheskoe obespechenie sel'skokhozyaistvennogo proizvodstva. Materialy mezhdunarodnoi nauchno-prakticheskoi konferentsii, posvyashchennoi godu ekologii v Rossii* (Scientific and Practical Ways to Improve Environmental Sustainability and Social Economic Support of Agricultural Production. Proc. Int. Sci.-Pract. Conf. Dedicated to the Year of Ecology in Russia), Shcherbakova, N.A. and Seliverstova A.P., Solenoe Zaimishche: Prikaspiisk. Nauchno-Issled. Inst. Aridnogo Zemledeliya, 2017, pp. 302–310.

Shomurodov, Kh.F., Forage plants of Kyzylkum and prospects for their use, *Extended Abstract of Cand. Sci. (Biol.) Dissertation*, Tashkent, 2018.

Shomurodov, Kh., Saribaeva, Sh., and Akhmedov, A., Distribution pattern and modern status of rare plant species on the ustyurt plateau in Uzbekistan, *Arid Ecosyst.*, 2015, vol. 5, no. 4, pp. 261–267.

Sharipova V.K, Rakhimova T, Rakhimova N.K. Ecological state of some pasture differences of Haloxylon ammodendron of Karakalpak Ustyurt (Uzbekistan). 2022. E3S Web Conf 361: 04028. https://doi.org/10.1051/e3sconf/202236104028

Turovtsev, V.D. and Krasnov, V.S., *Bioindikatsiya: uchebnoe posobie* (Bioindication: Textbook), Tver: Tversk. Gos. Univ., 2004.

Vasina, A.N., *Ispol'zovanie rastenii dikikh vidov dlya bor'by s vreditelyami sadovykh i ovoshchnykh kul'tur* (Use of Wild Species of Plants for Pest Control of horticultural and Vegetable Crops), Moscow: Kolos, 1972.

Viktorov, S.V., *Pustynya Ustyurt i voprosy ee osvoeniya* (The Ustyurt Desert and the Issues of Its Development), Moscow: Nauka, 1971.

Zaripov, Kh., Tursunbaev, K., and Allaniyazov, A., *Rastitel'nost', pastbishch Yugo-Vostochnogo Ustyurta* (Vegetation of Pastures in South-Eastern Ustyut), Tashkent: Fan, 1972.

Zenkina, T.E. and Sagalaev, V.A., Regional and demographical structure of cenopopulations of *Halocnemum strobilaceum* (Pall.) Bieb. Chenopodiaceae) in the Republic of Kalmykia, *Vestn. Volgograd. Gos. Univ.*, 2012, vol. 11, no. 1, pp. 10–17.

Translated by I. Bel'chenko