Ecological restoration of fodder productivity of degraded pastures in the foothill desert zone of Central Asia

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Abstract. Irrational, ecologically unregulated economic activity in the vast deserts of Central Asia has led to biodiversity depletion, decrease in the fodder productivity of natural pastures and, as a result, deterioration in the fodder base of grassland farming. Forage production of these degraded pastures requires ecological restoration. To enrich the species composition and to increase the fodder productivity of degraded pastures we conducted strip sowing of black saxaul. Restorative succession on degraded pastures led to the formation of a long-term halophytic shrub-ephemeral pasture community consisting of two layers: upper (I) layer represented by black saxaul and lower (II) layer composed of ephemerals, ephemerals and annual saltwort. Ephemerals are short-growing fodder plants (March–April); Haloxylon aphyllum refers to long-growing (226–242 days) fodder plants, which sprout in the period from late March to early December. Annual salsolas Salsola carinata and Halocharis hispida develop well under the crown of Haloxylon aphyllum. Here they are much larger than between the crowns. The shrub-ephemeral pasture community is dominated by annual grasses and Poa bulbosa. They are mainly concentrated on the outer border of the undercrown ring and are characterized by lush development. In the halophytic semi-shrub-ephemeraloid pasture community, the total yield of forage mass of ephemera was 0.90 t/ha; the total yield of forage mass of annual saltwort was 0.14 t/ha; the total yield of forage mass of Haloxylon aphyllum was 0.89 t/ha; the total yield of forage mass was 1.93 t/ha.

1. Introduction
Natural pasture ecosystems in the foothill regions of Central Asia, represented mainly by wormwood-ephemeral xerohalophilic vegetation, have been used since ancient times for grazing beef cattle, sheep, horses, and camels throughout the year [1]. Irrational, ecologically unregulated economic activities have led to degradation of these pastures and biodiversity depletion, decrease in fodder productivity and, as a result, deterioration in the fodder base of pasture livestock and the quality of life of the population living in this region of Central Asia.

Currently, degradation processes have acquired a global character, and it is necessary to solve this problem at the global level by the joint global efforts [2]. Currently we observe rapid environmental degradation and destruction of many parts of the Earth’s biota occurring in “catastrophically short terms” [3, 4].
Due to deterioration of the environment and increase in the area of degraded ecosystems, at 69th meeting on March 1, 2019 the United Nations General Assembly adopted Resolution 73/284, according to which the period from 2021 to 2030 was proclaimed as the United Nations Decade for the Restoration ofDegraded Ecosystems. Also it called on member states to promote the mobilization of available resources, strengthening scientific research in the field of ecosystem restoration at the global, regional, national, and local levels. [5]

In this context, the aim of the work is to restore the zonally typical shrub-ephemeral pasture vegetation on the basis of sowing phytocenotically balanced combinations (mixtures) of black saxaul and ephemerals, i.e. representatives of natural (wild) flora.

2. Materials and methods
A comparative ecological study of the formation of forage shrub-ephemeroïd grazing communities was conducted in the foothill desert zone of Central Asia. The study area was located in the lower belt of the foothill desert at an altitude of 354 m above sea level. The local climatic conditions were characterized by high aridity and continentality. The growing season consists of mesothermal and xerothermal periods, characterized by certain temperature and moisture regimes; the mesothermal period lasts from November to April. At this time, the annual mean precipitation in the study area is 224 mm. The xerothermal (dry) period lasts from May to October. In summer, the soil is dried out by physical evaporation and transpiration by vegetation under the influence of high temperatures, insolation, and constantly blowing winds. The average air temperature is 14.8 °C; the maximum air temperature is +47 °C; the minimum air temperature is -27 °C. The annual mean relative humidity is 30%; summer mean relative humidity is 10%.

The work performed in the soil cover as well as in the entire lower belt of the foothill desert was aimed at restoring the productivity of degraded pastures. The soils in this region are mainly light gray. A characteristic feature of the soil profile is its layered structure including alternation of horizons of light, medium, and heavy loam with sandy loam. The soils are largely saline.

The main plant, which was used to restore the floristic composition and forage productivity of degraded pastures, was black saxaul (*Haloxylon aphyllum* (Minkw.) Iljin.). Black saxaul was sown by plowing on medium loamy sierozem of the foothill desert in December 2012. Before plowing, the vegetation of natural pastures was represented by sedge-bluegrass association with a small admixture (1–2%) of monocotyledonous and dicotyledonous forbs mainly represented by *Carex pachystylis* J. Gay and *Poa bulbosa* L. There were also *Bromus tectorum* L., *Eremopyrum orientale* (L.) Jaub. & Spach, *Astragalus filicaulis* Fisch. & CA Mey. ex Kar. & Kir., *Malcolmia grandiflora* (Bunge) Kuntze, annual salsolas *Salsola sclerantha* C.A. Mey, *Salsola carinata* C.A. Mey., *Halocharhis hispida* (C.A. Mey.) Bunge, and single plants of *Cousinia resinosa* Juz.

Studies at the experimental site were conducted on the basis of the following techniques [6, 7].

3. Results and discussion
In terms of adaptive strategy Haloxerohalophytic shrub black saxaul, according to L.G. Ramensky [8], refers to violents. Violents are plant species that, while vigorously developing, seize territory suppressing their rivals with the energy of vital activity and the full use of environmental resources.

In the created shrub-herbaceous pasture community, black saxaul predominates in the crops in the first two years. Ephemerals (mainly annual grasses) are found singularly; the ephemeroïds *Carex pachystylis* and *Poa bulbosa* are found mainly on the flaws of arable land. The three-year (2015) black saxaul-ephemeral pasture community already includes up to 7 plant species from 4 families. These are mainly annual salsolas; there are 3 types of them (Table 1). By this time, the bushes of black saxaul reach 78–203 cm in height with a crown diameter of 66–172 cm.

In 2015, favorable meteorological conditions were formed for the growth and development of ephemerals, in particular from the genus *Bromus* L. They reached 50 cm in height; salsola reached 30 cm in height (Table 2). The yield of fodder mass of shrub-herbaceous pasture communities in 2015 was 2.02 t/ha of air-dry mass. In the composition of the forage mass, the yield of annual saltwort was 0.92 t/ha; the yield of ephemeral was 0.67 t/ha; the yield of black saxaul was 0.43 t/ha.
Table 1. The structure of the restored black saxaul-ephemeral pasture community in the foothill desert.

| Year                  | Black saxaul                     | Ephemera                              | Annual hodgepodge |
|-----------------------|----------------------------------|---------------------------------------|-------------------|
|                       | number of individuals per 1 ha   | Plant height, cm                      | Crown diameter, cm |
|                       | calm                             |                                       | Fodder yield, t/ha |
| 3rd year (2015)       | 1260                            | 78-203                                | 66-172            |
|                       |                                 |                                       | 0.43              |
|                       |                                 |                                       | 8                  |
|                       |                                 |                                       | 8-50              |
|                       |                                 |                                       | 0.67              |
|                       |                                 |                                       | 3                  |
|                       |                                 |                                       | 12-30             |
|                       |                                 |                                       | 0.92              |
| 5th year (2017)       | 1260                            | 53-190                                | 67-146            |
|                       |                                 |                                       | 0.47              |
|                       |                                 |                                       | 9                  |
|                       |                                 |                                       | 2-12              |
|                       |                                 |                                       | 0.18              |
|                       |                                 |                                       | 3                  |
|                       |                                 |                                       | 3-7               |
|                       |                                 |                                       | 0.11              |
| 6th year (2018)       | 1260                            | 63-255                                | 77-210            |
|                       |                                 |                                       | 0.54              |
|                       |                                 |                                       | 9                  |
|                       |                                 |                                       | 8-20              |
|                       |                                 |                                       | 0.22              |
|                       |                                 |                                       | 3                  |
|                       |                                 |                                       | 5-18              |
|                       |                                 |                                       | 0.23              |
| 7th year (2019)       | 1260                            | 50-270                                | 50-250            |
|                       |                                 |                                       | 0.41              |
|                       |                                 |                                       | 23                 |
|                       |                                 |                                       | 2-40              |
|                       |                                 |                                       | 0.16              |
|                       |                                 |                                       | 5                  |
|                       |                                 |                                       | 0.5-15            |
|                       |                                 |                                       | 0.09              |
| 8th year (2020)       | 1200                            | 75-310                                | 60-280            |
|                       |                                 |                                       | 0.89              |
|                       |                                 |                                       | 21                 |
|                       |                                 |                                       | 6-23              |
|                       |                                 |                                       | 0.90              |
|                       |                                 |                                       | 2                  |
|                       |                                 |                                       | 5-20              |
|                       |                                 |                                       | 0.14              |

At the age of four to five years in the shrub-herbaceous pasture community, there were 10 plant species belonging to four families. Annual saltwort still prevailed. The number of cereals has also increased; there are already 3-4 species of them (Table 2).

Table 2. Species composition of plants in the black saxaul-ephemeral pasture community in the foothill desert.

| Plant specie                | Abundance according to Druda |
|-----------------------------|------------------------------|
|                             | 2015 г. | 2017 г. | 2018 г. | 2019 г. | 2020 г. |
| Astragalus filicaulis       | —       | sol     | sp      | sp      |
| Aphanopleura capillifolia  | —       | —       | sol     | sp      |
| Aegilops sp.                | —       | —       | —       | sp      |
| Alissum desertorum         | —       | —       | —       | sp      |
| Boissiera pumilio           | —       | —       | —       | sp      |
| Bromus dantoniae            | —       | sp      | sol     | sp      |
| Bromus sp.                  | cop2    | sol     | —       | sp      |
| Ceratocarpus utriculosus   | sol     | sol     | sol     | sp      |
| Cressa cretica             | —       | —       | —       | —       |
| Carex pachystylis           | —       | —       | —       | —       | sp      |
| Chrosophora sabuloca       | —       | —       | —       | —       | sp      |
| Ceratocephalus falcatus     | —       | —       | —       | —       | sp      |
| Chorispora tenella          | —       | —       | —       | —       | sp      |
| Cousinia resinosa           | sol     | —       | sol     | —       | sp      |
| Diarthron vesiculosum       | —       | —       | —       | sol     | sp      |
| Euclidium siriacum          | —       | —       | —       | —       | sp      |
| Eremodacous lehmannii      | —       | —       | —       | sol     | sp      |
| Eremopyrum orientale       | —       | sp      | sol     | sp      |
| Heterocarum rigidum         | —       | —       | —       | —       | sol     |
| Hypecoum parviflorum        | —       | —       | sol     | sol     |
| Halocharis hispida          | sol     | sol     | sol     | sp      |
| Heliotropium sp.            | —       | —       | —       | —       | sol     |
| Hordeum leporinum           | —       | —       | —       | sol     | sp      |
| Haloxylon aphyllum          | sp      | sp      | sp      | sp      |
| Koelpinia linearis          | —       | —       | —       | —       | sp      |
| Leptaleum filiforme         | sol     | sp      | —       | —       | —       |
| Papaver pavoninum           | —       | —       | —       | —       | sp      |
At the age of six to seven years, the shrub-herbaceous pasture community includes 22–24 species belonging to 9–11 families. At the same time, there are up to 5–7 species of cereals and many annual salsolas.

The source of natural plant regeneration in plowed areas is the stocks of seeds preserved in the soil. In addition, seeds can be brought from virgin areas where ephemero-ephemeral vegetation grows. Arable land with destroyed sod of sedge-bluegrass vegetation is a favorable environment for the growth of forbs.

Over the years increase not only the number of species but also the projective cover of ephemera. In the 3rd year, the projective abundance of ephemerals is 15%; in the 7th year, it is 45%. Black saxaul and natural grasses do not oppress each other, but mutually complement and ensure high forage productivity.

The restored shrub-ephemeral pasture community is structurally a two-tiered phytocenosis. The upper (I) layer is represented by black saxaul, the lower (II) is composed of ephemero-ephemerals and annual saltwort. The general list of plant species of this association is presented in Table 2.

Black saxaul trees are located at some distance from each other; only in thickened areas the crowns occlude and sometimes even overlap each other.

One-year salsolas Salsola carinata and Halocharis hispida develop well namely under the canopy of black saxaul. Here they are much larger than between the crowns. In contrast to virgin sedge-bluegrass pastures, the shrub-ephemeral pasture community is dominated by annual grasses and Poa bulbosa.

In the eight-year (2020) black saxaul-ephemeral pasture community, the total yield of fodder mass was 1.93 t/ha; the total yield of ephemerals was 0.90 t/ha; the total yield of annual saltwort was 0.14 t/ha, the total yield of Haloxylon aphyllum was 0.89 t/ha.

### Table 2

| Species                  | sp | sol | sp | —  |
|--------------------------|----|-----|----|----|
| Poa bulbosa              |    |     |    |    |
| Salsola sclerantha       |    |     |    |    |
| Salsola lanata           |    |     |    |    |
| Salsola carinata         | sp | sol | sp |    |
| Salsola sp.              |    |     | sol|    |
| Trigonella grandiflora   |    |     | sol| sp |

4. Conclusion

The purpose of strip sowing of black saxaul was to enrich the species composition and to increase the fodder productivity of degraded pastures. As a result of the restorative succession, a long-term halophytic shrub-ephemeral pasture community was formed on the site of degraded pastures, consisting of two layers: the upper (I) layer is represented by black saxaul; the lower (II) is composed of ephemero-ephemerals, and annual saltwort. Ephemerals are short-growing fodder plants (their growing period lasts from March to April); Haloxylon aphyllum is long-growing plant (226–242 days); its growing period lasts from late March to early December.

The restored multispecies black saxaul-ephemeral pasture community, including shrubs and grasses of different heights, provides a layered arrangement of the leaf apparatus of plants for effective photosynthesis. In the underground sphere, various life forms of plants, forming root systems of different depths and power, contribute to the development of different ecological niches for the use of reserves of soil moisture and mineral nutrients. Space under the crown of Haloxylon aphyllum is a good environment for the development of annual salsolas Salsola carinata and Halocharis hispida. In contrast to virgin sedge-bluegrass pastures, the shrub-ephemeral pasture community is dominated by annual grasses and Poa bulbosa. In the halophytic semi-shrub-ephemero-ephemeral pasture community, the total yield of fodder mass was 1.93 t/ha: the total yield of ephemerals was 0.90 t/ha; the total yield of annual hodgepodge was 0.14 t/ha; the total yield of Haloxylon aphyllum was 0.89 t/ha.
Thus, the restored multi-species black saxaul-ephemeral pasture in the foothill desert is a fairly highly productive and stable community; its forage productivity is 3–5 times higher than the forage productivity of natural pastures in the foothill desert.

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