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SYSTEMATIC STUDY OF ARID TERRITORIES

Dedicated to the blessed memory of Professor P.D. Gunin

Vegetation of the Sand Massifs of the Northern Gobi Desert

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Abstract—The plant communities of the sandy massifs of the Northern Gobi Desert on the territory of the Bulgan Omnogovi aimag are considered. The classification of vegetation by the Braun–Blanquet method, first carried out for vegetation of the flat part of the Bulgan soum, revealed six vegetation associations belonging to three unions of three orders of the class *Stipetea glareosae-gobicae* Hilbig 2000. The flora of sandy massifs includes 108 species from 73 genera and 28 families. The species structure of genera and families reflects the specifics of the flora of this desert–steppe region within the Bulgan soum. In the spectrum of life forms of plants in sandy communities, perennial and annual and biennial grasses predominate, although in terms of participation in the structure of plant communities, the dominant phytocenotic role belongs most of all to woody plants. Dominant types of vegetation of the sandy massifs (*Krascheninnikovia ceratoides*, *Caragana korshinskii*, *Haloxylon ammodendron*, *Psammochloa villosa*, *Nitraria sibirica*, *Brachanthemum gobicum*, etc.) are natural sand fixers. At the same time, these species are for the most part well-eaten food for livestock. Consequently, grazing in such habitats must be strictly regulated.

Keywords: Northern Gobi, sand massifs, desert steppes, steppe deserts, plant communities, psammophytes, Braun–Blanquet, blowing and blown sands, sand drift

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Sand massifs in Mongolia occupy about 43700 km^2, or 2.8% of the territory, and are found everywhere, covering all physical and geographical areas, including forest and forest–steppe zones, but are distributed extremely unevenly (Baasan, 2003; Vostokova et al., 2007). Sands are most widespread in the Great Lakes Basin and the Gobi part of the country (Murzaev, 1947; Selivanov, 1969). Half of the total area of sand accumulations in Mongolia falls on only 5–6 large massifs (Dash, 2015).

A significant amount of research has been devoted to the study of sand flora and vegetation. B.B. Polynov and I.M. Krasheninnikov (1926) conducted a study of the soils and vegetation of the Mongol Els sands (Erdenesant somom of the Central aimag). Works by E.G. Pobedimova (1933, 1935) are considered the first independent studies of the flora and vegetation of sandy sediments of Mongolia. She described in detail the vegetation and origin of the Ongon els and Moltsog els sands (Ongon and Naran soum of the Sukhebator aimag), and also noted the finely hummocky sands with vegetation of saltpeter and tamarisk at the mouths of the Khaliun and Sharga rivers of the Gobi–Altai aimag. A.A. Yunatov (1950, 1974) emphasized the prospects of using the vegetation of the sands of the Great Lakes Basin as pastures for livestock. E.M. Lavrenko (1978) established that the formation of saxaul communities occurs mainly on sand in steppe deserts. Zh. Gal (1970, 1973) conducted research on the classification of saxaul communities and also revealed the principle of the formation of sandy mounds under *Tamarix* sp. Kh. Buyan-Orshikh (1976, 1981) studied flora and vegetation and the food supply in the large sandy massifs of Borig del els (Dzungobi and Baruunturuun somons of the Ubsunur aimag), Bor Khyar els (Urgamal and Dzabkhanmandal somons of the Dzabkhan aimag) and Mongol els (somons of the Ubsunur aimag) Khukhmort and Bayan-Uul of the Gobi–Altai aimag). The ecology of saxaul, saltpeter, and other desert species on the sands was studied in Borzon Gobi (*Fitoekologicheskie...*, 1993). A rich floristic composition is noted in the

Enkhiin els massif (Lun somon of the Central aimag) and Mongol els (Rashaant somon of the Bulgan aimag) (Bayasgalan, 2007).

In the landscapes of the desert zone of Mongolia, sand deposits are most often presented in the form of dunes, mounds, blown sands, and sands blown by the wind into the depressions of mountain and inter-hill valleys, basins, and flat areas, as well as along belyam mountain ranges (Murzaev, 1947). P.D. Gunin (2022) classifies sand massifs as a special type of functionally specialized ecosystem that he identified, which, although they do not play a significant role in the production of organic matter in the desert zone, but, being in the system of paragenetic landscape complexes, do provide resources and energy to multifunctional ecosystems. The sandy massifs here are mainly fixed by plants adapted to grow in conditions of mobility of the substrate, its strong heating, and poor mineral nutrition. During the dry period, when vegetation withers, and during strong winds, sands are transported to nearby areas, occupying new spaces. A significant role in the destruction of sand vegetation belongs to the anthropogenic factor, namely, grazing loads and cutting down saxaul trees for winter fuel. The breaking up of sand is also facilitated by the woody branches of old dried out shrubs that are spread over a large area. In sandy flat areas, intensive livestock grazing destroys the vulnerable turf horizon. Broken loose sands as a result of wind-erosion processes occupy another larger area, which leads to desertification of the surrounding areas. In this regard, sand massifs in the desert zone are the source and cause of desertification of ecosystems. To prevent these processes, it is important to study the plants and vegetation of sands and their adaptation to extreme conditions. In this regard, the purpose of this study is to study the vegetation of the sandy massifs of the Northern Gobi, identifying their syntaxonomic, taxonomic, and ecological–coenotic diversity.

MATERIALS AND METHODS

The study of the vegetation of sandy massifs was carried out in the years 2008–2017 on the territory of the desert–steppe station of the Joint Russian–Mongolian Complex Biological Expedition of the Russian Academy of Sciences (JRMCBE) in the Bulgan soum of the Omnogovi aimag. The territory of the somon is distinguished by maximum wind speeds in the Omnogovi aimag, reaching 40 m/s or more. The number of days with a wind speed of 10 m/s, according to long-term data, was 110–120. During the years of research (2008–2017), the number of days with high wind speeds of 18–27 m/s increased to 360 days/year (Enkh-Amgalan, 2008).

The Bulgan soum ranks third in terms of area occupied by sand among the soums of the Omnogovi aimag: 60% of its territory is susceptible to desertification (Haulenbeck, 2019). The soil cover of such sands is dominated by brown desert–steppe and brown steppe–desert soils (Dorzhgotov, 2003).

According to botanical and geographical zoning, the study area belongs to the Ulan-Nur district of the Central North Gobi (Prialashan) subprovince of the North Gobi province of the Central Asian subregion of the Sahara–Gobi region (Rachkovskaya, 1993). In Bulgan soum, vegetation is characterized by vertical changes due to an increase in the height of the territory from north to south. Thus, in the northern part of the somom, there are more euxerophytic variants of steppe deserts, which are replaced by desert and desert and mountain dry steppes to the south. Significant areas in the composition of the vegetation of steppe deserts are occupied by psammophyte communities with dominance *Brachanthemum gobicum*, *Zygophyllum xanthoxylum*, and *Haloxylon ammodendron* in areas with aeolian sediments of varying thickness. These communities occupy over 20% of the territory of steppe deserts (Kazantseva, 2009).

Complete geobotanical descriptions were carried out in plant communities of sandy massifs at 100 m^2 with 8- to 10-fold repetition depending on the area occupied by the community. Plant abundance was determined according to the following scale: **r**, the view is single with insignificant coverage; **+**, less than 1%; **1**, 1–4%; **2**, 5–25%; **3**, 26–50%; **4**, 51–75%; **5**, 76–100%. The classification of communities was carried out using the Braun–Blanquet method, which had not previously been carried out for the vegetation of the flat part of the Bulgan soum. The names of vegetation syntaxa are given according to the works of K. Wesche et al. (2005) and H. von Wehrden et al. (2006, 2009). The nomenclature of plant species is given on the website of the Global Biodiversity Information Facility (2024). In addition, the bare sandy surface and its rubble between the bases of plants were assessed as a percentage of the total survey area.

RESULTS AND DISCUSSION

Syntaxonomic diversity of vegetation of the sandy massifs of the Northern Gobi. As a result of this study, we identified six associations related to different unions and class orders of *Stipetea glareosae–gobicae* Hilbig 2000:

Class *Stipetea glareosae–gobicae* Hilbig 2000

Order *Allietalia polyrrhizi* Hilbig 2000

Union *Allion polyrrhizi* Hilbig 2000

Association *Allio polyrrhizi–Stipetum glareosae* Hilbig (1987) 1990

Subassociation *Eurotietosum ceratoidis* nov. hoc loco

Association *Stipo glareosae–Anabasietum brevifoliae* Hilbig (1987) 1990

Subassociation *Reaumuria soongarica* von Werden et al. (2006)

Salsola passerina option

Order *Reaumurio soongoricae–Salsoletalia passerinae* (Mirkin in Kasapov et al., 1988) Mirkin & al. 1988 em. Hilbig 2000

Union *Reaumurio soongoricae–Salsolion passerinae* (Kasapov et al., 1988) Mirkin & al. 1988 em. Hilbig 2000

Association *Salsolo passerinae–Reaumurietum soongoricae* Kasapov et al., ex Hilbig 2000

Order *Zygophyllo xanthoxyli–Brachanthemetalia gobici* (Mirkin in Kasapov et al., 1988) Mirkin et al., 1988

Union *Zygophyllo xanthoxyli–Brachanthemion gobici* (Mirkin in Kasapov et al., 1988) Mirkin et al., 1988

Association *Eurotio ceratoidis–Zygophylletum xanthoxyli* Hilbig (1987) 1990

Association *Caragano bungei–Brachanthemetum gobici* Kasapov & al. 1988

Association *Calligono mongolici–Haloxyletum ammodendronis* Hilbig (1987) 1990

Subassociation *Reaumuria soongarica*

Communities *Caragana korshinskii* (position is not clear).

Communities *Psammochloa villosa* (position is not clear).

Association *Allio polyrrhizi–Stipetum glareosae* Hilbig (1987) 1990: subassociation *Eurotietosum ceratoidis* nov. hoc loco (Table 1: 26, 27, 29, 30, 31). Diagnostic types: *Ajania fruticulosa*, *Allium mongolicum*, *Krascheninnikovia ceratoides* (=*Eurotia ceratoides*), *Stipa glareosa*. The subassociation occupies sandy-gravel saury, crossing gently undulating plains in the northern part of the somon in a strip of steppe deserts (1100–1200 m a.s.l. BS (Baltic System)), as well as saury on the piedmont plain of the Gurvan-Saikhan Reserve (1200–1551 m a.s.l. BS) with cyro-brown soils, often gravelly, in a strip of desert steppes. The surface of bare sand reaches 50%, and the rubble content reaches 30%. The total projective coverage varies from 23 to 48%. The dominant species is the true subshrub teresken (*Krascheninnikovia ceratoides*), which forms 8–30% coverage. The plant is well eaten by all types of livestock and can be used to consolidate sand.

Along sand saury to communities from *K. ceratoides,* desert shrubs are mixed in *Zygophyllum xanthoxylum* and *Haloxylon ammodendron*. We classify this vegetation as **associations *Eurotio ceratoidis–Zygophylletum xanthoxyli* Hilbig (1987) 1990** union *Zygophyllo xanthoxyli–Brachanthemion gobici* (Mirkin in Kasapov et al., 1988) Mirkin et al., 1988 (Table 2: 28). Diagnostic types: *Krascheninnikovia ceratoides* and *Zygophyllum xanthoxylum*. The total projective coverage is 33%. The projective coverage of the teresken is 8%.

Association *Stipo glareosae–Anabasietum brevifoliae* Hilbig (1987) 1990: Subassociation *Reaumuria soongarica* von Werden et al. (2006). Option *Salsola passerine* (Table 1: 32, 33, 35). Diagnostic types of the association: *Anabasis brevifolia*, *Grubovia dasyphylla*, *Convolvulus ammannii*, and *Eragrostis minor.* Communities are mostly confined to flat areas with blown sand along the edges of salt marshes and terraces, and also to the edges of sandy drifts. The altitudinal limit of distribution of these communities is 1050–1200 m above sea level BS. The area of bare sand is 70–80%, and rubble is 10–20%. The projective coverage is 20–30%. The dominant, true subshrub is the passerine solyanka (*Salsola passerina*), which forms 11–20% coverage. This species has high feeding characteristics and is one of the main pasture plants of the Gobi. It is believed that *S. passerina* tolerates only surface sanding of the soil and does not grow on sand and sandy loam (Kazantseva, 2009).

Association *Salsolo passerinae–Reaumurietum soongoricae* Kasapov et al. ex Hilbig 2000 (Table 1: 34, 36). Diagnostic types: *Reaumuria songarica* and *Salsola passerina*. This association occurs in lower areas with brown solonetzic soils, where the participation of herbaceous species of the association *Allion polyrrhizi* (*Allium mongolicum*, *A. polyrhizum*, *Neopallasia pectinata*, and *Stipa tianschanica* (=*Stipa gobica*)) becomes rarer compared to the previous association. The surface of loose sand in such areas is 50–65% of the total area of the site, and the rubble content is 25–35%. Projective coverage is 19–39%.

Association *Caragano bungei–Brachanthemetum gobici* Kasapov et al., 1988 (Table 2: 19–25). Diagnostic types of association, union, and order: *Caragana korshinskii*, *Zygophyllum xanthoxylum*, and *Brachanthemum gobicum*. Association distributed mostly on hilly plains with pale-brown soils with sand-borne sands of considerable thickness at an altitude of 1100–1200 m above sea level BS. In the central part of the somom, in the strip in front of the ledge separating plains of different levels and acting as a natural boundary between desert steppes and steppe deserts, communities are common where perennial saltworts *Reaumuria songarica* and *Salsola passerina* on alkali-saline sandy steppe–desert soils become codominant. Bare sand here makes up 60–85%, and rubble varies between 1–30%. The total projective coverage is 12–39%. The dominant species is the true subshrub *Brachanthemum gobicum*, forming from 5 to 15% coverage. Brachantemum is a satisfactory food for camels.

Communities of *Caragana korshinskii* (Table 2: 1–10) on the territory of the Bulgan somon occupy quite large areas in places of blown sand at altitudes from 1000 to 1500 m a.s.l. BS. The surface of bare sand occupies 40–70%, and rubble varies widely, 10–70%. The projective cover of vegetation of caragana communities is 22–63%. The dominant, desert-steppe shrub *Caragana korshinskii* forms from 5 to 30% cov-

Table 1. Associations of unions *Allion polyrrhizi* Hilbig 2000 and *Reaumurio soongoricae–Salsolion passerinae* (Kasapov et al., 1988) Mirkin et al., 1988 em. Hilbig 2000

Community number	26	27	29	30	31	32	33	35	34	36
OPP, %	23	32	45	48	43	25	30	39	20	19
Total species	24	21	19	4	34	16	14	13	9	9
Subassociation *Eurotietosum ceratoidis* nov. hoc loco										
Ajania fruticulosa	–	–	–	–	2	–	–	–	–	–
Kraschenninnikovia ceratoides	2	2	2	3	2	–	–	–	–	–
Association Allio polyrrhizi–Stipetum glareosae Hilbig (1987) 1990										
Stipa glareosa	–	1	1	–	+	–	–	–	–	–
Stipa tianschanica	1	1	1	–	+	+	2	2	1	1
Association *Stipo glareosae–Anabasietum brevifoliae* Hilbig (1987) 1990 (subassociation *Reaumuria songarica* von Werden et al. (2006), *Salsola passerina* option)										
Anabasis brevifolia	–	–	–	–	–	+	1	–	–	+
Convolvulus ammanii	+	1	1	–	–	+	1	1	–	–
Eragrostis minor	+	+	–	–	–	1	–	–	–	–
Grubovia dasyphylla	+	1	1	–	–	1	–	–	–	–
Union *Allion polyrrhizi* Hilbig 2000 and order *Allietalia polyrrhizi* Hilbig 2000										
Allium mongolicum	–	–	1	–	–	–	–	+	–	–
Allium polyrhizum	1	2	2	–	–	1	2	2	–	–
Neopallasia pectinata	1	1	1	–	–	–	+	1	+	–
Association *Salsolo passerinae-Reaumurietum soongoricae* Kasapov et al., ex Hilbig 2000 (Kasapov et al., 1988) Mirkin et al., 1988 em. Hilbig 2000										
Reaumuria songarica	–	–	+	–	–	1	1	+	1	+
Salsola passerina	–	–	–	–	–	2	2	2	2	2
Union *Reaumurio soongoricae–Salsolion passerinae* (Kasapov et al., 1988) Mirkin et al., 1988 em. Hilbig 2000										
Kalidium gracile	–	–	–	–	–	–	+	+	–	–
Order *Reaumurio soongoricae–Salsoletalia passerinae* (Mirkin in Kasapov et al., 1988) Mirkin et al., 1988 em. Hilbig 2000										
Zygophyllum rosowii	+	–	–	+	–	–	–	–	–	–
Class *Stipetea glareosae–gobicae* Hilbig 2000										
Ajania achilleoides	+	–	1	–	–	–	–	–	–	–
Arnebia fimbriata	–	–	–	–	+	–	–	–	–	–
Arnebia guttata	–	–	–	–	+	–	–	–	–	–
Artemisia scoparia	–	–	–	–	+	–	–	–	–	–
Asparagus gobicus	–	–	–	–	–	+	–	–	–	+
Cleistogenes songorica	+	1	1	–	–	1	+	+	1	+
Lagochilus ilicifolius	+	+	–	–	+	–	–	–	–	–
Other types										
Alyssum lenense	–	–	–	–	–	–	+	+	–	–
Aristida adscensionis	+	+	–	–	–	–	–	–	–	–
Artemisia macrocephala	+	1	1	–	+	–	–	–	–	–
Bassia prostrata	+	+	–	–	+	–	–	–	–	–
Brachanthemum gobicum	–	–	–	–	–	+	+	+	+	+
Caragana pygmaea	+	1	+	–	1	–	–	–	–	–
Carex duriuscula	–	–	–	–	–	–	+	1	+	–
Chenopodium album	+	1	–	–	–	–	–	–	–	–
Chenopodium acuminatum	+	+	1	–	1	–	–	–	–	–
Corispermum mongolicum	+	+	–	–	–	1	–	–	–	–
Dontostemon integrifolius	–	–	–	–	–	–	1	–	+	–
Halogeton arachnoideus	+	1	–	–	–	–	–	–	–	–
Haloxylon ammodendron	–	–	–	–	–	1	–	–	–	+
Heteropappus altaicus	+	+	–	–	1	–	–	–	–	–
Neotrinia splendens	1	1	–	–	–	–	–	+	–	–
Peganum nigellastrum	–	–	–	–	–	–	+	–	+	–
Potaninia mongolica	1	–	–	–	–	1	–	–	–	–
Salsola collina	+	1	1	–	1	1	–	–	–	–
Setaria viridis	–	–	+	–	+	–	–	–	–	–
Zygophyllum xanthoxylon	–	–	–	–	–	+	–	–	–	1

Additions by species to communities: 26, *Carex stenophylla* subsp. *stenophylloides*; 29, *Achnatherum inebrians*, *Atraphaxis frutescens, Iris bungei*; 30, *Caragana bungei*, *Prunus mongolica*; 31, *Artemisia anethifolia*, *Artemisia dracunculus*, *Asterothamnus centraliasiaticus*, *Atraphaxis pungens*, *Caryopteris mongolica*, *Crepidiastrum tenuifolium*, *Dracocephalum foetidum*, *Ephedra equisetina*, *Ephedra przewalskii*, *Ephedra sinica*, *Euphorbia humifusa*, *Euphorbia kozlovii*, *Ferula bungeana*, *Hypecoum lactiflorum*, *Nepeta annua*, *Panzerina lanata*, *Prunus pedunculata*, *Silene jeniseensis*, and *Stipa krylovii*.

Table 2. Associations of the union *Zygophyllo xanthoxyli–Brachanthemion gobici* (Mirkin in Kasapov et al., 1988) Mirkin et al., 1988, and communities of *Caragana korshinskii* and *Psammochloa villosa*

Community number	28	19	20	21	22	23	24	25	11	12	13	14	15	16	17	18	1	2	3	4	5	6	7	8	9	10	37	38
OPP, %	33	12	17	18	28	39	18	18	32	39	14	17	34	21	22	19	22	63	41	33	32	27	41	34	28	40	23	24
Total species	28	23	31	27	22	28	24	33	17	19	6	27	39	12	18	19	20	42	26	17	15	12	26	20	26	17	17	3
Association *Eurotio ceratoidis–Zygophylletum xanthoxyli* Hilbig (1987) 1990																												
Asterothamnus centraliasiaticus	+	–	–	–	–	–	–	–	–	–	–	r	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Krascheninnikovia ceratoides	2	–	–	r	–	–	–	1	–	–	–	–	–	–	–	–	–	1	+	1	–	–	+	+	–	–	–	–
Prunus mongolica	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	1	–	–	–	–	–	–
Association *Caragano bungei-Brachanthemetum gobici* Kasapov et al., 1988 and communities *Caragana korshinskii*																												
Caragana korshinskii	–	–	–	–	–	+	+	1	–	–	–	–	–	–	–	–	2	3	2	2	2	2	2	2	2	2	–	–
Subassociation *Reaumuria soongarica*																												
Halogeton arachnoideus	1	r	1	r	–	–	r	r	–	–	–	1	+	1	1	–	r	–	–	–	–	–	–	–	–	–	–	–
Reaumuria songarica	–	1	1	r	–	–	–	–	–	–	–	+	2	+	+	+	1	–	–	–	–	–	–	–	+	–	–	–
Salsola passerina	–	1	1	1	r	1	–	–	–	–	–	1	1	1	–	+	+	–	–	–	–	–	–	1	1	–	–	–
Association *Calligono mongolici–Haloxyletum ammodendronis*																												
Calligonum mongolicum	1	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	+	+	–	–	–	–	–	–	–	–	–	–
Haloxylon ammodendron	1	–	r	1	+	+	–	–	2	2	2	2	2	2	2	2	2	–	–	–	–	–	–	–	–	–	1	–
Union *Zygophyllo xanthoxyli–Brachanthemion gobici* (Mirkin in Kasapov et al. 1988) Mirkin et al., 1988																												
Zygophyllum xanthoxylon	1	r	1	–	2	1	1	–	1	–	–	1	1	–	1	1	1	2	–	–	–	–	–	–	+	–	1	–
Order *Zygophyllo xanthoxyli–Brachanthemetalia gobici* (Mirkin in Kasapov et al., 1988) Mirkin et al., 1988																												
Brachanthemum gobicum	–	2	2	2	2	2	2	2	–	1	–	–	+	–	–	+	1	2	–	–	–	–	–	–	–	–	–	–
Communities *Psammochloa villosa*																												
Psammochloa villosa	–	–	–	–	–	–	–	–	2	–	–	–	r	–	r	r	–	r	–	–	–	–	–	–	1	1	2	2
Class *Stipetea glareosae–gobicae* Hilbig 2000																												
Ajania achilleoides	–	r	r	–	–	1	2	r	–	–	–	r	r	–	–	–	–	r	1	–	–	–	1	1	r	–	–	–
Allium mongolicum	+	r	r	r	r	r	r	r	–	r	–	r	1	+	–	–	+	1	r	1	1	–	r	1	–	1	–	–
Arnebia fimbriata	–	–	–	–	–	–	–	–	–	–	–	–	r	–	–	r	–	–	–	–	–	–	–	–	r	–	–	–
Arnebia guttata	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Artemisia scoparia	–	–	–	–	–	–	–	r	–	–	–	r	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Asparagus gobicus	–	r	r	r	r	r	r	r	–	–	–	r	r	–	–	–	–	r	r	–	–	–	r	–	–	1	–	–
Cleistogenes songorica	2	r	–	r	–	1	r	r	r	–	–	–	–	–	+	–	1	r	1	1	1	1	1	1	+	–	+	–
Lagochilus ilicifolius	–	–	–	–	–	–	–	r	–	–	–	–	–	–	–	–	–	r	r	–	+	+	r	r	–	–	–	–
Stevenia canescens	–	r	–	–	r	–	r	r	–	–	–	–	–	–	–	–	–	r	r	r	+	+	r	1	r	+	–	–
Stipa glareosa	+	r	r	+	1	1	r	1	1	–	–	–	–	–	r	r	–	–	–	–	–	–	–	–	–	–	1	–
Stipa tianschanica	–	–	r	+	1	1	1	1	–	–	–	r	–	–	–	r	1	1	2	2	2	2	1	1	1	1	–	–
Other types																												
Agriophyllum pungens	1	–	r	+	–	–	–	–	1	2	1	–	r	–	1	–	–	1	–	–	–	–	–	1	–	–	1	–
Allium anisopodium	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	r	–	–	–	–	r	–	–	–	–	–
Allium leucocephalum	–	–	–	–	r	–	–	–	–	–	–	–	r	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Allium polyrhizum	–	–	–	r	–	r	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	1	–	–	–	–	–
Anabasis brevifolia	+	1	r	r	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	r	–	–	–
Aristida adscensionis	+	r	–	–	–	1	–	–	–	–	–	1	r	–	–	–	r	–	–	–	–	–	–	–	–	–	–	–
Artemisia sphaerocephala	+	–	–	+	1	1	–	–	–	–	–	–	r	–	+	–	–	r	–	–	–	–	–	–	1	–	–	–
Artemisia xerophytica	–	r	r	+	1	1	1	1	–	r	–	–	r	–	–	–	+	1	2	+	1	+	2	2	+	+	–	2
Astragalus junatovii	–	–	–	–	r	–	r	–	–	r	–	–	r	–	–	–	–	r	r	–	–	–	–	–	r	r	–	–
Astragalus monophyllus	–	–	–	r	–	r	–	–	–	–	–	–	–	–	–	–	–	r	r	–	–	–	r	–	–	–	–	–
Astragalus variabilis	–	–	–	+	–	r	–	–	–	–	–	r	–	–	–	r	–	–	–	–	–	–	–	–	–	–	–	–

Table 2. (Contd.)

Community number	28	19	20	21	22	23	24	25	11	12	13	14	15	16	17	18	1	2	3	4	5	6	7	8	9	10	37	38
Atraphaxis frutescens	1	–	–	–	–	–	–	r	–	1	–	–	1	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–
Atraphaxis pungens	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	+	–	–	–	–	–	–	–	–	–	–
Caragana pygmaea	1	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–	+	+	+	–	1	–	+	–	–	–	–	–
Carex stenophylla subsp. *stenophylloides*	+	–	–	–	–	–	–	–	–	–	–	–	r	–	–	r	–	r	–	–	–	–	–	–	–	–	–	–
Caryopteris mongolica	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–
Chenopodium acuminatum	–	–	–	–	–	–	–	r	–	–	–	–	–	–	–	–	–	–	r	–	–	–	r	–	–	–	–	–
Chesneya mongolica	–	–	r	–	–	–	–	–	–	–	–	–	r	–	–	r	–	–	–	–	–	–	–	–	–	–	–	–
Chloris virgata	–	–	–	1	–	–	–	r	–	–	–	r	r	–	–	–	–	r	–	–	–	–	–	–	–	–	–	–
Convolvulus ammannii	–	r	r	–	r	r	–	–	1	+	–	r	1	1	r	1	–	–	r	+	1	–	1	1	r	–	1	–
Convolvulus fruticosus	+	r	1	–	–	–	–	–	r	1	–	–	–	–	–	–	1	–	–	–	–	–	–	–	+	–	1	–
Corispermum mongolicum	+	–	r	1	r	2	r	1	r	1	r	r	+	r	1	–	r	1	r	2	–	–	r	1	1	1	+	–
Cynanchum thesioides	–	–	–	–	–	–	–	–	–	r	–	–	–	–	–	r	–	–	–	r	–	–	–	–	–	–	–	–
Dontostemon crassifolius	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	+	–	–	–	–	–	–
Echinops gmelinii	–	–	–	r	–	–	–	r	r	–	–	–	–	–	r	–	–	1	–	–	–	–	–	–	–	–	+	–
Enneapogon desvauxii	+	–	r	–	–	–	–	–	–	–	–	–	r	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Eragrostis minor	+	–	–	–	–	–	–	r	–	r	–	1	r	r	+	–	–	r	–	–	–	–	–	–	–	–	–	–
Euphorbia kozlovii	–	–	–	–	–	–	–	–	–	–	–	–	r	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–
Ferula bungeana	–	r	–	–	r	r	r	r	–	–	–	r	r	r	–	–	–	r	r	–	–	–	r	r	–	r	–	–
Grubovia dasyphylla	+	–	–	r	r	–	r	r	r	1	r	r	1	1	1	–	–	–	r	+	–	–	–	r	–	–	1	–
Haplophyllum dauricum	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	r	r	–	+	+	r	–	–	r	–	–
Heterochroa desertorum	–	–	r	–	–	–	–	–	–	–	–	–	–	–	–	–	–	r	–	–	–	–	r	–	r	–	–	–
Heteropappus hispidus	–	–	–	–	–	–	–	–	–	–	–	–	r	–	–	–	–	–	r	–	–	–	1	1	–	–	–	–
Iris bungei	–	–	–	r	–	–	r	–	–	–	–	–	r	–	–	+	–	r	1	–	–	–	r	1	1	1	–	–
Iris tenuifolia	–	–	r	–	1	r	r	r	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Jurinea mongolica	–	–	–	–	r	r	+	r	–	r	–	–	–	–	–	–	–	r	–	r	–	–	–	r	r	r	–	–
Limonium aureum	–	r	r	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Limonium tenellum	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	r	–	–	–	r	–	–	–	–	–
Lipschitzia divaricata	–	r	r	–	–	r	r	r	r	–	–	r	–	–	–	+	–	r	r	r	+	+	–	r	r	r	+	–
Nitraria sibirica	1	–	r	–	1	r	–	–	1	–	1	1	1	1	+	–	–	–	–	–	1	1	–	–	1	2	+	–
Orobanche coelurescens	–	–	–	–	r	–	r	r	–	–	–	–	–	–	–	–	–	r	–	–	–	–	–	–	–	–	–	–
Oxybasis glaucum	–	–	r	–	–	–	–	–	–	–	–	r	r	1	r	–	–	–	–	–	–	–	–	–	–	–	–	–
Oxytropis aciphylla	–	r	r	–	–	1	1	r	+	+	–	–	+	–	–	–	1	+	–	–	1	1	1	–	1	1	1	+
Peganum nigellastrum	–	–	–	–	–	–	–	–	r	r	–	–	r	–	+	1	–	–	–	r	–	–	–	–	–	–	1	–
Potaninia mongolica	–	r	–	–	–	–	–	1	–	–	–	–	+	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–
Rheum nanum	–	–	–	+	–	–	–	r	–	–	–	–	–	–	–	–	–	r	r	–	–	–	r	–	–	–	–	–
Salsola collina	1	r	1	+	–	r	–	r	–	1	–	–	+	–	+	–	r	r	1	1	–	–	1	1	–	–	1	–
Salsola laricifolia	–	–	–	–	–	–	–	–	–	–	–	–	r	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–
Salsola tragus	–	–	1	–	–	–	–	–	r	–	–	r	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Setaria villosa	–	–	r	–	–	–	–	r	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Setaria viridis	+	–	–	–	–	–	–	–	–	–	–	r	–	–	–	–	–	–	–	r	–	–	–	–	–	–	–	–
Takhtajaniantha capito	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	r	–	–	–	–	–	–	–	r	–	–
Tribulus terrestris	+	–	1	r	–	–	–	1	–	–	r	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Zygophyllum potaninii	–	–	–	1	–	r	–	–	–	–	–	r	–	–	–	+	–	–	–	–	–	–	–	–	1	–	–	–
Zygophyllum rosowii	–	r	r	–	r	–	r	r	r	1	–	r	r	–	–	–	–	r	–	–	–	–	–	–	r	–	1	–

Additions by species to communities: 28, *Ajania fruticulosa*, *Takhtajaniantha pseudodivaricata*; 15, *Olgaea lomonossowii*; 2, *Ephedra equisetina*; 4, *Nepeta lophanthus*.

erage. The species is a plant eaten well by livestock. On thicker sandy deposits, they become codominant *Brachanthemum gobicum*, *Psammochloa villosa*, and *Nitraria sibirica*. At the mouths of the saury, under the influence of the alluvial fan, and along the foothills of small hills with deluvial deposits, in addition to sand, quite a lot of rubble accumulates. In such places in addition to *Caragana korshinskii* one encounteres *Cleistogenes songorica*, *Ajania achilleoides*, *Psammochloa villosa*, and *Prunus mongolica*. Sands occupy a significant area in the western part of the somom. The codominants here are rhizomatous grass *Psammochloa villosa* and the annual *Agriophyllum pungens*. On undulating plains with blown sands, caragana is mixed with *Artemisia xerophytica*. The question of the syntaxonomic position of the Caragana korshinskii communities remains open (Wesche et al., 2005) and requires the collection of additional data both on the territory of the studied somon and in the eastern parts of the Gobi.

Association *Calligono mongolici–Haloxyletum ammodendronis* Hilbig (1987) 1990 (Table 2: 11–18). Diagnostic types: *Haloxylon ammodendron* and *Calligonum mongolicum*. On the territory of the soum, the association is distributed at altitudes of 1000–1497 m above sea level BS along the sandy edges of salt marshes, wide inter-hill valleys with blown sands, and in wide saury covered with sands of varying thickness. Pure thickets of saxaul *H. ammodendron* or saxaul with the participation of dzhuzgun *C. mongolicum* extended to sand deposits in the Bayanzag and Talyn Gunii els basins. Tall saxauls are found in the western part of the somon in a basin at the southern foot of the Arts Bogd mountains. The habitats of saxaul communities are characterized by a predominance of bare sandy surfaces, 80–95%, while rubble is 5–10%. The total projective coverage is 14–32%. Dominant, *H. ammodendron*, changes its life form from a tree to a low-growing shrub depending on the habitat (Kazantseva, 2009). The life form of the species is also influenced by grazing (von Wehrden et al., 2009). The plant is eaten well by goats and camels. In addition, saxaul is widely used as fuelwood, which is the main reason why true forests are rare and predominantly small shrubby species occur (Wesche et al., 2005). The projective coverage of saxaul is 10–20%. In addition, there are abundant *Agriophyllum pungens* and *Psammochloa villosa*. Among other shrubs, saltpeter has a noticeable presence of *Nitraria sibirica* and parfolia *Zygophyllum xanthoxylum*.

At the bottom of the Bayanzag basin on pale-brown solonetzic–solonchakous soils, the codominants in the saxaul forests are the salt-tolerant subshrubs *Reaumuria songarica* and *Salsola passerina,* which are diagnostic species **subassociations *Reaumuria songarica***, associations *Calligono mongolici–Haloxyletum ammodendronis* (Table 2: 14–18). The bare sand surface here is 60–90%, and the rubble content is 5–30%. The total projective coverage is 17–34%. Saxaul coverage is 7–15%.

Communities of *Psammochloa villosa* (Table 2: 37–38). On the territory of the Bulgan soum, this plant forms almost pure thickets on the sandy sediments of the territory of the Dan and Dal subdistricts, as well as in the Bayanzag tract and at the foot of the Tevsh mountains. The sandy surface between the bases of plants is 95–99%, and there is almost no crushed stone on the surface (1–3%). The total projective coverage is no more than 24%. Dominant *Psammochloa villosa* forms 8–14% coverage. This rhizomatous grass is a typical psammophyte, the flexible shoots of which can withstand the constant movement of sand. The species reproduces by seeds and long underground rhizomes, thanks to which sand sediments are well fixed. Also involved in the composition of vegetation are *Haloxylon ammodendron*, *Agriophyllum pungens*, and *Oxytropis aciphylla*. *P. villosa* is a characteristic type of fluttering sand massifs in northern Mongolia, the vegetation of which belongs to the class *Brometea korotkyi* Hilbig et Koroljuk 2000. However, none of the characteristic types *B. korotkyi* (*Bromus pumpellianus* (=*Bromopsis korotkiji*), *Corethrodendron fruticosum*, *Leymus racemosus*, etc.) is found in the Omnogovi aimag (Wesche et al., 2005). Due to this position, the communities of *P. villosa* remain unclear.

Taxonomic diversity of higher vascular plants of the sandy massifs of the Northern Gobi. The flora of the sandy massifs of the Bulgan soum of the Omnogovi aimag consists of 108 species, 73 genera, and 28 families, which is slightly higher than their number noted on the ecological profile of the desert–steppe station JRMCBE (Kazantseva, 2009). The most diverse genera are represented by *Artemisia* (6), *Allium* (4), *Ephedra* (3), *Stipa* (3), *Salsola* (3), *Astragalus* (3), *Caragana* (3), and *Zygophyllum* (3). The number of species is dominated by the families *Asteraceae* (20), *Amaranthaceae* (16), *Poaceae* (13), and *Fabaceae* (8). In the families *Lamiaceae*, *Alliaceae*, *Polygonaceae*, *Brassicaceae*, *Zygophyllaceae*, *Ephedraceae*, *Cyperaceae*, *Iridaceae*, *Caryophyllaceae*, *Rosaceae*, *Euphorbiaceae*, *Plumbaginaceae*, *Convolvulaceae*, and *Boraginaceae*, 2–5 types are presented. One species was noted in the families *Asparagaceae*, *Orobanchaceae*, *Tetradiclidaceae*, *Nitrariaceae*, *Rutaceae*, *Tamaricaceae*, *Apiaceae*, *Apocynaceae*, *Verbenaceae*, and *Papaveraceae*. In general, the species structure of genera and families reflects the specificity of the flora of the lowland part of the Bulgan soum (Sanchir, 1980) and the ecological profile (Kazantseva, 2009).

Ecological and phytocenotic groups of species and life forms. The vegetation of sandy massifs is dominated by species of the desert–steppe group (*Allium mongolicum*, *A. polyrhizum*, *Artemisia xerophytica*, *Stipa glareosa*, *S. tianschanica*, etc.), amounting to 57%. Steppe species (*Carex duriuscula*, *Caragana pygmaea*, *Haplophyllum dauricum*, etc.) form 15% of the flora; desert

(*Ephedra przewalskii*, *Haloxylon ammodendron*, *Krascheninnikovia ceratoides*, etc.), 13%; steppe–desert species (*Agriophyllum pungens*, *Rheum nanum*, *Corispermum mongolicum*, etc.) account for 8%; and mountain–steppe (*Alyssum lenense*, *Caryopteris mongolica*, *Silene jeniseensis*, etc.), 5%. The most common types are *Chenopodium album* and *Setaria viridis*.

According to the participation of ecological groups in the flora of sandy massifs, xerophytes predominate at 55%. Xeropetrophytes make up 12%, and mesoxerophytes and halophytes, 8% each. 17% of species belong to psammophytes proper. Of these, obligate psammophytes are *Caragana korshinskii*, *Atraphaxis pungens*, *Psammochloa villosa*, *Carex stenophylla* subsp. *stenophylloides*, *Agriophyllum pungens*, *Corispermum mongolicum*, *Aristida adscensionis*, and *Iris tenuifolia*.

The structure of life forms in communities is dominated by herbs, including Polycarpic grasses, which account for 43%, and monocarpic grasses, which account for 27%. Up to 30% of the flora is represented by woody species.

CONCLUSIONS

The syntaxonomic diversity of vegetation in the sandy massifs of the Northern Gobi is represented by one class, three orders, three unions, and six associations.

In total, the studied sand communities recorded 108 species from 73 genera and 28 families. Among those represented in communities with families, the most numerous are *Asteraceae*, *Amaranthaceae*, *Poaceae,* and *Fabaceae*. The predominance of these four families in the flora of Bulgan soum was noted by Ch. Sanchir (1980) and T.I. Kazantseva (2009). This shows that the floristic features of sandy plant communities are generally similar to the floristic features of this desert–steppe region within the Bulgan soum.

In the spectrum of life forms of plants in sandy communities, perennial and annual and biennial grasses predominate, although in terms of participation in the structure of plant communities, the dominant phytocenotic role belongs most of all to woody and semi-woody plants. An exception is the perennial long-rhizome grass *Psammochloa villosa*.

Dominant types of vegetation of sandy massifs (*Krascheninnikovia ceratoides*, *Caragana korshinskii*, *Haloxylon ammodendron*, *Psammochloa villosa*, *Nitraria sibirica*, *Brachanthemum gobicum*, etc.) are natural sand fixers. At the same time, these species are, for the most part, well-eaten food for livestock. Consequently, grazing in such habitats must be strictly regulated. Sand plants from different natural zones of Mongolia, especially the desert zone, should be subject to detailed study in the future due to the need to use them for the purpose of phytomelioration of destroyed ecosystems. As noted by V.A. Obruchev (1951), the most reliable method of phytomelioration of sands is the use of indigenous plant species that have adapted over a long time to the worst growing conditions.

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ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This work does not contain any studies involving human and animal subjects.

CONFLICT OF INTEREST

The authors of this work declare that they have no conflicts of interest.

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