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Bush Encroachment of Forest-steppe Landscapes in the Mongolian Part of the Lake Baikal Basin

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Abstract

The character of competitive relationships between woody and shrub vegetation in the southern (Mongolian) part of the Lake Baikal basin was studied via model polygons. Depending on the environmental conditions, native forests are being replaced by different types of shrubs. The main factors contributing to these changes are the aridization of the climate and human activity. It is shown that the current state of shrub communities and their progressive dynamics along the southern border of boreal forests in Mongolia allow us to consider them stable cenoses, which prevent a natural renewal of coniferous (pine, larch) forests in this region. However, some shrub species may be considered indicators of ecotopes' suitability for natural or artificial reforestation because their ecological requirements are similar to those of forest trees.

Keywords: Lake Baikal basin, ecotone area, destruction of forests, bush encroachment

1. Introduction

Currently, the sparse forests in the southern part of the Lake Baikal basin, which are almost entirely located in the ecotone zone of Southern Siberia and Inner Asia, are highly susceptible to disappearance. Special studies have found that the renewal of indigenous conifer species occurs in only 30% of the area. Birch and aspen are being

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renewed in 43% of the area, while in 27% they are slowly being replaced with non-forest ecosystems [1–3]. Over a vast area, forest stands are being replaced with pure or mixed thickets of xerophytic, mesoxerophytic and xeromesophytic shrubs: *Amygdalus pedunculata* Pall., *Armeniaca sibirica* L. Lam., *Betula fusca* Pall. ex Georgi, and *Dasiphora fruticosa* L. Rydb., as well as several species of *Caragana* (*C. microphylla* Lam., *C. bungei* Ledeb., *C. spinosa* L. Vahl ex Hornem.) (Table 1).

Table 1: Ecological and biological characteristics of shrub species substituting pine and larch forests in the southern part of the Lake Baikal basin (using data [4, 5]).

№	Species	Type of Area	Ecological-phytocenotic Type	Requirements for Water	Requirements for Soil
1	*Amygdalus pedunculata*	Daur-Mongolian-Northern Chinese	Shiplyak	Xerophyte	Petrophyte
2	*Armeniaca sibirica*	Dauro-Mongolian-Manchurian	Shiplyak	Mesophyte (xeromesophyte)	Psammo-petrophyte
3	*Betula fusca*	Siberian-North-Mongolian	Ernik	Hygrometric	Petrophyte
4	*Caragana bungei*	South Siberian-Inner Asian	Desert-steppe	Xerophyte	Psammo-petrophyte
5	*Caragana microphylla*	South Siberian-Dauro-North Mongolian	Steppe, forest-steppe	Xerophyte	Psammo-petrophyte
6	*Caragana spinosa*	Inner Asian	Valley-floodplain	Mesophyte	Petrophyte
7	*Dasiphora fruticosa*	Siberian-North-Mongolian	Forest-steppe	Mesophyte	Petrophyte

The main mutually exclusive factors contributing to deforestation and reforestation are desiccation, the waterlogging of soils, and competitive relationships between woody and shrub vegetation. These factors act both in a relatively isolated manner and in different combinations.

The purpose of this study was to find out the features of the competitive relationships between woody and shrub vegetation in the southern part of the Lake Baikal basin which lead to declining of forest ecosystems.

2. Methods

The study of the current state of forest-steppe communities and shrub successions occurring during the degradation of forest ecosystems was carried out on model polygons in Northern and Central Mongolia in the southern part of the Lake Baikal basin (Figure 1):

(i) Pine forests with *Dasiphora fruticosa* on polygons 'Shariingol', 'Bornur' and 'Ikh-ul';

(ii) Pine forests with *Ulmus pumila* and *Caragana microphylla* on polygon 'Salkhit';

(iii) Pine forests with *Ulmus pumila* on polygon 'Jargalant';

(iv) Pine forests with *Armeniaca sibirica* on polygon 'Shaamar';

(v) Larch forests with *Caragana bungei* and *C. spinosa* on polygons 'Tosontsengel' and 'Numrog';

(vi) Larch forests with *Betula fusca* on polygon 'Nalaikh'.

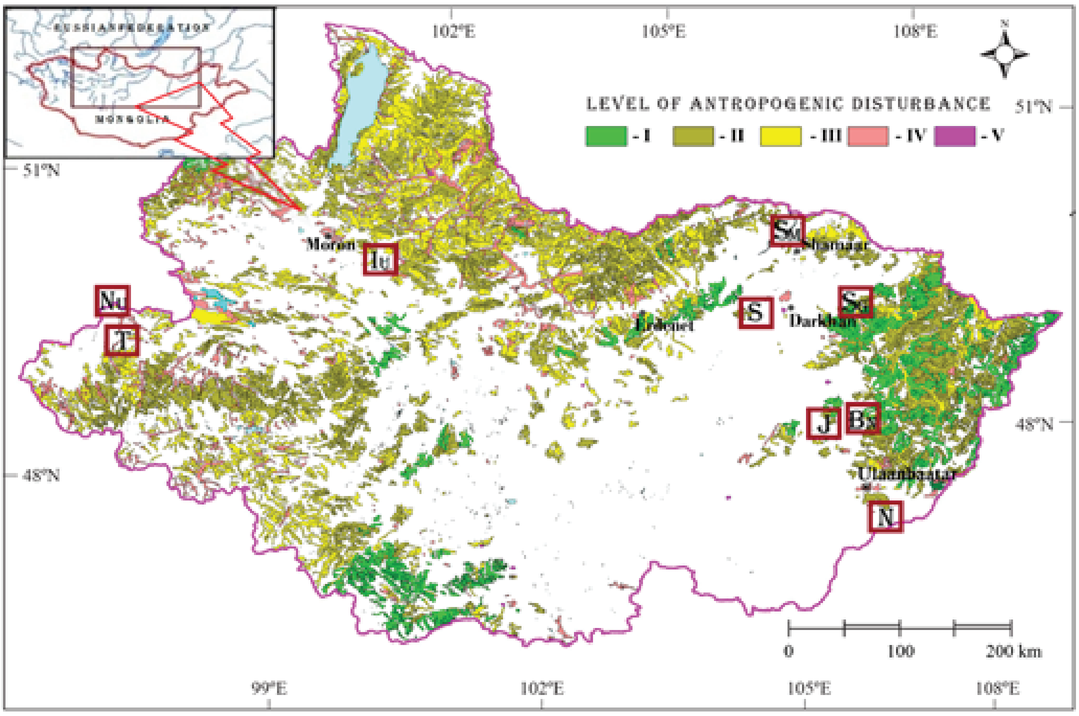

Figure 1: Location of polygons on a map of the anthropogenic disturbance of forest ecosystems in the southern part of the Lake Baikal basin. Model polygons: **Sm** – Shaamar; **Sg** – Shariingol; **S** – Salkhit; **N** – Nalaikh; **T** – Tosontsengel; **J** – Jargalant; **Bn** – Bornur; **Iu** – Ikh-ul; **Nu** – Numrog. **Source:** Authors' own work.

Standard forestry and geobotanical methods were used to determine the degree of anthropogenic disturbance and the nature and direction of successional shifts [6]. The current state of communities was assessed on the basis of data on floristic composition, abundance, condition and vitality of the species. Areas for geobotanical descriptions in forests and bushes were 400 m^2; for taxation – 100–10 000 m^2, depending on vegetation density and the size of plant individuals. The inventory measurements were performed in forest stands of *Pinus sylvestris* and *Larix sibirica*, and in thickets of *Betula fusca, Caragana microphylla, C. bungei, C. spinosa, Dasiphora fruticosa, Armeniaca sibirica* and *Amygdalus pedunculata*. They included measurements of the height and diameter of trunks for each tree species and the number of trunks, heights and diameters for bushes. To evaluate the above-ground phytomass of shrubs, model individuals were selected, usually from three different dimensional groups. The cut phytomass was dried to an absolutely dry state at 105 °C and weighed. The renewal of woody plants was estimated on registration sites of 1 m^2, but if self-seeding and undergrowth were very sparse, the sites were increased to 100 m^2 or more.

3. Results

Successions in forest-steppe ecosystems occur differently depending on climatic conditions and the nature of anthropogenic loads.

3.1. Competitive relationships of *Pinus sylvestris* and *Dasiphora fruticosa*

The vegetation of the 'Shariingol' and 'Bornuur' polygons is a combination of forest, steppe, and meadow communities. Forests occupy the watershed part of the spurs of the Western Khentei ridges and are composed of pine and birch. Their age is about 30. Pine stands have the fertility rate III, birch stands – II; crown density is 0.7–0.9. Forests are disturbed by cutting and grazing. Typical successions show abundant growth of *Dasiphora fruticosa*, the projective cover of which reaches 40–45%, while the above-ground phytomass exceeds 12 centner/ha. This is a fairly photophilous mesophytic shrub, essentially an indicator of the suitability of habitats for forest growth. Usually it grows along the edges and in the gaps of a forest stand; if the stand thins, it moves under a canopy. If these trends are maintained, the forest communities of the polygon could be completely replaced by this bush.

3.2. Competitive relationships of *Pinus sylvestris*, *Ulmus pumila*, and *Caragana microphylla*

The model polygon 'Salkhit' is representative of the Selenga middle mountains between Western Khentei and Eastern Khangai. Pine forests grow on fixed sand dunes in the terrace of the Khara River. The typical forest stand is about 40 years old: the crown density is 0.7–0.8 and the fertility rate is II-III. The full succession series is presented by five stages: I – indigenous coniferous forests, II – small-leaved forests with the participation of indigenous species, III – small-leaved forests without the participation of indigenous species, IV – bushes without the participation of trees, V – lands of the state forest fund completely deprived of trees and shrubs. The pine is first replaced with *Ulmus pumila*, then with *Caragana microphylla*. Later, the succession leads to the predominance of desert species, including *Thymus gobicus, Kochia prostata, Corispermum mongolicum* and *Agriophyllum pungens*.

3.3. Competitive relationships of *Larix sibirica* and *Caragana bungei*

The studies were conducted in larch forests on the Western mega slope of the Khangai plateau ('Tosontsengel'). The age of the stands is very different. Crown density is 0.6–1.0 and the fertility rate is II–III. We conducted the first survey here in 2004. On some of the sample plots, taxation was conducted again in 2014. Over the years, the projective cover of *Caragana bungei* has increased significantly on almost all sample plots, mostly in mountain larch forests (up to 2.3 times). This trend indicates the strengthening of the cenotic positions of *Caragana*, in particular under the canopy of larch forests. One of important features of this species is its high photosynthetic ability, which gives it an advantage in competition with larch [7].

3.4. Competitive relationships of *Larix sibirica* and *Caragana spinosa*

The interaction of these species was studied on the 'Numreg' polygon along transects in larch forests, which are replaced down the profile by shrub and meadow-steppe cenoses. The crown density is 0.6–1.0 and the fertility rate is II–III. The optimal conditions for *Caragana spinosa* are slightly lower than the larch forest edge, where it forms phytomass up to 77.0 centner/ha, while the least favorable conditions are to be found under the forest canopy. *Caragana spinosa* forms monodominant thickets several hundred hectares across on slopes of low mountains, which are potentially suitable for the growth of *Larix sibirica*. Thus, the larch forests of the western macroslope of the Khangai lose their ecological stability, as evidenced not only by the structure of stands but also by the penetration of *Caragana spinosa* and *C. bungei* under the canopy of the forests.

3.5. Competitive relationships of *Larix sibirica* and *Betula fusca*

Trees and shrubs of the polygon 'Nalaikh' give an example of successions caused by waterlogged soil due to the geological-geomorphological features of the area. Fragments of larch forests are interspersed with low-growing birch forests composed of *Betula platyphylla* and *B. fusca*. The larch has two age groups: 40–45 and 20–25 years. The crown density is 0.7 and the fertility rate is II. The communities composed of *Betula fusca* occupy about 85% of the forested area and indicate cold, excessively moist soils. The value of its overground phytomass ranged from 15.8 up to 170.0 centner/ha. The main factor hindering the renewal of larch is the high humidity of the soil, reaching 76–97% in habitats of *Betula fusca*. Areas with potential for the natural regeneration of larch decreased by 50–60% [8].

3.6. Competitive relationships of *Pinus sylvestris, Armeniaca sibirica*, and *Amygdalus pedunculata*

The area within the polygons 'Shaamar' and 'Jargalant' is the forest corridor between Khangai and the Khentei highlands. Xerophytic-motley grass pine forests prevail on sandy and sandy-loam soils with a sparse living ground cover. Forest stands consist of an alternation of parcels that are in different stages of age development. Such a structure of a forest stand testifies to its stability [9]. The fertility rate is II. By the age of 40, the wood stock reaches 180–200 m^3/ha; after that, the pine forests are subjected to selective felling [10]. Consideration of moisture conditions under the pine forests and their replacement with thickets of *Armeniaca sibirica* showed that the lowest level of soil moisture was under thick thickets of *Armeniaca*. Our data indicates displacement of pine by *Armeniaca sibirica*, which is adapted to climate aridization. *Amygdalus pedunculata* inhabits more dry and rocky southern slopes, forming a phytomass up to 137 centner/ha [11]. Its appearance under the canopy of sparse pine trees indicates a far-reaching desiccation of soil and marks ecotopes that are not suitable for reforestation.

4. Conclusion

The current state of shrub communities and their dynamics on the southern border of boreal forests in Mongolia allow us to consider them as stable cenoses that prevent a natural renewal of indigenous forests. The increase in anthropogenic loads, enhanced by climate aridization, deepens the transformation of these secondary communities and leads to the domination of digressive varieties of shrubby wastelands and shrub steppes with low environmental and economic value.

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