

Ecological Restoration of Degraded Pasture Ecosystems Biodiversity and Fodder Productivity in the Central Asian Desert

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Abstract. The increasing pressure of anthropogenic and technogenic factors on the soil and vegetation cover in the Central Asian desert is due to their degradation which dictates the need for ecological restoration of these destroyed pasture lands. For restore the lost biodiversity and fodder productivity of degraded pasture ecosystems in the Central Asian Karnabchul desert, dominant species of fodder plants were sown: *Haloxylon aphyllum* (15%), *Halothamnus subaphyllus* (20%), *Artemisia diffusa* (50%) and *Poa bulbosa* (15%) – representatives of climax communities. The climax stage is the adult state of the ecosystem, the peak of its development and it is the longest. The life forms of dominant plant species involved in the formation of climax communities are characterized by increased resistance to the abiotic and biotic stresses. This ensures the formation of poly-species multi-tiered pasture ecosystems with high and stable fodder productivity over the years in the conditions of the Central Asian desert. Fodder shrubs, semishrubs and grasses, along with high adaptive properties, are characterized by nutritional value. *Haloxylon aphyllum* contains 10-12% protein (in fruits up to 20%), 2.2-2.7% fat. *Halothamnus subaphyllus* fodder in the budding phase contains 24.7% protein, 2.7% fat. *Artemisia diffusa* is a very valuable fodder for sheep, goats, camels. The ephemeroid *Poa bulbosa* on the pastures is perfectly eaten by all kinds of animals, especially sheep. During the growing season, bluegrass fodder contains up to 24% protein, 1.6-4.1% fat.

1 Introduction

The current state of the Central Asia desert pastures is characterized by a disturbed structure and destabilized functions in pasture communities [1]. Their productivity does not exceed 0.15-0.3 t/ha of dry fodder mass. In addition, the yield of desert pastures is highly dependent on meteorological conditions. In this regard, the amount of fodder mass formation varies greatly in different seasons of the year. Depending on hydrothermal conditions, there are three productive, four medium-yielding and three lean years in each decade [2].

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In recent years, there has been an ever-increasing anthropogenic pressure on the soil and vegetation cover of desert pastures, which causes their degradation.

The current massive degradation of pasture ecosystems in arid regions of the Central Asia occurs in a short time, which dictates the need for ecological restoration of these destroyed pasture lands [3, 4].

According to the data of domestic [5] and foreign [6, 7, 8] authors, the process of restorative succession on desolate lands proceeds spontaneously for 80-100 years. In the conditions of the Central Asian desert with a rigid xerothermal regime with chronic moisture deficiency, the restorative succession proceeds for an even longer time [9, 10, 11]. Such a long nature of the recovery period is due to the determinism of intermediate stages in it: ruderal-segetal, wheatgrass, subzonal serial phytocenoses [12]. Are there scientific prerequisites in science for the implementation of accelerated ecological restoration of lost biodiversity and fodder productivity of degraded pastures?

The British ecologist Grime [13, 14] in his works showed that restorative successions consist in the replacement of plants of pioneer communities (R-species) by plant populations of ruderal ecology and plant communities of violentic (C-species), or of a patient (S-species) ecology with the packing of ecological niches by seeding dominant plant life forms.

The United Nations General Assembly, by resolution 73/284, adopted at the 69th plenary meeting on March 1, 2019, decided to proclaim 2021-2030 the "UN Decade for the Restoration of Degraded Ecosystems" and called on UN Member States to strengthen political will, mobilize available resources, strengthen scientific research in the field of ecosystem restoration at the global, regional, national and local levels [15].

In this context, the purpose of our work is to show the possibility of accelerated ecological restoration of lost biodiversity and fodder productivity of degraded pasture ecosystems in the Central Asian desert.

2 Materials and Methods

The research was carried out in the Central Asian sagebrush-ephemeral Karnabchul desert. The experimental site is located at an altitude of 310 m above sea level. The dominant type of soil is light gray soils and transitional from light gray soils to gray-brown. Soils of layered structure: horizons of light loam are replaced by medium loam, sandy or dressy loam, not saline or slightly saline. Humus is contained in insignificant amounts: in the upper layers – from 0.30-0.79 to 0.81%, in the lower its content drops to 0.17%. Groundwater lies at a depth of 14-20 m. The average annual air temperature is +16°C, in June-July in the shade reaches 40-45°C. The temperature transition through 0°C occurs at the end of January – beginning of February, and after +5°C – on the third decade of February. The relative humidity of the air for the year is on average at the level of 30%, in spring, especially in summer, 8% drops to 10-20%. The average annual precipitation is 167 mm.

To restore the lost biodiversity and fodder productivity of degraded pasture ecosystems in the Central Asian Karnabchul desert, dominant species of fodder plants were sown: *Haloxylon aphyllum* – 15%, *Halothamnus subaphyllus* – 20% shrubs, *Artemisia diffusa* semishrub – 50% and *Poa bulbosa* ephemeroid – 15%. Phenological observations, biometric records of plant growth, development, and phytomass formation were carried out according to the method [16].

3 Results and Discussion

The structural organization of the shrub-semishrub-herbaceous (ephemeroid) agroecosystem consists of four tiers interacting with each other, occupied by ecological niches.

The tree-like shrub black saxaul (*Haloxylon aphyllum* (Minkw) Iljin) occupies the first, upper dominant tier in the restored ecosystem. The height of the black saxaul is 350-400 cm, the life expectancy is 60-90 years.

The black saxaul, being a haloxerophytic specie, is characterized by high resistance to the drought and salt stress; it is characterized by rapid growth in the first year of life, reaching a 1.5 m height. At the age of five, it reaches 3-4 m height, developing a powerful root system that penetrates deeply into the soil up to 10 m, which allows the use of moisture, along with atmospheric precipitation, groundwater.

Black saxaul is endowed with a high phytomeliorative and price-forming ability. It combines well with semishrubs and grasses, forming multicomponent stable and highly productive pasture agroecosystems. According to L.G. Ramensky [17], Grime [13], the adaptive strategy of violent, has the ability to maintain a stable water balance and a normal state of hydration in extremely harsh desert climate conditions, which provides resistance to the drought and tolerance to the salt stress [18].

The second tier is occupied by populations of *Halothamnus subaphyllus* (C.A. Mey) Botsch. Plants are 70-150 cm high, with a root system reaching a depth of 6 m in the soil. It has a long growing season – 235-250 days. The excellent plant for creating autumn-winter pastures is hyperxerophyte, characterized by the extreme environmental resistance to a complex of abiotic stresses.

Halothamnus subaphyllus combines the features of violentum and patientum according to an adaptive strategy, has the ability to maintain a stable water balance and a normal state of hydration in extremely harsh desert climate conditions, which ensures resistance to drought and tolerance to salt stress.

Halothamnus subaphyllus plants have an average height of 90 cm with a crown width of 105 cm. *Halothamnus subaphyllus* does not close, and the air space at a height of 100-105 cm from the ground surface remains unfilled. At the same time, the crowns of the black saxaul, *Halothamnus subaphyllus* and the dwarf semishrub of the sagebrush, as a rule, close at different heights, sometimes even overlap, mechanically not touching each other.

In the underground sphere, the root system of *Halothamnus subaphyllus* occupies a soil niche with a thickness of 0-1015 cm. The roots of *Halothamnus subaphyllus* deepen to the humidification zone by groundwater. *Halothamnus subaphyllus* is an ecologically plastic species, capable of growing on both clay and sandy soils. In culture, it grows and develops rapidly, reaching a height of 50-60 cm in the first year of life and often entering the generative phase. It has a stable fodder productivity (1.2-1.7 t/ha of dry fodder mass), contains up to 24.78% protein.

Sagebrush (*Artemisia diffusa* Krasch.) forms the third tier in the vegetation cover of the restored shrub-semishrub-herbaceous pasture ecosystems. In the aboveground sphere, the height of plants is 25 cm, the roots occupy the thickness of the soil – 01-115 cm, the lateral roots break up into many roots of the second, third and subsequent orders with numerous absorbing roots.

The fourth tier of herbaceous plants there are ephemerooids and ephemera. Their height in the aboveground sphere does not exceed 18-20 cm, and the roots occupy a surface soil niche – 0.15 cm, forming turf.

In the process of regenerative succession of multi-species shrub-semishrub-herbaceous pasture communities, differentiation and rational packing of ecological niches occurs by means of tiered complementarity of plants involved in regenerative succession. Differentiation of ecological niches occurs both in the aboveground and underground spheres.

Polydominant pastures of year-round use occupy different tiers in the aboveground sphere in height: tree-like shrub saxaul black up to 320-400 cm, shrub *Halothamnus subaphyllus* up to 120-140 cm, semishrub *Artemisia diffusa* up to 65-70 cm. This ensures the rational

placement of the photosynthetic apparatus of plants in the air space for the efficient use of solar energy. In the underground sphere, the various life forms of fodder plants form root systems, develop various ecological niches for a more efficient use of soil moisture and mineral nutrition elements.

Along with the tiered complementarity in these shrubby-semishrubby-grassy pastures, differentiation also occurs according to the principle of seasonal complementarity of species. These pastures are formed from phenologically diverse plant species: *Haloxylon aphyllum*, *Halothamnus subaphyllus*, long-vegetated (226-242 days), from the end of March to the beginning of December, as a rule, they are in a green state until winter frosts. Ephemerooids are *Poa bulbosa* and *Carex pachystylis* with a short growing season: the beginning of regrowth from February to mid-April, i.e. they use the resources of the environment, especially the reserves of soil moisture before the start of regrowth of dwarf semishrubs.

In the first two years after the creation of the pasture agroecosystem, ephemera occur in the herbage only once, in subsequent years their number increases rapidly and within 4-5 years there are 1,800-2,350 thousand ephemera and ephemerooids per 1 hectare. Starting from the 5th year of life of the agroecosystem, the abundance of ephemera and ephemerooids mainly depends on the amount of precipitation in spring. The maximum of ephemerooids and ephemerooids is fixed at the 7th year of life – 1015 pcs /m². At the age of 8-10 years, the agroecosystem was fully formed and turned into a shrub-semishrub-herbaceous pasture ecosystem with a stable number of plants and productivity, which is an example of a sustainable community.

Our observations have shown that under the crown of the black saxaul, *Halothamnus subaphyllus* and wormwood sown by it are found in large numbers and in good vital condition, ephemera are insignificant, mainly *Schismus arabicus*, *Herniaria hirsute*, *Hordeum leporinum*, *Heliotropium dasycarpum*. The projective coverage of ephemerooids is 5-10%. Between crown, the ephemeral cover of multi-species communities, depending on the meteorological conditions of the year, consists of 21-39 species. Their projective coverage is very high – 50-60%, on the curb ring up to 90-95%.

The basis of the ephemeral cover is *Bromus tectorum*, *Bromus danthoniae*, *Boissiera purnilio*, *Trigonella grandiflora*. Quite a lot of *Leptaleum filifolium*, especially in important years. These annual plants account for up to 95% of the harvest of the grass cover of multi-species communities.

Semi-crown and intercron microphytocenoses differ sharply not only in species composition and number of species, but also in the height of the herbage: in the semi-crown, the height of ephemera does not exceed 8-10 cm, in the intercron – 18-25 cm. Ephemera grow especially strongly in the ecotone between the described microphytocenoses reaches 35-40 cm in height, which indicates a negligible effect due to the favorable soil moisture conditions. It is appropriate to note here that more moisture accumulates under the crown of the black saxaul than in open pastures and aisles.

The figure shows data characterizing the fodder productivity of the restored multicomponent shrub-semishrub-herbaceous pasture ecosystem.

At the 3rd year of life, when the restored pasture ecosystem is recommended for use for grazing, the total fodder stock of the plants composing it is 2 times higher than the natural sagebrush-ephemeral pastures (0.36 t/ha) of Karnabchul. In the future, up to the 9th year of life, the fodder productivity of the restored pasture ecosystem continuously increases and stabilizes. This agroecosystem has accumulated the maximum fodder capacity by the 10th year of life, as can be seen from the figure.

Halothamnus subaphyllus and sagebrush are characterized by unstable yields. Sharp fluctuations in the yield of *Halothamnus subaphyllus* are associated with widespread damage for 7-10 years of life by rust and powdery mildew. In sagebrush, a decrease in yield is the result of the influence of the competitive power of the populations of black saxaul and dense

ephemeral herbage. Due to such changes, the share of sagebrush in the total yield of agroecosystem fodder is reduced from 20.0 to 1.8%. The basis of fodder productivity is black saxaul (38.6-94.1%).

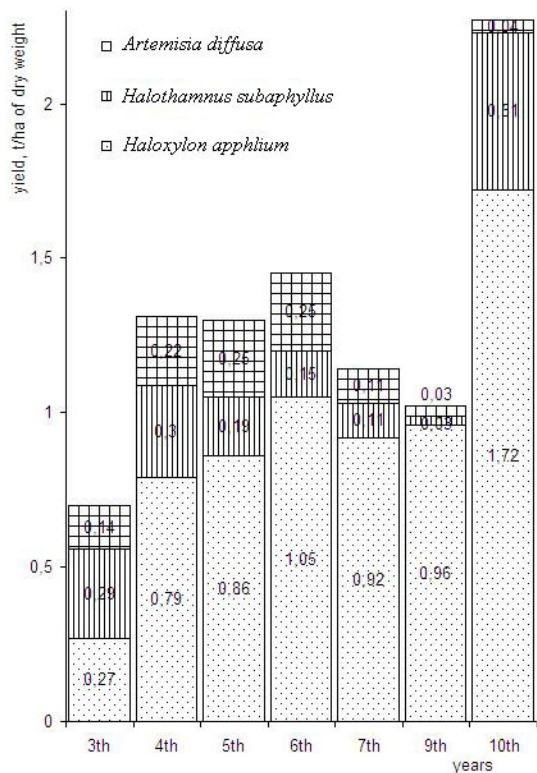


Fig. 1. Fodder productivity of the restored shrub-semishrub-herbaceous pasture ecosystems of the Central Asian desert.

It should be noted that ephemera and ephemeroïds that have appeared in the pasture ecosystems, starting from 5-7 years of life, accumulate a significant (0.17-0.35 t/ha) fodder yield.

4 Conclusion

- Based on the results obtained, the following conclusions can be drawn:
1. Recreated multi-species pasture ecosystems consisting of the haloxerophytic tree-like shrub of the black saxaul (*Haloxylon aphyllum*), the fodder shrub *Halothamnus subaphyllus*, the semishrub *Artemisia diffusa*, and the ephemeroïd *Poa bulbosa*, provide a tiered arrangement of the aboveground part of plants involved in regenerative succession, rational placement of the leaf photosynthetic apparatus of the fodder plants in air sphere for efficient photosynthesis process. The life forms of shrubs, semishrubs and ephemeroïd grasses form root systems in different layers of the soil for the effective development of water and mineral resources.
 2. Polydominant pastures, consisting of various life forms and dominant plant species based on the differentiation of ecological niches in the aboveground and underground

spheres, ensure the formation of fodder products 3-5 times higher than the production of natural sagebrush-ephemeral pastures in the Central Asian desert.

3. Restored multi-species multi-tiered shrub-semishrub-herbaceous pasture ecosystems effectively perform a nature protection function in desert conditions: the processes of desertification of arid lands are suspended, dust storms stop, the optimal environmental parameters are restored.

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