6. Vegetation of the Deserts of Turkmenistan

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Abstract

The desert vegetation in Turkmenistan consists predominantly of semishrub sagebrush-halophyte and psammophyte communities, with dominant formations of *Haloxyleta*, *Salsoleta*, *Calligoneta*, and *Artemiseta*. We have separated plant communtites into 26 formations and 28 groups of associations with a relatively simple phytocoenological structure and homogeneous species composition. The community structure is usually determined by a few dominant species of semishrubs which also provide most of the phytomass. Other sinusia, such as herbaceous cover, are built mainly by annual ephemerous species which do not play a significant role in the community structure.

In deserts, which occupy more than 80% of the territory of Turmenistan, vegetation is a valuable feed resource for the livestock industry. Desert areas are used throughout the year for sheep and camel grazing. Desert vegetation provides an important ecological role by stabilizing the sand. Several natural reserves and other protected areas have been established to preserve desert vegetation and landscapes in Turkmenistan.

Introduction

The desert vegetation of Turkmenistan is relatively well studied. All basic plant communities have been described and characterized and a number of studies conducted on the dynamics and productivity of many desert plant communities as well as on the role of natural and anthropogenic factors. This review is based on data published by other authors as well as on our original data gleaned from many years of studies in the various desert regions of the republic.

Desert vegetation strongly depends on climatic conditions. In the deserts of Turkmenistan, the severe water deficiency (annual precipitation does not exceed 120 to 130 mm, and in some regions is even as low as 75 mm), an unequal seasonal distribution of this scarce precipitation, and high summer temperatures have resulted in many specific evolutionary adaptations in desert

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plants. For instance, desert plants may partially lose leaves (or lose assimilating branches that replace leaves) in the summer; leaves may possess protective hairs or wax cover; fewer stomata may be present than in non-desert species, and their size may be smaller or they may become embedded in the leaf tissue; the root system can be extremely developed and reach the level of ground water or the horizon of capillary moisture; and a system of accessory roots may develop in plants growing on sand dunes.

Characteristics of Desert Vegetation

Deserts of Turkmenistan present various types of habitats and plant communities. The vegetation in the sand desert of Karakum is dominated by such shrub species as saksaul, cherkez, and kandym, with an herbaceous cover of sand sedge (*Carex physodes*) and ephemerous plants. The black saksaul (*Haloxylon aphyllum*) sometimes forms peculiar "desert forests." Clay deserts (*takyrs*) are almost devoid of vascular plants but possess specific communities of algae and lichens. Vast clay and gravel plateaus of West Turkmenistan are dominated by semishrub sagebrush-halophyte communities. Below, we present a classification scheme for the desert vegetation in Turkmenistan (Table 1), and give characteristics of its formations and associations. Each subdivision in this classification has a number code referred to in the text.

1. Euxerophyte Desert Vegetation

This vegetation type embraces the most common plant communities found both in the sand desert and low plateaus. Within this type, we distinguish between two classes of formations: desert semishrub and small shrub vegetation (1.1) and desert shrub and large shrub vegetation (1.2). The most common small semishrub communities are characterized by formations of sagebrushes and halophytes. Shrub and large shrub vegetation is found in sand deserts and on thin *kyr* sands underlaid by maternal rocks. In the Karakum and Chilmamedkum sand deserts, the most characteristic communities are those of saksaul and psammophite shrubs (the latter dominated by cherkez, dzhuzgun, or syuzen).

1.1. Desert Semishrub and Small Semishrub Vegetation

This class of formations includes communities dominated by a typical desert ecobiomorph of small semishrubs; these are predominantly various sagebrush (*Artemisia*) species of the subgenus *Seriphidium*, species of *Salsola* (*S. gemmascens* and *S. orientalis*), biyurgun (*Anabasis salsa* and *A. ramosissimum*), and sarsazan (*Halocnemum strobilaceum*). Desert small semishrub vegetation is diverse and dominates the desert vegetation. Within this class of formations, we

Table 1. Classification of desert vegetation of Turkmenistan

Vegetation type	Class of formations	Group of formations	Formation	Groups of associations
1. Euxerophyte desert vegetation	1.1. Desert semishrub vegetation	1.1.1. Sagebrush deserts	1.1.1.1. Kemrud sagebrush formation (*Artemisia kemrudica*)	typical Kemrud sagebrush associations; ephemerous and ephemeroid Kemrud sagebrush associations; psammophyte Kemrud sagebrush associations
			1.1.1.2. Badghyz sagebrush formation (*Artemisia badhysi*)	typical Badghyz sagebrush associations; ephemerous and ephemeroid sagebrush associations
		1.1.2. Halophyte semishrub deserts	1.1.2.1. Tetyr formation (*Salsola gemmascens*)	typical tetyr associations; ephemerous and ephemeroid tetyr associations
			1.1.2.2. Kevreik formation (*Salsola orientalis*)	typical kevreik associations
			1.1.2.3. Biyurgun formation (*Anabasis salsa*)	typical biyurgun associations
		1.1.3. Succulent-halophyte deserts	1.1.3.1. Sarsazan formation (*Halocnemum strobilaceum*)	typical sarsazan associations
		1.1.4. Small halophyte shrub deserts	1.1.4.1. Boyalych formation (*Salsola arbuscula*)	typical boyalych associations; ephemerous and ephemeroid boyalych associations
			1.1.4.2. *Reaumuria* formation (*Reaumuria* spp.)	typical *Reaumuria* associations; ephemerous and ephemeroid *Reaumuria* associations

Table 1. Continued

Vegetation type	Class of formations	Group of formations	Formation	Groups of associations
	1.2. Desert shrub and large shrub vegetation	1.2.1. Saksaul deserts	1.2.1.1. White saksaul formation (*Haloxylon persicum*)	typical (shrub) white saksaul associations
			1.2.1.2. Black saksaul formation (*Haloxylon aphyllum*)	typical (shrub) black saksaul associations; ephemerous and ephemeroid black saksaul associations; moss/black saksaul associations
			1.2.1.3. Mixed saksaul formation (*Haloxylon persicum* and *Haloxylon aphyllum*)	typical mixed saksaul associations
		1.2.2. Psammophyte shrub deserts	1.2.2.1. Syuzen formation (*Ammodendron conollyi*)	typical syuzen associations
			1.2.2.2. Dzhuzgun formation (anthropogenic) (*Calligonum* spp.)	typical dzhuzgun associations
			1.2.2.2. Cherkez formation (*Salsola arbuscula*)	typical cherkez associations
			1.2.2.4. Bordzhok formation (*Ephedra strobilacea*)	typical bordzhok associations
2. Mesoxerophyte desert vegetation	2.1. Desert herbaceous vegetation	2.1.1. Large perennial herbaceous vegetation	2.1.1.1. Selin formation (*Aristida pennata*)	
			2.1.1.2. Yuzarlik formation (*Peganum harmala*)	

Table 1. Continued

Vegetation type	Class of formations	Group of formations	Formation	Groups of associations
			2.1.1.3. *Agropyron*formation (*Agropyron fragile*)	
		2.1.2. Ephemerous-grass vegetation	2.1.2.1. Yepelek formation (*Anisantha tectorum*)	
			2.1.2.2. Arpagan formation (*Eremopyrum orientale*)	
		2.1.3. Annual halophyte vegetation	2.1.3.1. Ebelek formation (*Ceratocarpus utriculosus*)	
			2.1.3.2. Ketgen formation (*Salsola paulsenii*)	
3. Psychroxerophyte desert vegetation	3.1. Desert thallomous vegetation	3.1.1. Algal vegetation (on takyrs)		
		3.1.2. Lichen vegetation (on takyrs)		
		3.1.3. Moss vegetation		

separate three groups: sagebrush deserts, halophyte small semishrub deserts, and succulent-halophyte deserts.

1.1.1. Sagebrush Deserts

Sagebrush communities are typical in the deserts of Turkmenistan, where they are widespread and well-studied (Prozorovsky 1940; Rodin 1940, 1963; Korovin and Granitov 1949; Momotov 1953; Kogan 1954; Nechaeva 1956; Rodin and Rubtsov 1956; Rachkovskaya 1957; Korovin 1961; Rustamov 1962; Granitov 1967). Sagebrush communities are present on the vast lowlands of the Krasnovodsk and Ustyurt Plateaus, in the modern and old deltas of the Amudarya River, and in the Trans-Unguz Karakum. In the Karakum Desert proper, relatively homogeneous sagebrush communities are found in lowland and small-dune sands. Formations of sagebrush are represented also in the underhill lowland and foothills of Kopetdagh (Rodin 1963). Soils under sagebrush communities are loams, sandy loams, grey-brown soils, and sometimes light serozyoms.

Dominant in sagebrush communities are *Artemisia kemrudica*, *A. badhysi*, *A. badhysi* var. *arenicola*, *A. halophida*, and *A. santolina*. The most characteristic, widespread, and prevailing formation is that of *Artemisia kemrudica* (Table 2).

Table 2. The vegetation of the formation *Artemisieta kemrudicae*

Species	Height (cm)	Abundance (Drude scale)	Coverage (%)	Density (plants/ha)
Shrubs:				
Salsola richteri	70	Sol	1–2	200
Calligonum alatum	40–60	Sol	1–2	200
Salsola arbuscula	30–80	Sp-Cop[1]	5–15	1,400–3,800
Small shrubs:				
Ephedra distachya	10–30	Sol	1	200
Semishrubs:				
Astragalus turcomanicus	35–40	Sol	1	200
Small semishrubs:				
Halothamnus subaphyllus	25	Sol	<1	100–200
Salsola orientalis	20–30	Sp	1–2	100–700
Salsola gemmascens	10–15	Sp	1–2	1,400–3,800
Artemisia kemrudica	20–45	Cop[1-3]	20–55	6,000–22,000
Perennial herbaceous species:				
Stipagrostis pennata	20–40	Sol	1–2	–
Iris longiscapa	10–20	Sol	<1	–
Carex pachystylis	10–20	Cop[1-3]	2–5	–
Carex physodes	15–20	Sp	2–5	–
Gagea reticulata	8–15	Sol-Sp	<1	–
Allium fibrosum	15–20	Sol	<1	–
Tulipa sogdiana	10–12	Sol	<1	1
Ferula foetida	35–40	Sp	2–3	500
Annual herbaceous species:				
Ceratocarpus utriculosus	5–10	Sol	<1	–

Table 2. Continued

Species	Height (cm)	Abundance (Drude scale)	Coverage (%)	Density (plants/ha)
Climacoptera lanata	15–20	Sol	<1	–
Ceratocephala falcata	2–5	Sol	<1	–
Hypecoum pendulum	10–20	Sol	<1	–
Roemeria hybrida	10	Sol	<1	–
Goldbachia laevigata	8–10	Sol	<1	–
Strigosella grandiflora	25–30	Sp	1	–
Strigosella sp.	10–15	Sol	<1	–
Tetracme quadricornis	10–12	Sol	<1	–
Isatis minuta	30–40	Sp	1	–
Leptaleum filifolium	4–5	Cop[1]	1	–
Astragalus oxyglottis	5–6	Sol	<1	–
Erodium oxyrrhynchum	5–6	Sol	<1	–
Lappula semiglabra	20	Sol	1	–
Nonea caspica	5–10	Sol	<1	–
Arnebia decumbens	5–20	Sol-Sp	<1	–
Koelpinia linearis	5–20	Sol	1	–
Senecio subdentatus	8–12	Sol	<1	–
Amberboa turanica	5–10	Sol	<1	–
Eremopyrum orientale	10–15	Sp-Cop[2]	1–2	–
Anisantha tectorum	15–20	Sol-Sp	1	–
Atriplex dimorphostegia	2–3	Sol	<1	–
Lallemantia royleana	3–4	Sol	<1	–

The Kemrud sagebrush communities occupy large areas in Northwest Turkmenistan, on the Krasnovodsk, Ustyurt, and Beltau Plateaus, and in the modern and old deltas of the Amudarya River, and are found on grey-brown sandy loams and light loams, covered by gravel, with gypsum-bearing rock located at a depth of 50 to 70 cm. These communities are rather homogeneous in structure: the upper layer, when present, is 60 to 100 cm high and consists of sparse shrubs of low *Haloxylon aphyllum* and *Calligonum* spp.; sometimes, on sandy soils, it includes sparse *Salsola richteri* and *Halothamnus subaphyllum* var. *arenaria*.

The major layer is the second one, built by *Artemisia kemrudica*, with participation of *Salsola arbuscula*, *S. gemmascens*, and occasional *Astragalus turcomanicus*. This layer is usually 20 to 40 cm; however, such species as *Salsola arbuscula* and *Astragalus turcomanicus* often form a separate superlayer up to 60 cm or higher. The dominant species, *Artemisia kemrudica*, is always outstanding and conspicuous. This plant is 30 to 60 cm high; its perennial portion is up to 15 cm long, and annual one is 15 to 30–35 cm long. During wet years, the annual shoots of this small semishrub can reach maximal length of 43 cm (Nechaeva 1956), whereas in dry years their length is 6 to 20 cm long. Lifespan of the Kemrud sagebrush is 15 to 20 years.

The vegetative period of *Artemisia kemrudica* begins in late February to early

March; growth occurs in April and May; flowering begins in late August and continues until September; seed production occurs in October. The root system of sagebrush changes significantly with age. In young plants, the main root is well developed, going down to 60 cm and producing a number of side roots. Later, the sagebrush root system develops primarily as side roots, and the main root almost completely disappears; this developmental peculiarity is a result of the differentiation of branches of an original plant which receives nutrition through side roots. The diameter of a sagebrush root system is about two meters, and the system can penetrate to a depth of 70 to 80 cm.

Also typical for *Artemisia kemrudica* growth is the change in aboveground to underground biomass ratio: juvenile plants can have two to three times more biomass above ground than underground (Nechaeva *et al.* 1973), whereas in adult plants these biomasses are almost equal.

Among other species that can subdominate in sagebrush communities are *Salsola arbuscula*, *S. gemmascens*, and *S. orientalis*; their abundance, however, is insignificant in ephemerous and ephemeroid Kemrud sagebrush communities. About one to two per cent of coverage in the main sagebrush layer can be contributed by *Ephedra distachya*, *Convolvulus* sp., and *Haplophyllum ramosissimum*. Rodin (1963) gives a total list of 20 species of semishrubs found in the Kemrud sagebrush communities; on the description plots this number does not exceed eight species.

The lowest (third) layer in the Kemrud sagebrush communities consists of herbaceous, primarily ephemerous and ephemeroid vegetation. A total list of 20 to 25 species is given for sagebrush pastures of Northwest Turkmenistan by Nechayeva (1956). On concrete plots there are five to ten, rarely up to fifteen, species of ephemers and ephemeroids. They develop primarily in the spring although growth is highly dependent on annual weather conditions.

Within the Kemrud sagebrush formation, four groups of associations can be found: typical, semisavanna, ephemerous and ephemeroid, and psammophyte. Species diversity is highest in typical and ephemerous and ephemeroid Kemrud sagebrush associations (up to 50 species of plants and more). More than 50% of this list consists of annual species, primarily ephemerous ones; plants with a short vegetative period (ephemers and ephemeroids combined) represent 55 to 66% of the species list in these communities. There are six species of semishrubs and small semishrubs, and five to six species of shrubs and small shrubs (altogether 22 to 24% of the species list). Less diverse are psammophyte Kemrud sagebrush communities, but here also more than half (54%) of the species are plants with a short vegetative period. In total, 60% of species present in the Kemrud sagebrush formation have a short vegetative period, and 22% are shrubs and semishrubs.

1.1.2. Halophyte Small Semishrub Deserts

This group of formations includes the typical desert zone small semishrubs tetyr (*Salsola gemmascens*), biyurgun (*Anabasis salsa*), and kevreik (*Salsola orientalis*).

1.1.2.1. Tetyr Formation (Salsola gemmascens) (table 3). Although tetyr formation is not the most widespread, it is one of the most typical desert formations of vegetation. Communities of *Salsola gemmascens* are represented in the Uzboi dry bed, in the southern Ustyurt and Krasnovodsk Plateaus next to the Karabogazgol Bay of the Caspian, and in the western Trans-Unguz area. Patches of tetyr communities are also found throughout the Karakum Desert in takyrs and takyr-like habitats among sand dunes.

S. gemmascens is found on grey-brown *solonets* loams and sandy soils bearing gypsum as well as on grey-brown primitive soils of takyrs (the latter may have a certain percentage of gravel and gypsum).

The dominant species of this formation, *Salsola gemmascens*, is a small (30 to 50 cm) shrub which is a typical xerophyte and, to a certain degree, a halophyte. Individual plants live for 10 to 15, and sometimes to 20 or 25 years, and can

Table 3. The vegetation of the formation *Salsoleta gemmascentes*

Species	Height (cm)	Abundance (Drude scale)	Coverage (%)	Density (plants/ha)
Shrubs:				
Salsola arbuscula	20–40	Sp	2–3	600
Small semishrubs:				
Salsola orientalis	20–30	Sol-Sp	2–3	600–800
Salsola gemmascens	10–15	Cop^{2-3}	10–25	7,600–28,100
Artemisia kemrudica	20–30	Sol-Sp	1–2	300–500
Perennial herbaceous species:				
Heliotropium sp.	n/a	Sp	<1	–
Astragalus xiphioides	5–10	Sol	<1	–
Carex pachystylis	10–20	Cop^{1-2}	1–2	–
Gagea reticulata	5–8	Sp	<1	–
Allium sp.	15–20	Sol	<1	–
Tulipa sogdiana	5–10	Sol	<1	–
Annual herbaceous species:				
Halimocnemis villosa	5–6	Sp	<1	–
Ceratocephala falcata	2–4	Cop^{1}	1	–
Hypecoum pendulum	8–15	Sol	<1	–
Roemeria hybrida	8–10	Sol	<1	–
Strigosella grandiflora	20–30	$Sp\text{-}Cop^{2}$	1–2	–
Strigosella sp.	5–7	Sol	<1	–
Leptaleum filifolium	3–15	$Sp\text{-}Cop^{2}$	1–2	–
Astragalus arpilobus	3–5	Sp	1	–
Astragalus oxyglottis	3–6	Sol	<1	–
Lappula semiglabra	5–12	Sol	<1	–
Nonea caspica	5–15	Sol	<1	–
Arnebia decumbens	8–10	Sol	<1	–
Koelpinia linearis	10–15	Sol	<1	–
Senecio subdentatus	20–25	Sp	<1	–
Eremopyrum orientale	7–20	$Sol\text{-}Cop^{1}$	1–2	–
Epilasia hemilasia	10	Sol	<1	–

annually produce up to 600 seeds. Seven- to ten-year old plants form an expressed crown and root system (which is superficial and reaches 70 to 100–125 cm; Nechaeva *et al.* 1973).

Habitus and condition of *Salsola gemmascens* vary with soil conditions. On the gravel- and gypsum-bearing soils of Krasnovodsk Plateau and areas south from Ustyurt, tetyr plants are depressed and small-sized (7 to 15 cm); their crown is poorly developed. On the other hand, on grey-brown soils with low content of gypsum and disrupted surface *S. gemmascens* grows more vigorously, develops a normal crown, and reaches a height of 20 to 40 cm. Depending on the habitat, coverage of tetyr can vary from 10 to 25%, and its density varies from 12,000–16,000 to 24,000–28,000 plants/ha (our data; Pelt 1956).

Floristically, this formation is relatively poor (the total list has 30 to 35 species; the concrete plots house 12 to 17 species). As in other desert formations, most of these species (especially ephemerous ones) are annual herbaceous plants (62 to 64% of the total list). The combined number of annual and perennial herbaceous species with spring and fall vegetative period (i.e., ephemers and ephemeroids) represent 57 to 75% of all species in the tetyr formation. Semishrubs and small semishrubs contribute 11 to 13%, and shrubs and small shrubs, only 4 to 8% of the species list. Certain shrubs that participate in this formation, such as *Calligonum setosum*, *Salsola arbuscula*, and *Haloxylon aphyllum*, are so depressed there that they rarely reach a height of 50 or 60 cm.

Vertical structure in tetyr communities is weakly expressed; it basically comprises two layers, but the lower layer is expressed only in the spring period, as in the sagebrush communities. The upper layer (20 to 40 cm high) is composed of *S. gemmascens*, with some participation of *Artemisia kemrudica*, *Salsola orientalis*, and *S. arbuscula*. Plants of the latter species can be taller than *S. gemmascens* but are sparse. The lower (herbaceous) layer, formed by 20 to 23 species of ephemers and ephemeroids, is no higher than 20 cm. The dominant species here is the desert sedge *Carex pachystylis*; other co-dominant ephemers are *Eremopyrum orientale*, *Ceratocephala falcata*, and the species *Leptaleum filifolium*, which is specific for some tetyr communities. In summer and fall, there is significant participation of annual plants with extended vegetative periods, such as *Climacoptera lanata*, *Salsola sclerantra*, *Halimocnemus villosa*, and *H. karelinii*. Soil in tetyr communities is covered by clusters of specific flour-white lichens.

In total, the tetyr formation is one of the most "desert" kinds, judging from the sparse coverage, poor species diversity, and low biomass/ha values. Within this formation, four goups of associations can be separated: typical, petrophyte, psammophyte, takyr, and halophyte communities of *S. gemmacsens*. Of these, typical tetyr associations are the most common ones.

*1.1.2.2. Biyurgun Formation (*Anabasis Salsa*) (table 4).* Biyurgun formation is widespread in the deserts of Middle Asia and Kazakhstan, especially in the subzone of northern deserts, and is fairly well described and studied. Kuznetsov (1959, 1966) conducted a study of biyurgun formation for the entire arid zone

Table 4. The vegetation of the formation *Anabaseta salsae.*

Species	Height (cm)	Abundance (Drude scale)	Coverage (%)	Density (plants/ha)
Shrubs:				
Atraphaxis spinosa	40–50	Sol	1	–
Semishrubs:				
Nanophyton erinaceum	5–10	Cop^1	4–5	2,500–5,600
Salsola gemmascens	15–20	$Sp\text{-}Cop^1$	2–3	3,000–5.000
Salsola orientalis	25–40	Sol-Sp	1	300–600
Artemisia kemrudica	20–25	Cop^{1-2}	2–3	2,000–3,500
Anabasis salsa	15–30 (40)	Cop^3	30–35	12,000–50,000
Anabasis eriopoda	10–15	Cop^{1-3}	20–55	6,000–22,000
Annual herbaceous species:				
Ceratocarpus utriculosus	5–10	Sol	<1	–
Suaeda arcuata	20–30	Sol	<1	–
Climacoptera lanata	10–12	Sol	<1	–
Halimocnemis karelinii	5–7	Sol	<1	–
Ceratocephala falcata	2–3	Sol	<1	–
Strigosella africana	5–6	Cop^1	1	–
Leptoleum filifolium	3–5	Sol	<1	–
Goldbachia laevigata	5–10	Sol-Sp	<1	–
Tetracme quadricornis	5–10	Sol	<1	–
Arnebia decumbens	5–10	Sol	<1	–
Nonea caspica	5–10	Sol-Sp	<1	–
Senecio subdentatus	5–8	Sol	<1	–
Amberboa turanica	5–10	Sol	<1	–
Eremopyrum orientale	5–7	Sol	<1	–
Lepidium perfoliatum	5–15	Sol	<1	–

the former USSR; in separate deserts, this formation was studied in detail by Korovin and Granitov (1949), Kogan (1954), Kubanskaya (1956) and Rodin (1963).

The communities of *Anabasis salsa* are especially characteristic for the Ustyurt Plateau and takyrs of the ancient delta of the Amudarya; small patches of biyurgun are found also within the sand dunes of the Trans-Unguz Karakum. Biyurgun formation is found on grey-brown, solonchaks, loams and grey-brown primitive (takyr) soils with a compressed surface covered by a film of algae.

The dominant species, *Anabasis salsa*, is a small shrub or semishrub, 10–15 to 20–40 cm high; pure *A. salsa* communities cover 20 to 30% of the soil surface, with the density 40,000 to 50,000 plants/ha. This number can drop to 14,000 to 18,000 plants/ha in the communities when other species co-dominate (e.g., *Artemisia kemrudica* or *Salsola gemmascens*; Nechaeva 1956); generally, the density can vary from 10,000 to 80,000 plants/ha (Korovin and Granitov 1949).

Communities of *A. salsa* usually appear to have only one (upper) layer (15 to 30 cm high) formed primarily by biyurgun, rarely in combination with *Artemisia*

kemrudica , *Salsola gemmascens*, or *S. orientalis*. Another species typical of this layer (but somewhat smaller, 5 to 15 cm high) is *Nanophyton erinaceum*.

A lower, herbaceous layer may sometimes be expressed. It is homogeneous and includes such ephemers as *Leptaleum filifolium*, *Strigosella africana*, *Lepidium perfoliatum*, *Goldbachia laevigata*, *Ceratocephala falcata*, *Arnebia decumbens*, and *Eremopyrum orientale*, as well as annual plants with summer and fall vegetative periods such as *Climacoptera lanata*, *Suaeda arcuata*, and *Halimocnemis karelini*. The diversity of species within this formation in Turkmenistan deserts is low (20 to 25); interestingly, Kubanskaya (1956) found 122 species for biyurgun formation in the Betpakdlala Desert (Kazakhstan), and Kuznetsov (1959) listed 218 species found within this formation throughout the arid zone of the former Soviet Union.

Annual herbaceous species constitute 40 to 90% of the species list, with annual ephemers representing 30 to 60%. The absence of perennial herbaceous species (including ephemeroids) is notable, and there are one to five (10 to 50%) species of semishrubs. Four groups of associations are separated within the biyurgun formation: typical, petrophyte, and takyr associations.

*1.1.2.3. Kevreik Formation (*Salsola Orientalis*) (table 5).* These communities are not as well studied as others, probably due to their limited distribution. Granitov (1967) found that *S. orientalis* is relatively common in the Southeast Kizylkum Desert (Uzbekistan) but rarely dominates plant communities. The kevreik formation was studied by Korovin and Granitov (1949), Nechaeva (1956), Rodin (1963), and Granitov (1967). In Turkmenistan, kevreik communities are common in the ancient alluvial plain of the Kunyadarya River and in the Meshed-Messerian Plain (Rodin 1963). Large areas covered by kevreik communites were recorded on the *kyr* plateau which lies between Koimat and the Uchtagan Sands (Nechaeva 1966), as well as in the Tashauz Region of Northwest Turkmenistan, near Edikhauz and Butentau. These communites grow mainly on the lands of ancient irrigation (Rodin 1963), on grey-brown, slightly loamy or sandy soils (rarely on sands).

The dominant species, *Salsola orientalis*, is a small semishrub, 30 to 50 cm high; it covers 20 to 30% of the soil surface and has a density of 5,000–7,000 to 10,000–12,000/ha. Community structure is similar to that of *S. gemmascens*; the upper layer is formed by *Salsola orientalis*, with sparse *Artemisia kemrudica*, *Salsola arbuscula*, and *S. gemmascens*. Rare *Haloxylon aphyllum* can form a sparse superlayer. The second (lower) layer is built of ephemers (15 species), ephemeroids, and certain annual Chenopodiaceae with a summer – fall vegetative period. In spring, the most conspicuous plants are *Carex pachystylis*, *Ceratocephala falcata*, *Leptaleum filifolium* and *Eremopyrum orientale*. Among less abundant species are *Strigosella grandiflora*, *S. circinata* , *Astragalus oxyglottis*, *Lappula semiglabra*, *Arnebia decumbens*, and *Koelpinia linearis*. In summer and fall, the annual species of Chenopodiaceae found in these communities are*Climacoptera lanata*, *Salsola sclerantha*, *Halimocnemis karelinii*, *Ceratocarpus utriculosus*, and *Girgensonnia oppositiflora*. Floristically,

Table 5. The vegetation of the formation *Salsoleta orientales*

Species	Height (cm)	Abundance (Drude scale)	Coverage (%)	Density (plants/ha)
Trees:				
Haloxylon aphyllum	80–100	Sol	1	–
Shrubs:				
Salsola arbuscula	40	Un	<1	–
Small semishrubs:				
Salsola orientalis	35–40	Cop[2]	20–25	5,000–12,000
Salsola gemmascens	10–20	Sp	2–3	2,300–3,400
Artemisia kemrudica	20–30	Sp	1–2	1,400–2,000
Anabasis eriopoda	10–15	Sol-Sp	1	–
Perennial herbaceous species:				
Carex pachystylis	10–150	Cop[1]	1–2	–
Annual herbaceous species:				
Ceratocarpus utriculosus	5–10	Sol	<1	–
Climacoptera lanata	10–15	Sol	<1	–
Salsola sclerantha	10–12	Sol	<1	
Halimocnemis karelinii	5–6	Sol	<1	–
Ceratocephala falcata	2–3	Sp-Cop[1]	1	–
Hypecoum pendulum	10–15	Sol	<1	–
Strigosella grandiflora	20–25	Sp	1–2	–
S. circinata	10–15	Sp	<1	–
Leptaleum filifolium	5–10	Sp-Cop[1]	1	–
Tetracme quadricorris	5–10	Sol	<1	–
Astragalus oxyglottis	5–6	Sol-Sp	<1	–
Arnebia decumbens	8–10	Sol	<1	–
Lappula semiglabra	10–12	Sol	<1	–
Nonea caspica	5–10	Sol	<1	–
Koelpinia linearis	10–12	Sol	<1	–
Epilasia hemilasia	10–15	Sol	<1	–
Amberboa turanica	5–10	Sol-Sp	<1	–
Eremopyrum orientale	5–6	Sol	<1	–
Girgensonnia oppositiflora	10	Sol-Cop[1]	1	–

this formation is not very different from that of *S. gemmascens*; the list of species for kevreik formation includes 20 to 60 species (Rodin 1963; Rustamov 1973). Of these, 66 to 75% are annual plants (mostly ephemers), and 13 to 27 species are small semishrubs. Perennials are represented here only by *Carex pachystylis*.

Within the kevreik formation, we separate typical and psammophyte kevreik groups of associations.

1.1.3. Succulent-Halophyte Deserts

Communities belonging to this group of formations are widespread on salt areas (solonchaks) and solonchak soils. The most typical formation is that of

*1.1.3.1. Sarsazan (*Halocnemum Strobilaceum*) (table 6).* Characteristics of these communities can be found in many sources (Prozorovsky 1940; Korovin

Table 6. The vegetation of the formation *Halocnemeta strobilaceae*

Species	Height (cm)	Abundance (Drude scale)	Coverage (%)	Density (plants/ha)
Trees:				
Haloxylon aphyllum	40–70	Sp	2–3	100–300
Shrubs:				
Tamarix sp.	40–60	Sol	1–2	200–400
Halostachys caspica	60–80	Sol	1–2	200–300
Nitraria schoberi	60–70	Sol	1	200
Lycium ruthenicum	30–40	Sol	1–2	200–300
Reaumuria fruticosa	40–50	Sol	1–2	200
Salsola arbuscula	40	Sol	1–2	100–300
Small shrubs:				
Limonium subfruticosum	35–40	Sol	1–2	200–400
Small semishrubs:				
Halocnemum strobilaceum	20–40	Cop^{1-3}	10–20 (25)	700–4,500
Salsola gemmascens	10–15	Sol	1	300
Perennial herbaceous species:				
Frankenia hirsuta	20–30	Sol-Sp	<1	–
Alhagi persarum	20–30	Sol	<1	–
Annual herbaceous species:				
Climacoptera lanata	10–20	Sol-Sp	<1	–
Salsola sclerantha	10–15	Sol	<1	–
Halimocnemis longifolia	10–15	Sol-Sp	<1	–
Petrosimonia glauca	10	Sol	<1	–

Granitov 1949; Kogan 1954; Kubanskaya 1956; Korovin 1961; Rustamov 1962; Rodin 1963; Granitov 1967); however, only a few of these authors published descriptions of concrete plots and floristic lists.

Sarsazan communities are found on typical solonchaks and in solonchak depressions covered by specific small salt hills (*chokalaks*). The largest areas occupied by *H. strobilaceum* are located in Southwest Turkmenistan around the ancient delta of the Atrek River, along the Kelkor solonchak, and on the shores of Karabogazgol Bay. These communities can be also found in combinations with other succulent-halophyte desert vegetation. In the Karakum Desert, small areas occupied by *H. strobilaceum* are typical for the solonchak depressions with close ground waters.

The dominant species, *Halocnemum strobilaceum*, is a stem succulent, leafless, small semishrub, 20 to 40 cm high. Its growth is not depressed even with high salt concentration in the soil. Roots of sarsazan can penetrate to the depth from 40–50 cm (Rumyantseva 1953) to 130–140 cm if ground water lies deep (Rustamov 1962). Sarsazan plants cover 10 to 20% of the soil surface, very rarely up to 25%. Its density varies from 700–1,200 to 2,200–4,500 plants/ha.

Typical sarsazan communities have only one layer, often formed exclusively by *H. strobilaceum*. Its characteristic flat crowns can be seen on small (50 to 100 cm high) hills of salt (*chokalaks*) standing two to three meters apart; there is

virtually no vegetation between chokalaks. When mineralized groundwater lies at deeper levels, sarsazan communities can include a number of species less tolerant to salt concentrations, such as *Halostachys caspica*, *Limonium subfruticosum*, *Nitraria schoberi*, and *Frankenia hirsuta*. Very rarely are found depressed shrubs of *Tamarix hispida*, *Haloxylon aphyllum*, and *Lycium ruthenicum*. Under lower soil salt content, the herbaceous cover is built mostly of annual Chenopodiaceae: *Climacoptera lanata*, *Salsola sclerantha*, *Halimocnemis longifolia*, and *Petrosimonia glauca*; sometimes, *Alhagi persarum* is present. Usually, there are no herbaceous species with winter-spring development. Diversity in sarsazan communities in Turkmenistan is very low, totalling about 15 species. Granitov (1967) described fifteen sarsazan associations from the Kizylkum Desert (Uzbekistan); of these, thirteen had one to sixteen species, and only two were unusually rich (31 and 39 species, including 5 or 6 species of ephemers). Kubanskaya (1956), however, listed 59 species for the sarsazan formation in the Betdpakdala Desert (Kazakhstan), and 53 species for the sarsazan association proper (including five species of ephemers and ephemeroids); interestingly, the coverage on these plots reached 50 to 65% which is a very significant figure for the communites of *H. strobilaceum*.

About 50% of all species in sarsazan communites are arboreal plants (mostly shrubs and semishrubs), about 25% are annual non-ephemerous species, and there are no ephemers. Even fewer species (13%) are small semishrubs and perennial herbaceous species.

Within the sarsazan formation, we separate two groups of associations: typical and meadow sarsazan associations.

1.2. Desert Shrub and Large Shrub Vegetation

This class of formations is represented by two groups: saksaul deserts (1.2.1) and psammophyte shrub deserts (1.2.2.). Desert shrub and large shrub vegetation is widespread in sand deserts, in clay desert (takyr) lowlands, and in modern and ancient river deltas.

1.2.1. Saksaul Deserts

This group includes formations of white saksaul (*Haloxylon persicum*), black saksaul (*Haloxylon aphyllum*), and a mixed formation with both *Haloxylon persicum* and *H. aphyllum*.

1.2.1.1. White Saksaul Formation (Haloxylon persicum) (table 7). This is the most characteristic formation of the sand dunes of the Karakum Desert. Within Turkmenistan, the white saksaul communities are widespread in the Trans-Unguz, Lowland and Southeast Karakum, as well as in the sand massifs of Uchtagan, Kumsebshen, and Chilmamedkum; they are found typically in sand dunes, more rarely in lowlands, depressions, and intradune depressions. These communities are found not only on sands proper, but also on the thick sand deposits covering maternal rocks. *Haloxylon persicum* also grows on weakly

Table 7. The vegetation of the formation *Haloxyleta persica*

Species	Height (cm)	Abundance (Drude scale)	Coverage (%)	Density (plants/ha)
Shrubs:				
Haloxylon persicum	140–250	Cop^{1-3}	15–25	400–900
Calligonum caput-medusae	140–200	Sol	2–3	100–200
Calligonum setosum	80–110	Sol-Sp	2–4	100–300
Salsola richteri	140	Sol	1–2	100
Ephedra strobilacea	50–100	Sol-Sp	2–3	200–400
Perennial herbaceous species:				
Stipagrostis pennata	40–50	Sp	2–3	100–300
Astragalus flexus	25–30	Sol	<1	–
Rheum turkestanicum	20–30	Sol-Sp	1–2	–
Eremurus anisopterus	30–40	Sol	1	–
Carex physodes	15–20	Cop^{1-3}	10–15	–
Gagea divaricata	5–7	Sol-Sp	<1	–
Tulipa sogdiana	10–15	Sol-Sp	<1	–
Annual herbaceous species:				
Ceratocephala falcata	5–6	$Sp\text{-}Cop^{1}$	1	–
Consolida rugulosa	30–35	Sol	<1	–
Hypecoum pendulum	20–30	Sol-Sp	1	–
Roemeria hybrida	25–40	Sol	<1	–
Streptoloma desertorum	10–20	Sol	<1	–
Isatis minima	50–60	Sol	<1	–
Strigosella circinnata	30–40	Sol-Sp	<1	–
Strigosella grandiflora	40–55	Sol	<1	–
Tetracme recurvata	20–25	Sol	<1	
Astragalus arpilobus	10–15	$Sp\text{-}Cop^{1}$	2–3	–
Erodium oxyrrhynchum	15–25	Sol-Sp	<1	–
Arnebia decumbens	20–25	Sol-Sp	<1	–
Lappula semiglabra	20	Sol	<1	–
Nonea caspica	15–20	Sol	<1	–
Koelpinia linearis	25	Sol	<1	–
Microcephala lamellata	10–12	Sol	<1	–
Senecio subdentatus	20–25	Sol-Sp	<1	–
Amberboa turanica	25–30	Sol	<1	–
Epilasia hemilasia	25–30	Sol	<1	–
Eremopyrum orientale	15–20	Sol	<1	–
Anisantha tectorum	25–30	Sp	1	–
Cutandia memphitica	20–30	Sol-Sp	<1	–

developed sandy soils of grey-brown type, which are humus-poor and sometimes low in salt content.

The communities of *H. persicum* have probably the most complex structure of all the desert plant communities of Turkmenistan; they contain several layers – at least two or three. The upper (first) layer is 1.5 to 2 meters high and consists of *H. persicum* and other large shrubs such as *Salsola richteri*, *Calligonum caput-medusae*, *C. setosum*, *C. eriopodum*, and *Ephedra strobilacea*. The second layer is represented by shrubs and semishrubs which are up to one meter high:

Ephedra intermedia, *Artemisia kelleri*, and *Astragalus spp.* A special sublayer can be formed by small semishrubs such as *Convolvulus divaricatus*, *C. korolkovii*, and *Acanthophyllum* sp.

The third (herbaceous) layer is formed by a large cespitose grass, *Stipagrostis pennata*, as well as by other perennials (*Heliotropium argusioides*, *Tournefortia sibirica*, and *Astragalus chivensis* and biennial *Cousinia oxiana*). Among perennial species with short vegetative periods (ephemeroids), a significant role is played by a desert sedge, *Carex physodes*, which creates thick turf; also found are *Rheum turkestanicum* and *Eremurus anisopterus*. Most herbaceous species are ephemerous (especially in years with high precipitation, when up to 30 or more species can be detected).

The white saksaul formation, therefore, is floristically diverse and may include representatives of almost all desert ecobiomorphs. Rodin (1963) listed more than 150 species for this formation in West Turkmenistan; within the associations, this number varies from 30 to 80, and on concrete plots there are usually 30 to 35 species.

In Northwest Turkmenistan, white saksaul communities include about 70 species (our data); in Southwest Kizylkum (Uzbekistan), from 28 to 48 species (Granitov 1967); and in the sand deserts of Kazakhstan, white saksaul communities also include several dozen species (Kurochkina 1966). Annual herbaceous plants prevail (51 to 64% of all species), especially ephemers (42 to 64%). The combined share of perennial and annual herbaceous plants is often more than 50% of the species list, and in ephemerous or ephemeroid white saksaul associations this share reaches 79%. Shrubs constitute 10 to 15% of all species.

The dominant species, *Haloxylon persicum*, is a large shrub, 3 to 5 meters high. It forms a short trunk (10–20 cm) and can produce six to seven levels of branches (Nechaeva *et al.* 1973). White saksaul lives to 30 years; its vegetative propagation and seed production do not occur every year. It has a root system of universal type which penetrates down to a depth of four to six meters (Petrov 1935; Nechaeva *et al.* 1973). The ratio of aboveground to underground dry biomass is 1:0.6.

Haloxylon persicum does not form dense thickets but rather grows as solitary bushes, with a density 100–200 to 400–700 plants/ha, and coverage of 10 to 30%. White saksalul communites are valued as pastures although they produce low edible biomass (0.3 to 0.5 ton/ha); they are used in all seasons (although primarily in winter). Size of white saksaul shrubs varies significantly with ecological conditions, as do number and abundance of species in these communities. Extensive grazing and woodcutting for many years in certain areas has led to the replacement of white saksaul communities by those of kandym (*Calligonum* sp. div.). Rodin (1963) separated three groups of associations within the white saksaul formation in West Turkmenistan: typical, ephemerous and ephemeroid, and moss/white saksaul associations. In the West Uzboi area we (Rustamov 1962) found three associations: *Haloxylon persicum* – *Stipagrostis pennata* + *Carex physodes* ass.; *Haloxylon persicum* – *Carex*

physodes ass.; and *Haloxylon persicum* + *Calligonum* sp. div. – *Stipagrostis pennata* + *Carex physodes* ass. For the Karakum Desert, Rodin (1963) listed seven common associations; the most widespread there are communities of *Haloxylon persicum* and *Carex physodes*. Within these communities, *H. persicum* is usually abundant and well developed.

1.2.1.2. Black Saksaul Formation (Haloxylon aphyllum) (table 8). These communities are found primarily in modern and ancient river deltas, as well as in depressions within the sand deserts of Middle Asia. Within Turkmenistan, the major areas covered by black saksaul are found in the lowland with ancient alluvial deposits along the Amudarya River, around the Sarykamysh Depression, in the Assake-Audan Depression (Rodin 1963), and within the sand desert of Southeast Karakum. Small areas of *H. aphyllum* can be found in the deserts of West and Northwest Turkmenistan, and also within the sands of the Trans-Unguz and Lowland Karakum, Uchtagan, and Kumsebshen.

Table 8. The vegetation of the formation *Haloxyleta aphylla*

Species	Height (cm)	Abundance (Drude scale)	Coverage (%)	Density (plants/ha)
Trees:				
Haloxylon aphyllum	60–220	Sol	1	–
Shrubs:				
Calligonum setosum	80–100	Sol	1	–
Salsola richteri	40	Un	<1	–
Ephedra strobilacea	80–100	Sol	1	–
Smirnowia turkestana	80–100	Sol	1	–
Astragalus excedens	80–100	Sol	1	–
Tamarix ramosissimum	80–100	Sol	1	–
Salsola arbuscula	80–100	Sol	1	–
Small semishrubs:				
Salsola gemmascens	40	Un	<1	–
Artemisia badhysi	40	Un	<1	–
Salsola orientalis	40	Un	<1	–
Perennial herbaceous species:				
Stipagrostis pennata	10–150	Cop[1]	1–2	–
Carex physodes	10–150	Cop[1]	1–2	–
Eremurus anisopterus	10–150	Cop[1]	1–2	–
Tulipa sogdiana	10–150	Cop[1]	1–2	–
Alhagi persarum	10–150	Cop[1]	1–2	–
Heliotropium dasycarpum	10–150	Cop[1]	1–2	–
H. argusioides	10–150	Cop[1]	1–2	–
Allium fibrosum	10–150	Cop[1]	1–2	–
Annual herbaceous species:				
Cutandia memphitica	10–15	Sol	<1	–
Eremopyrum orientale	5–6	Sol	<1	–
Halimocnemis longifolia	5–6	Sol	<1	–
Salsola incanescens	5–6	Sol	<1	–
S. sclerantha	5–6	Sol	<1	–

Table 8. Continued

Species	Height (cm)	Abundance (Drude scale)	Coverage (%)	Density (plants/ha)
Climacoptera lanata	5–6	Sol	<1	–
Ceratocephala falcata	2–3	Sp-Cop[1]	1	–
Consolida rugulosa	2–3	Sp-Cop[1]	1	–
Hypecoum pendulum	10–15	Sol	<1	–
Streptoloma desertorum	10–15	Sol	<1	–
Papaver pavoninum	10–15	Sol	<1	–
Atriplex dimorphostegia	10–15	Sol	<1	–
Senecio subdentatus	10–15	Sol	<1	–
Roemeria hybrida	10–15	Sol	<1	–
Isatis minima	10–15	Sol	<1	–
Strigosella circinnata	10–15	Sp	<1	–
Strigosella grandiflora	20–25	Sp	1–2	–
Tetracme recurvata				
Astragalus arpilobus	5–6	Sol-Sp	<1	–
Erodium oxyrrhynchum	10–15	Sp	<1	–
Arnebia decumbens	8–10	Sol	<1	–
Lappula semiglabra	10–12	Sol	<1	–
Nonea caspica	5–10	Sol	<1	–
Amberboa turanica	5–10	Sol-Sp	<1	–
Epilasia hemilasia	10–15	Sol	<1	–
Koelpinia linearis	10–12	Sol	<1	–
Matricaria lamellata	10–15	Sp	<1	–

In the modern river valleys and temporary (seasonal) river beds, communities of *Haloxylon aphyllum* form an ecological transition to riparian forests (tugais), e.g., in the lower portion of the Kunyadarya, Murghab, and Tedzhen deltas, along the Uzboi, in the Sarykamysh Depression, and in the ancient delta of the Amudarya. Small patches of *H. aphyllum* are found in the large salt depression of Eroylanduz in Badghyz.

Communities of black saksaul are found mainly in places with close ground water and additional surface water supply, on primitive (often takyr) soils such as serozyom and grey-brown, usually solonchak or slightly solonchak, sometimes gypsum-bearing, and rarely sandy soils. *H. aphyllum* has high ecological plasticity and can form different ecobiomorphs. In valley-like depressions with close ground water, black saksaul can form peculiar forests, in which it grows as a large shrub or even a tree, seven to nine meters high (Nechaeva *et al.* 1973). In small depressions, *H. aphyllum* is four to five meters high and grows sparsely, forming mixed saksaul communities with *H. persicum*. A specific ecobiomorph of black saksaul, a small, one-to-two meter tall tree, grows on grey-brown soils of kyrs in Northwest Turkmenistan. In the upper portion of the Tedzhen and Murghab deltas, *H. aphyllum* grows sparsely as a small-sized (1 to 1.5 m) shrub.

The total number of species in *H. aphyllum* formation has been estimated as

132 for all communites in West Turkmenistan (Rodin 1963); in some local communities, such as those in Repetek (Southeast Karakum), species diversity can be more than 140 species (Mikhelson 1955). Our data (Rustamov 1962) showed 30 to 35 species in *H. aphyllum* communities on description plots along the western part of Uzboi. Of 132 species found in black saksaul formation listed by Rodin (1963), 40 species were shrubs and semishrubs, and 10 species were perennial herbaceous plants with prolonged vegetation; there were also 13 species of ephemeroids, 20 summer – fall annual herbaceous species, and 49 species of ephemers.

The concrete plots in West Turkmenistan usually have only 7 to 18 species (Rodin 1963). Black saksaul communities have a simple structure: the upper layer is built primarily of *H. aphyllum*, sometimes together with *Salsola richteri*, *Calligonum* sp. div., and *Reaumuria oxiana*. In some cases there is a sparse synusium of small shrubs, usually of *Salsola arbuscula*, and rarely of *Reaumuria fruticosa* and *Atraphaxis spinosa*. The second layer (30–40 cm) is built predominantly by small semishrubs: *Artemisia kemrudica*, *Salsola orientalis*, and (less often) *Salsola gemmascens*. Their density and abundance are usually low.

The third (lowest) layer is formed mainly by annual herbaceous plants; ephemeroids (except *Carex physodes*) and perennial species with a long vegetative period are nearly absent. Among the common ephemers are *Eremopyrum orientale*, *Anisantha tectorum*, *Ceratocephala falcata*, *Leptaleum filifolium*, *Arnebia decumbens*, *Lappula semiglabra*, and *Amberboa turanica*. Ephemeroids are represented by *Carex physodes* and *C. pachystylis*; rarely found are *Ferula assafoetida*, *Tulipa sogdiana*, and *Allium sabulosum*. The desert moss *Tortula desertorum* often completely covers the soil in black saksaul communities, sometimes together with lichens. The moss saksaul communities are especially typical of the interdune depressions in the Trans-Unguz Karakum. There, the black saksaul and other shrubs are sparse, small and suppressed in growth, and there are many dried branches and dead shrubs.

The dominant species of the formation, *Haloxylon aphyllum*, has a peculiar growth form. It can reach 5 to 8 meters high, with a trunk of 50 to 70 cm long and 25 to 40 cm in diameter; it produces seven to eight levels of branches. Black saksaul lives 50 to 70 years, and some individual plants have been found to be about 100 years old. It matures by age 25 or 30; seed production starts at 5 to 6 years but does not occur every year. A well-developed root system penetrates down to four to seven meters (Petrov 1935; Prikhodko 1968). The ratio of aboveground to underground dry biomass is 1:0.5, often with 100 to 150 kg of aboveground dry biomass. Under favorable conditions for seed propagation, black saksaul communities can restore themselves in the place of cuttings in about ten years. In places where *H. aphyllum* has not been cut or removed, there is usually a great amount of dried saksaul (often more than live shrubs).

Within the formation of *H. aphyllum* we (Rustamov 1973) distinguished typical, ephemer-ephemeroid, and moss associations. Rodin (1963) separated five groups of associations for West Turkmenistan: typical, tugai, petrophyte,

semisavanna, and moss black saksaul associations. Of these, the typical black saksaul communities are primarily concentrated in the ancient alluvial deposits along the Amudarya River and around the Sarykamysh Depression. Tugai communities of *H. aphyllum* are widespread in the Uzboi Valley, along the dry beds of Daryalyk and Daudan, and in the Kunyadarya lowland; small patches of tugai black saksaul communities are found also on the kyrs of the Trans-Unguz area and on the plateaus of Eshek-Ankren-Kyr and Tarimkaya. The semisavanna (ephemer-ephemeroid) black saksaul communities are common in the Trans-Unguz Karakum, around the Sarykamysh, in the upper portion of the Uzboi, and in the sands of Uchtagan. Most widespread in Turkmenistan are the moss communities of *H. aphyllum* which are found in the Trans-Unguz Karakum, around the Sarykamysh, on the plateaus of Eshek-Ankren-Kyr and Tarimkaya, in the upper portion of the Uzboi, and in the sands of Uchtagan.

1.2.1.3. Mixed Saksaul Formation (Haloxylon persicum and Haloxylon aphyllum). The communities of this formation are far less common than pure white or black saksaul ones. Sometimes, however, they occupy significant areas, e.g., in the Uzboi Valley, in the eastern part of the Trans-Unguz Karakum, and in the extreme southeastern Karakum desert, between the Amudarya and Murghab Rivers. Floristically, these communities are also mixed and probably closer to those of white saksaul.

Haloxylon persicum and *Haloxylon aphyllum* co-dominate in these communities and form the upper layer; other shrubs present include *Salsola richteri*, *Ephedra strobilacea*, and various *Calligonum* species (usually *C. setosum*). Small semishrubs such as *Convolvulus korolkovii* and *Artemisia santolina* are found solitarily. Perennial long-vegetating herbaceous plants are represented by sparse *Stipagrostis pennata*; the most common are ephemeroid *Carex physodes* and various ephemers. There are also typical "patches" of halophyte species around black saksaul plants; in spring, these patches are distinguished by the presence of ephemerous species.

The number of species in mixed saksaul communities varies from 15 to 55; there are usually 5 to 20 species of ephemers and 7 to 19 species of shrubs and semishrubs. Three groups of associations are distinguished: typical, petrophyte, and moss/mixed saksaul associations.

1.2.2. Psammophyte Shrub Deserts

This group of formations is characteristic for sand dunes, including both stabilized and non-stabilized sand (barkhans). Typical formations are dominated by syuzen (*Ammodendron conollyi*), dzhuzgun (*Calligonum* sp. div.), cherkez (*Salsola richteri*), and bordzhok (*Ephedra strobilacea*).

1.2.2.1. Syuzen Formation (Ammodendron conollyi). These communities are found on non-stabilized sands in the Karakum Desert. Syuzen *(Ammodendron conollyi)*, the endemic species of Middle Asian sand deserts (Karakum and Kizylkum), dominates these communities. It is a tree, 4 to 10 meters high and 8

to 10 cm in trunk diameter, with a lifespan of 50 to 60 years. *A. connolyi* produces each year up to 900 seeds which may retain the ability to germinate for several decades; Perskaya (1963) reported syuzen seeds that gave shoots after 60 years of storage in a herbarium. Vegetative propagation of syuzen is achieved by the formation of offshoots from horizontal roots which are exposed from under the sand by wind action.

In the southern part of the Central Karakum Desert, abundance of syuzen can reach 75 plants/ha, and biomass 570 kg/ha (Nechaeva *et al.* 1973). The root system is of the universal type, which develops vertically (main root penetrating 2 to 3 m deep) as well as horizontally (side roots which lie in the two upper meters of the soil and spread sidewards to 5 to 8 m).

Floristically, this formation is very poor and is built primarily of perennial herbaceous psammophytes. Of all trees and large shrubs, only *Ephedra strobilacea* can be found here; shrubs and small shrubs are represented by *Calligonum caput-medusae*, *C. arborescens*, *C. microcarpum*, *Eremosparton flaccidum*, *Smirnowia turkestana*, and *Convolvulus divaricatus*. Only about five perennial herbaceous non-ephemeroid species are found here, with *Stipagrostis pennata* dominant; ephemeroids are absent. Common summer – fall annuals include *Agriophyllum minus*, *A. latifolium*, *Corispermum papillosum*, *C. lehmannianum*, *Horaninovia ulicina*, and *Chrozophora gracilis*. Compared to other sand communities, very few ephemers are recorded here: *Isatis emarginata*, *Chartoloma platycarpum*, *Citharelloma vernum*, *C. lehmanni*, and *Spirorhynchus sabulosus*.

1.2.2.2. Dzhuzgun Formation (Calligonum sp. div.). These communities are dominated by species of the extremely polymorphic genus *Calligonum*; they are typical of non-stabilized and stabilized sands alhough they occupy small areas and have highly variable composition of dominant and subdominant species. More than ten *Calligonum* species are found, including *C. eriopodum*, *C. caput-medusae*, *C. arborescens*, *C. rubens*, *C. leucocladum*, *C. setosum*, and *C. microcarpum*. Other shrubs are *Salsola richteri*, *Halothamnus subaphyllus*, *Smirnovia turkestana*, and sometimes solitary *Haloxylon persicum*; semishrubs *Mausolea eriocarpa*, *Convolvulus divaricatus*, and *Acanthophylum elatus* are also found. Common herbaceous plants are *Stipagrostis pennata*, *Heliotorpium dasycarpum*, *Ferula assafoetida*, *F. litwinowiana*, and *Senecio subdentatus*.

Dominant species, dzhuzguns (*Calligonum* sp. div.), often participate in other desert plant communities, particularly ones of *Haloxylon persicum*. Among *Calligonum* species, there are tree-like forms and large shrubs (3 to 6 m high), as well as medium and small shrubs (0.6 to 2.5 m high). Depending on growth conditions and especially on level of ground water, the same species can acquire different growth forms, e.g., *Calligonum eriopodum* and *C. caput-medusae*. The root system of dzhuzgun is universal and specialized; numerous roots are developed horizontally next to the sand surface and can stretch 15 to 30 m in length. The main root develops within the first year, and side roots form later. On the portions of the *Calligonum* stem that become covered by sand, additional

roots may develop which can extract atmospheric and condensed moisture from the surface layer of sand (Petrov 1933, 1935). In nature, *Calligonum* propagates only by fruits and does not form root offshoots.

The abundance of *Calligonum* varies with habitat, from 50–100 plants/ha on non-stabilized (barkhan) sands to 100–300 plants/ha on stabilized sands. Annual productivity of green biomass varies from 50 to 150 kg/ha (Nechaeva *et al.* 1973).

The communities of *Calligonum* are one of the stages in the natural succession of sand vegetation from non-stabilized to stabilized sands. Most of present *Calligonum* communities are believed to be replacements of former white saksaul communities which were destroyed by human activities.

1.2.2.3. Cherkez Formation (Salsola richteri). This is widespread on all types of sands along the Amudarya, in Southwest Turkmenistan, and in the Lowland Karakum. These communities are also found around old, rarely-used wells along the West Uzboi.

The dominant species is cherkez (*Salsola richteri*), a constant subdominant of many other psammophyte communities. It is a large shrub, 1.5 to 2 m high; its lifespan is 25 to 30 years.

The root system of cherkez is of a universal type, developed both in vertical and horizontal directions. The main root goes down to 120 cm, the side roots stretch 7 to 9 m and give vertical extensions which go down 3 to 4 m and reach the ground water level (Petrov 1933, 1935). On sands where ground water level is deep (20 to 25 m), the roots of cherkez grow mostly horizontally, whereas on sands with close water level (8 to 10 m) they are developed primarily vertically. As do many other shrubs, *S. richteri* forms additional roots on stems covered by sand, but it does not produce shoots from roots which are exposed by wind.

The vegetative period of cherkez is extended from late March to October or November; it flowers from May to July and forms fruit in September to October. One plant can produce up to 1300 seeds. The abundance of *S. richteri* in the Karakum desert varies from 15 to 100 plants/ha, and the annual productivity of green biomass is 30 to 50 kg/ha (Nechaeva *et al.* 1973).

From 12 to 20 species of plants have been recorded in the *S. richteri* formation; all are adopted to life in non-stabilized sands (Rodin 1963). From seven to ten of these species are large shrubs (*Calligonum* sp. div., *Eremosparton flaccidum*, and *Smirnowia turkestana*), and small semishrubs (*Artemisia santolina*, *A. dimcana*, *Convolvulus divaricatus*, and *Acanthophyllum elatus*). There are only five herbaceous species with a long vegetative period: *Stipagrostis karelinii*, *S. pennata*, *Heliotropium argusioides*, *H. dasycarpum*, and *Cistanche flava*; the common ephemeroids are *Prangos diduma* and *Carex physodes*. There are few annual herbaceous species: summer – fall annual species are represented by *Agriophyllum minus*, *Horaninovia ulicina*, and *Salsola leptoclada*; and ephemers, by *Euphorbia turkomanica*, *Lappula semiglabra*, *Anisantha tectorum*, *Senecio subdentatus*, and *Cutandia memphitica*.

Salsola richteri and related *S. paletzkiana* are used as important species for

sand-stabilizing melioration in the desert zone of Middle Asia. They also have importance for the livestock industry both as erosion inhibitors of pasturelands and as feed (young shoots, leaves, and seeds of cherkez are consumed by grazing sheep).

1.2.2.4. Bordzhok Formation (Ephedra strobilacea). Vegetation belonging to this formation is found in barkhan sands of the northern part of Central Karakum and on solonchaks of this area; it also occupies small territories around the sands of Chilmamedkum, Khanbaagykum, and the sands of the Dardzha Peninsula of the Caspian (Rodin 1963).

The dominant species, bordzhok (*Ephedra strobilacea*), is a gymnosperm shrub, one to two m high; it can participate as a subdominant in *Haloxylon persicum* and many other psammophyte communities. Bordzhok is found in the deserts of Middle Asia (Karakum and Kizylkum) on thick dune sands but also is an indicator of gypsum-bearing soils containing chloride and sulphate salts (Mukhammedov 1972, 1979).

Ephedra strobilacea is a dioecious species; the female plants bear about 11,000 seeds. It is one of the longest-lived desert shrubs, with a lifespan of 50 to 70 or even 100 years (Mukhammedov 1972). The root system of *E. strobilacea* is universal and well-developed; its tap root penetrates 0.5 to 4 m; numerous side roots and rhizomes stretch to 3 to 4 m; horizontal roots are more strongly expressed in plants growing on thin sands with close maternal rock than elsewhere.

The abundance of *E. strobilacea* in the Karakum varies from 100 to 400 plants/ha. It dominates the floristically poor formation, with rare *Salsola richteri*, *Haloxylon persicum*, *Calligonum caput-medusae*, and *C. setosum* found in the shrub layer; the lower layer is represented by solitary *Artemisia santolina*, *Salsola arbuscula*, and *Convolvulus erinaceus*. Perennial herbaceous plants include only *Stipagrostis karelinii* and *S. pennata*. The cover of ephemers and ephemeroids is represented by *Carex physodes*, *Eremopyrum orientale*, *Koelpinia lineata*, and *Hordeum leporinum*. *Agriophyllum minus* and *Salsola leptoclada* are typical summer – fall annual species.

2. Mesoxerophyte Desert Vegetation

Communities of this type are fragmentary in deserts and occupy patches usually less than one hectare in size. Many of the herbaceous communiites described here are common as synusia in shrub and semishrub associations. Three groups of formations belong here: large perennial herbaceous vegetation, ephemerous-grass vegetation, and annual halophyte vegetation.

2.1.1. High Perennial Herbaceous Vegetation

This vegetation is represented by formations with a dominance of selin (*Stipagrostis karelinii* and *S. pennata*), yuzarlik (*Peganum harmala*), and

Agropyron fragile. We will give a brief characteristic of the selin formation (2.1.1.1.)

2.1.1.1. Selin Formation. The large grasses *Stipagrostis karelinii* and *S. pennata*, widespread in the Karakum Desert, rarely dominate plant communities. *Stipagrostis karelinii* is a perennial grass 1 to 1.2 m tall; it grows solitarily or in groups on barkhan sands. Sparse groups of selin are not in contact with each other and threfore cannot be defined as true communities (Korovin 1961). However, due to the ability of its root system to form accessory roots and stabilize the sand, *S. karelinii* serves as a pioneer species, which is followed by other perennial species in the process of succession occurring on barkhan sands. Another selin species, *Stipagrostis pennata*, forms denser communities (covering 10 to 25%) and inhabits more or less stabilized sand dunes. *S. pennata* is 60–70 cm high, and its density varies from 1,200 to 2,600 plants/ha.

Shrubs and small shrubs are found only occasionally in these communities; these include *Calligonum* sp. div., *Salsola richteri*, *S. arbuscula*, *Halothamnus subaphyllus*, and *Ephedra strobilacea*. Semi-shrubs and small semishrubs, including *Astragalus ammodendron*, *A. transcaspicus*, *Convolvulus erinaceus*, *Mausolea eriocarpa*, *Artemisia santolina*, and *A. badhysi*, are more frequent but have low abundance. The herbaceous vegetation is represented, first of all, by long-vegetating annual species of Chenopodiaceae such as *Horaninovia* sp., *Agriophyllum latifolium*, *Kochia odontoptera*, and *Ceratocarpus utriculosus*. Ephemers (e.g., *Eremopyrum orientale*, and *Lappula semiglabra*) are rarely found. Among perennial plants, *Heliotropium argusioides* and, sometimes, *Cousinia schistoptera*, *Peganum harmala*, *Carex pohysodes*, and *Ferula assafoetida*, as well as *Stipagrostis pennata*, are present. Total floristic composition of *S. pennata* and *S. karelinii* communities is about 30 species, and on concrete plots thare are rarely more than ten to twelve species. Abundance of virtually all of these plants is low, and no codominant species can be separated.

2.1.2. Ephemerous-grass Vegetation

This group includes formations with two dominant grass species: yepelek (*Anisantha tectorum*; 2.1.2.1) and arpagan (*Eremopyrum orientale*; 2.1.2.2).

2.1.2.1. Yepelek (Anisantha tectorum); and 2.1.2.2. Arpagan (Eremopyrum orientale). Their role in desert vegetation (especially that of *E. orientale*) is rather insignificant; these communities are found mainly in the submontane plain of Kopetdagh.

Communities dominated by *Anisantha tectorum* are found in the depressions between sand dunes where the dune crests are occupied by the ephemerous-grass sagebrush communities, as well as by shrub and semishrub communities (*Calligonum* sp. div., *Ephedra strobilacea*, *Astragalus* sp.). Ephemerous-grass vegetation can form independent communities as well as participate as

secondary sinusia in sagebrush vegetation. The dominant species, *Anisantha tectorum*, is an ephemerous grass 15 to 30 cm tall; its coverage is commonly 15 to 20%, and can reach 25 to 30%. *Eremopyrum orientale* often subdominates in these communities.

Floristically, the formation of *Anisantha tectorum* is composed of 22 to 25 mostly ephemerous species with fall – spring and spring developmental cycles, such as *Eremopyrum orientale*, *Carex physodes*, *Hypecoum pendulum*, *Astragalus oxyglottis*, *Eriodium oxyrrhynchum*, *Arnebia decumbens*, *Nonea caspica*, *Koelpinia linearis*, *Epilasia hemilasia*, and (sometimes very abundant) halophyte *Salsola carinata*. Of other Chenopodiaceae, solitary *Horaninovia* sp., *Agriophyllum latifolium*, *Kochia schrenkiana*, and *Salsola sclerantha*. Only rarely these communities include solitary small semishrubs such as sagebrush.

2.1.3. Annual Halophyte Vegetation

Within this group of formations, we separate formations with two dominant species: ebelek (*Ceratocarpus utriculosus*; 2.1.3.1) and ketgen (*Salsola paulsenii*; 2.1.3.2).

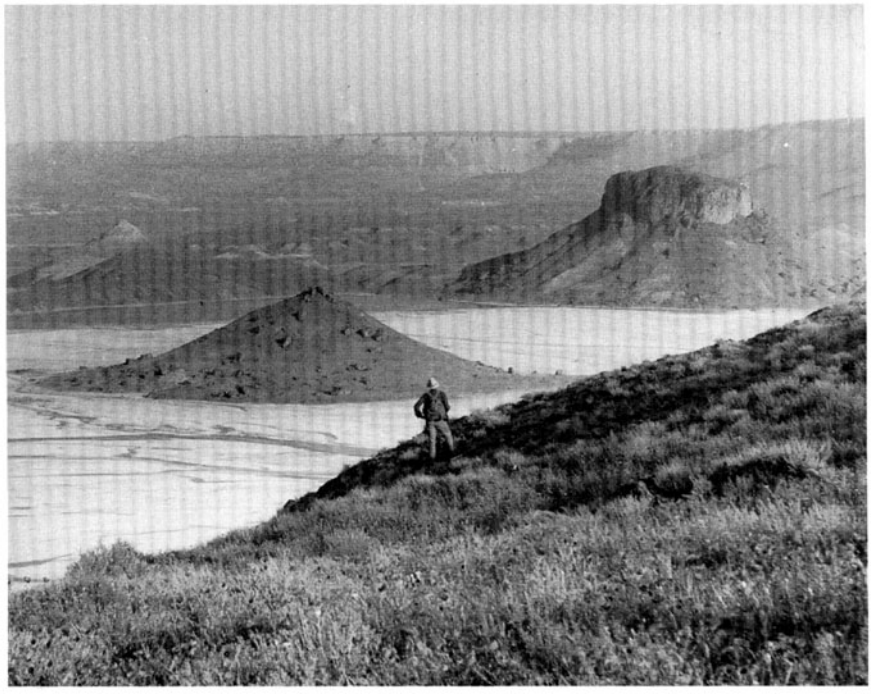
2.1.3.1. Ebelek (Ceratocarpus utriculosus); and 2.1.3.2. Ketgen (Salsola paulsenii. Characteristic communities of the ebelek have evident anthropogenic origin and are found on roadsides and degraded pastures. The dominant species, *Ceratocarpus utriculosus*, is a long-vegetating annual plant only 5 to 10 cm high. It has coverage of 10 to 25%, and often grows on gypsum soils with high gravel content. Globular bushes of ebelek are formed toward the fall period; due to the root fragility, plants can be easily broken and dispersed by the wind, which is its means of seed dispersal. Floristic composition of these communities is very poor; there are about 10 to 15 species, with not more than 5 or 6 species on description plots. There is only one (herbaceous) layer with participation of annual Chenopodiaceae such as *Salsola sclerantha*, *S. carinata*, and *Halimocnemis villosa*, and solitary epehemers (*Eremopyrum orientale*, *Ceratocephala falcatus*, *Strigosella* sp., and *Astragalus oxyglottis*).

Conclusion

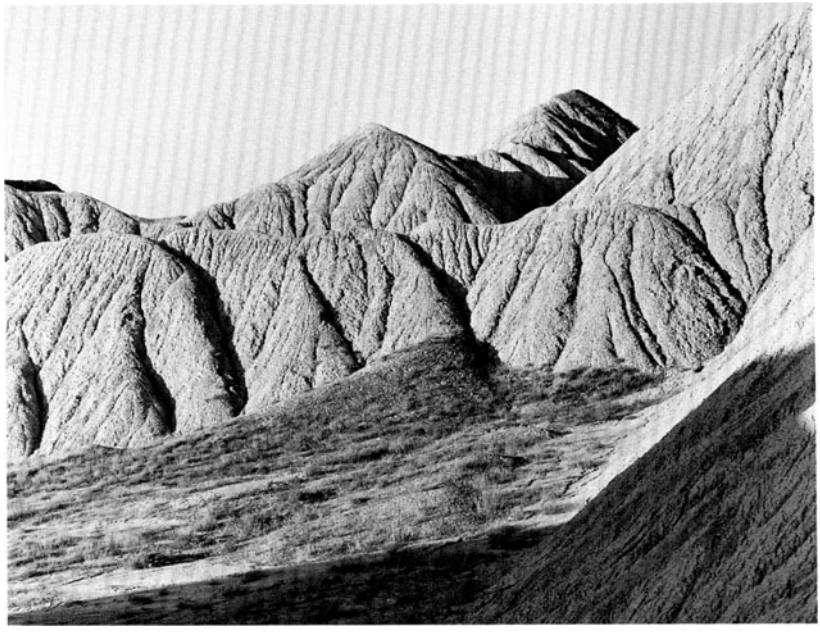
Desert vegetation of Turkmenistan consists mostly of small semishrub sagebrush-halophyte and shrub psammophyte communities with a relatively simple structure and a homogeneous species composition. The structure of most phytocoenoses is determined by a few dominant species providing most of productivity. Other sinusia, in particular the herbaceous cover, consist mainly of annual ephemerous species.

Deserts occupy more than 80% of the territory of Turmenistan and are used throughout the year for sheep and camel grazing, thus providing a feed resource for a profitable livestock industry. In recent decades negative anthropogenic influence on desert vegetation has increased. Overgrazing, combined with

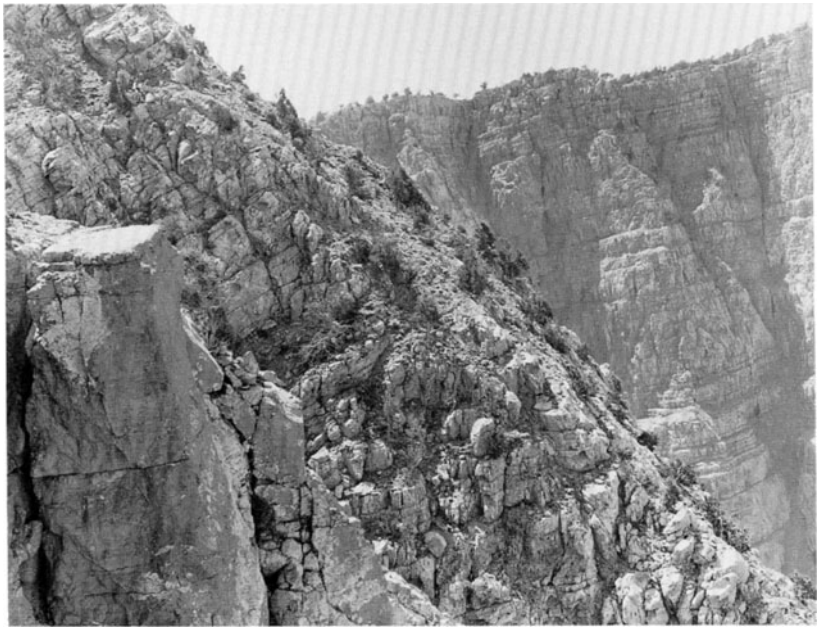
cutting of shrubs for firewood, has led to the decreasing productivity of desert pastures (e.g., those in the southern part of Central Karakum Desert). Several natural reserves and other protected areas have been established in order to preserve and restore desert vegetation and landscapes in Turkmenistan. Extension of this network and other forms of environmental protection is essential to the preservation and optimal management of desert landscapes in Turkmenistan.



Lake Yeroyulanduz, a salt desert depression in Badghyz (1 of 2). Photo by H.R. Levenshtein and I.A. Mukhin.



'Bad lands' near the town of Kara-Kala, Southwest Kopetdagh (outcrops of Cenomanian clays in the foothills). Photo by I.A. Mukhin.



Juniper forest on rocky slopes in Central Kopetdagh. Photo by I.A. Mukhin