Yielding capacity of pyrogenic communities in Central Kazakhstan

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Abstract. Fires in the ecosystems of Central Kazakhstan trigger a pyrogenic succession for 1-2 decades as usual. In recent years, changes of climate and land use in region have led to the intensification of fires and the gradual steppification of the territory, where desert vegetation was previously successfully restored. We analyzed the change in aboveground phytomass stocks during 40 years of pyrogenic succession. In the zonal communities, the phytomass reaches the background values in eight years after the fire and does not change later. For intrazonal communities in river valleys and gullies, aboveground phytomass stocks at the 4th and 16th years of succession do not differ significantly, and the structure of phytomass fractions by the 16th year resembles background zonal communities. This can be associated with a more intense grazing on the intrazonal communities in river valleys and gullies in the studied region.

1 Introduction

Periodic fires are often considered as a regular factor in the functioning of many arid ecosystems. Pyrogenic communities that have formed over millions of years of evolution under conditions of regular burnout and depend on periodic fires can be found widely throughout the world [1, 2]. Edificator species of these communities are usually well adapted to the experience of fire. For example, cespitose grasses dominating in the steppe reliably protect the buds of renewal in the thickness of the tussocks that are not exposed to high temperatures during a fire [3]. Geophytes that are common in steppes and deserts survive fires due to perennial underground organs (rhizomes, bulbs, etc.). At the same time, subshrubs and shrubs of arid ecosystems are more vulnerable to fire. For example, communities of sagebrushes (species of the subgenus Seriphidium, e.g. Artemisia terrae-albae, A. pauciflora, A. sublessingiana, etc.) or some species of the genus Salsola (e.g. S. arbusculiformis) common in the deserts of Central Asia have a great injure from fire and replace with communities of annuals and cespitose grasses [3]. The impact of wild ungulates and domestic cattle that prefer to eat grasses rather than (sub)shrubs is usually considered as a main factor that drives the restoration of subshrub and shrub communities. However, in Central Asia we can watch, on the one hand, the intensification of the pyrogenic impact due to climate change, and on the other hand, changes in the economic regime in recent decades associated with the collapse of the USSR, a decrease in the
number of livestock and the cessation of the distant grazing (in areas located on a large away from settlements). As a result, processes of steppification can be observed over large areas [4]. In the context of these changes, studies of the dynamics of natural communities of arid ecosystems in Eurasia are relevant, even those that have been relatively well studied earlier.

In Central Kazakhstan, in addition to widespread natural and anthropogenic sources of ignition of arid communities (such as dry thunderstorms or careless handling of fire), a regular factor in the occurrence of fires is the fall of the first stages of launch vehicles launched from the Baikonur Cosmodrome [5]. As a result, the most frequently exploited areas of the first stage falling regions located in the Ulytau region of Kazakhstan can be considered as model areas regularly exposed to pyrogenic effects. According to remote sensing data, over the nearly 40 years a considerable part of these falling regions have burned out repeatedly [5]. As a result, the vegetation cover of stage falling regions can be described as a mosaic of communities at various stages of pyrogenic succession.

The purpose of this study is to analyze the dynamics of the phytomass of communities in Central Kazakhstan during pyrogenic succession.

2 Materials and methods

The study area is located in the southwestern part of the Kazakh uplands (Ulytau region of the Republic of Kazakhstan), 50-80 km southwest of the city of Zhezkazgan, in the interfluve of the rivers Sarysu and Duisembay. The interfluves are represented by isolated residual uplands dissected by U-shaped gullies with gentle, occasionally terraced slopes. Soil cover is complex due to the influence of saline ground waters and the micro relief. Aridic Gypsisols, as well as the Gypsisols and Solonetz complexes occur in the watersheds and at the slopes of hummocks. Fluvisols and Calcisols are common in the higher lying floodplain river terraces and dry gully bottom [5].

In botanic scope, the studied territory belongs to the North Turan province of the Iran-Turan subregion of the Sakhara-Gobi desert region [6, 7]. Zonal communities on interfluves are represented by semishrub vegetation with a predominance of sagebrushes (the most common species is Artemisia terrae-albae). In the recently burned areas, communities of cespitose grasses (Stipa sareptana, Agropyron desertorum) and annuals (especially Ceratocarpus arenarius) are widespread. Intrazonal vegetation includes halophytic complexes in saline areas (Anabasis salsa, Atriplex cana, Limonium suffruticosum, Suaeda physophora, etc.), which are almost not subject to fires due to the low projective cover of communities. In addition, communities of xeromesophytic species (Leymus angustus, Carex dimorphotheca, Elytrigia repens, Phlomis tuberosa, Sibbaldianthe bifurca, etc.) are in the valleys of rivers and gullies.

The aboveground phytomass was collected from squares of 1 m² in May 2021 within the territories that burned out in the same or similar years and grouped as follows: 1) four years after the fire; 2) eight years after the fire; 3) 16 years after the fire; 4) 35 years after the fire; 5) not burned out for at least 35 years (the period of availability of remote sensing data). Zonal communities are represented in all age groups (Table 1). For intrazonal communities, plots aged four and 16 years after the fire were found, which also differ in pasture load. In the first group (four years after the fires), valleys with intensive and low pasture load were taken into account. In the second group (16 years after the fires), only areas with intensive grazing load were found within the study area. In total, 36 phytomass samples were processed. In each same-age group, the repetition was from three to nine samples.
Table 1. Dominants of studied communities.

<table>
<thead>
<tr>
<th>Age of fire, years</th>
<th>Zonal vegetation at interfluves and gentle slopes</th>
<th>Valleys of rivers and gullies</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td><em>Ceratocarpus arenarius, Stipa sareptana</em></td>
<td><em>Carex dimorphotheca, Juncus soranthus, Sibbaldanthe bifurca, Artemisia proceriformis</em></td>
</tr>
<tr>
<td>8</td>
<td><em>Stipa sareptana, Artemisia terrae-albae</em></td>
<td>-</td>
</tr>
<tr>
<td>16</td>
<td><em>Stipa sareptana, Artemisia terrae-albae</em></td>
<td><em>Artemisia proceriformis, Poa bulbosa</em></td>
</tr>
<tr>
<td>35</td>
<td><em>Artemisia terrae-albae</em></td>
<td>-</td>
</tr>
<tr>
<td>&gt;35</td>
<td><em>Artemisia terrae-albae</em></td>
<td>-</td>
</tr>
</tbody>
</table>

Note. Dash (-) means that these communities were not found in the study area.

Plants were cut at the level of the root collar and were divided into the following groups:
1) ‘Shrubs’ (include subshubs, predominately *Artemisia*, less often various *Amaranthaceae* species)
2) ‘Grasses’ (*Poaceae* species);
3) ‘Sedges’ (*Cyperaceae* and *Juncaceae* species);
4) ’Legumes’ (*Fabaceae* species);
5) ‘Misc herbs’ (other species).

In addition to green phytomass, mortmass (dead aerial shoots of plants on the soil surface, including those from last year) was collected separately from aboveground phytomass. All samples were weighed in the air-dry state.

Significant differences were determined using the Mann-Whitney U test at a threshold p-value = 0.05.

3 Results and Discussion

In the conditions of Central Kazakhstan, for most of the fire hazard period (from May-June to September) [5], most of the aboveground phytomass passes into the category of mortmass due to the drying of shoots, which allows us to consider not only the aboveground phytomass and mortmass separately, but also the total combustible material as a sum of these values. The dynamics of the total aboveground phytomass and mortmass during the pyrogenic succession in the studied communities is shown in Figure 1.

In the background zonal communities that have not been exposed to pyrogenic impact for at least 40-50 years, the pure aboveground phytomass is about 150-200 g/m², with the mortmass - 200-300 g/m² (minimum and maximum are 189 and 314 g/m², respectively). Therefore, it does not exceed the lower limit (300–600 g/m²) of the aboveground phytomass that was previously reported for the subboreal deserts in [8].
Despite the relatively fast restoration of the total projective cover of zonal communities to the background values / pre-fire level (30-40%) in 3-4 years, the restoration of the pre-fire level of phytomass takes a longer period of time. At the sites burnt out four years ago, the value of the total combustible material is significantly (p=0.036) less than in the background zonal communities, while the differences of above-ground phytomass and above-ground mortmass are only at the trend level (p=0.14 and 0.09, respectively). After another 4 years, a total combustible material and above-ground mortmass are already close to background values both in terms of average and variance. At the same time, the pure above-ground phytomass is still somewhat below the background values (p = 0.14). The low values of the total combustible phytomass in the first few years after the fire correspond to the known terms of fire turnover (10-20 years) in the sagebrush communities of Kazakhstan. However, according to our data, the stock of a combustible material reaches the background level already by the eighth year of succession. According to our data, in the communities under consideration, the threshold supply of combustible material (dry rags and bedding) of 254 g/m², at which the probability of a steppe fire from a burning match reaches 77% [3], is reached already 5-6 years after fire. At the same time, the minimum period for which repeated burnout of the same areas is observed in the study area is about three years [5]. Over a period of 8-35 years or more, the average values of the indicators practically do not change, which indicates a continuing high fire hazard for the plant cover for decades at a constant level.

The data obtained for intrazonal communities of rivers and gully valleys indicate that the communities retain lower phytomass stocks for at least 16 years. We believe that, to the greatest extent, such features can be explained with intensive grazing pressure, which under the desert conditions, first of all, typical of the valleys of rivers and gullies as areas preferred by wild and domestic ungulates for grazing. High grazing pressure leads to the preservation of low stocks of aboveground phytomass and a significant reduction in mortmass in communities, which, in turn, greatly reduces the probability of the territory burning out. In turn, for valleys with low grazing intensity, we assume quite frequent burnouts due to the rapid accumulation of phytomass (primarily mesophytic and xerophytic grasses) under conditions of better moisture, which makes it difficult to build a long
succession series. Further studies are needed for a more detailed analysis of the phytomass dynamics of intrazonal xeromesophytic meadow communities. The structure of the phytomass of the studied communities is shown in Figure 2.

![Figure 2: The ratio of phytomass fractions of the studied communities of Central Kazakhstan.](image)

Both in zonal and intrazonal communities, there is a general trend of growth in the proportion of (semi)shrubs during pyrogenic succession, which is expressed both in the total mass (in both types of communities, the phytomass of shrubs triples from the first to the last considered fire age category), and in quantitative ratio with other phytomass fractions. During the pyrogenic succession, the proportion of grasses decreases to the greatest extent (grasses and sedges for intrazonal communities). The observed change corresponds to the known data [3] on the decrease in a grass cover during succession under the influence of ungulates. It is curious that in intrazonal communities experiencing the greatest pasture load, already 16 years after the fire, the ratio of phytomass fractions is very similar to that observed in zonal communities at the latest stages of a pyrogenic succession (the “No fire” group – at least 40 years after the fire). It once again confirms the role of ungulates in the restoration of the subshrub communities of the deserts after fires. A certain increase in the proportion of legumes (mainly Astragalus, Trigonella and Glycyrrhiza) in the early stages of succession is also noted. It was previously known that fires can stimulate the growth of legumes, but usually do not lead to an increase in the phytomass, affecting primarily the rate of germination [9, 10].

4 Conclusion

Despite the low reserves of phytomass in the studied communities of Central Kazakhstan, after several years of pyrogenic succession, the amount of combustible material is sufficient for repeated burnout and restart of pyrogenic succession. Already by eight years of pyrogenic succession, phytomass reserves reach the level of the background zonal communities. At the same time, cespitose grasses continue to play a considerable role in the vegetation cover, growing in the first few years after the fire. Grazing takes the greatest part in reducing the share of grasses in the community, which is especially evident in the
example of intrazonal communities that experience a more intensive pasture load in the study region.

Acknowledgements

The study was carried out within the framework of the Russian Science Foundation project No. 20-77-10010.

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