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The natural transformations of the Northern Kulunda in the second half of the Holocene based on studying the microbiomorphic profile of swampy phytocenosis

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The article presents the analysis of the microbiomorphic soil profile of the swampy meadow. Phytoliths, spicules of sponges and Rhizopoda shells are abundant in the soil. There are spores of fungus and mosses, as well as zoogenic material. The change in the natural conditions of the object during the second half of the holocene was reconstructed based on the obtained data. Differences in the content of microbiomorphs in different horizons of the soil profile of the swampy meadow correspond to the general regional and local processes of climate and vegetation dynamics in Northern Kulunda and adjacent territories.

Key words: Holocene; Microbiomorphic profile; Phytoliths; Pollen; Rhizopoda; Spores; Sponges

Introduction

Knowing, how the environment has evolved in the past, is important for assessing possible future changes. Investigations of the climate fluctuations and vegetation changes in the holocene (Rudaya et al., 2016; Rudaya et al., 2018; Zhilich et al., 2017) due to the human appearance and expansion the role of human influence on nature (Kiryushin 2017, 2019; Papin et al., 2018; Sitnikov et al., 2014; Fedoruk et al., 2017) are significant for the territory of Northern Kulunda. Landscapes of the Kulundinskaya steppe were formed in the holocene in the unstable climate (Hotinskiy et al., 1979; Orlova, 1990; Zyikin et al., 2011; Silanteva, 2008; Blyakharchuk, 2009) and under the influence of pastoral crops (Kiryushin, 2017, 2019; Papin et al., 2018). The materials of archaeological sites often study human influence on the vegetation formation. So, the processes of forest clearing and steppe formation of local territories, which are reconstructed on the basis of phytoliths analysis (Solomonova et al., 2016, 2017), are noted for the some pastoral crops on the territory of Northern Kulunda in the second half of the holocene.

These processes were matched up the general trend of increasing aridity of the region, proven by palynological investigations of adjacent territories (Rudaya et al., 2012; Zhilich et al., 2016).

The expansion of ideas about the interaction between human and nature is possible due to attracting new research methods. Both palynological or phytolytic methods, and also the general analysis the totality of microbiomorphic or non-pollen palynomorphs have the wide paleoecological potential (McCarthya et al., 2018; Misumi et al., 2018; Demske et al., 2013; Khokhlova et al., 2019; Rusakov et al., 2018). Initial data indicates that such analysis is perspective (Paradossky, Solomonova, 2018). The research group is the microbiomorphic profile of the swampy meadow.

Materials and Methods

The object of investigation is the swampy meadow located in the ancient floodplain of the river Burla (Khabarovsky district, Altai Territory, Russia). The total projective coverage is 100%. Dominated by: *Saussurea amara* L. D.C. (cop 2) and *Scolochloa festucacea* (Willd.) Link (cop 3). In the grassy abundance of hygrophytes: *Alopecurus arundinaceus* (sp), *Bolboschoenus planiculmis* (F. Schmidt) T.V. Egorova (sp), *Phragmites australis* (sp). Among grasses *Agrostis gigantea* (sp) is also found. Abundant forbs: *Inula britannica* L. (sp), *Lactuca tatarica* (L.) C.A. May. (sol), *Lycopus exaltatus* L. (sp), *Stachys palustris* L. (sp), *Plantago cornuti* Gouan (sp), *Potentilla anserina* (sp) and *Ptarmica cartilaginea* (Ledeb. ex Rchb.) Ledeb. (sp).

Soils on the site are peat-bog, peat depth up to 50 cm, below is the whitish layer of sapropel. That is, earlier there was the lake, then there was the period of water flow. When the plot had overgrown with herbs, the processes of swamping began, which formed the thickness of the peat. At the end of the Atlantic period, the archaeological eneolithic settlement Novoilinka-VI was located by the lake. There is an evidence of lake pollution by human. It is highly probable that the change of hydrological regime has become the main reason for people leaving the settled territories (Goleva, Kiryushin, 2015).

The method of enrichment the samples with microbiomorphs consists in the fact that before the investigation the sample must be sieved through the sieve with a 0.25 mm cell and transferred to the 1000 ml heat-resistant measuring battery cup. After this, the sample is treated with the 5% hot solution of sodium pyrophosphate (up to the level of 200 ml), and after 2 hours it is added with hot water to the level of 1000 ml, after these the sample settles for a day. After the time, the sample is washed every 3 hours until the supernatant liquid becomes clear. The next step is drying the sample in the water bath, followed by centrifugation the sample with the heavy liquid (KI and CdI solution, specific gravity is 2.2). Centrifugation is carried out for 20 minutes at 2 thousand rpm; then the layer of heavy liquid with the upper part of the precipitate are mixed and centrifuged again. The upper layer of liquid, enriched with pollen, is poured into the glass with a volume of 250 ml and diluted 4 times with distilled water.

Collection and centrifugation in narrow-conical tubes at 2 thousand rpm for 15 minutes 3 times are carried out after sedimentation of the sample for a day (each time draining the supernatant and topping up the tube with distilled water to wash off heavy liquid). The final step of enriching the sample is drying in the water bath.
The Olympus BX-51 microscope using the Olympus XC-50 digital camera and cellSens Standard software with the 20x lens magnification carried out the microbiomorph investigation. Microbiomorphs were counted up to 300 specimens from one sample. The main categories of counted microbiomorphs are phytoliths, diatoms, sponge spicules, various plant spores, pollen, mycelium and fungal spores, zoogenic remains and foraminifera shells.
The following literature sources were used to determine the microbiomorph: 1) Pollen analysis; 2) Demske D. Atlas of pollen, spores and further non-pollen palynomorphs recorded in the glacial-interglacial late quaternary sediments of lake suigetsu, central japan; 3) Lyudmila Shumilovskikh, Guidelines for working with non-pollen palynomorphs; 4) Proshkina-Lavrenko A.I., Sheshukova V.S. Diatom collection and other. Phytoliths were determined based on illustrative material on the territory of Northern Altai (Solomonova et al., 2019).

Results and Discussion

Phytoliths (Figures 1, 2D and 2G) (about 90%) silicon structures, which are formed in plant cells, are the basis of biogenic particles in the upper part of the microbiomorphic profile to the depth of 55 cm. This is typical for soils under phytocenoses with grasses dominance (Solomonova et al., 2019). The phytoliths of grasses in the lake sapropel are half as much. Apparently, they belong to species, which grow along the banks of previously existing reservoir. Phytolith analysis revealed the dominance of reed phytoliths during the existence of the lake (Paradossky, 2019).

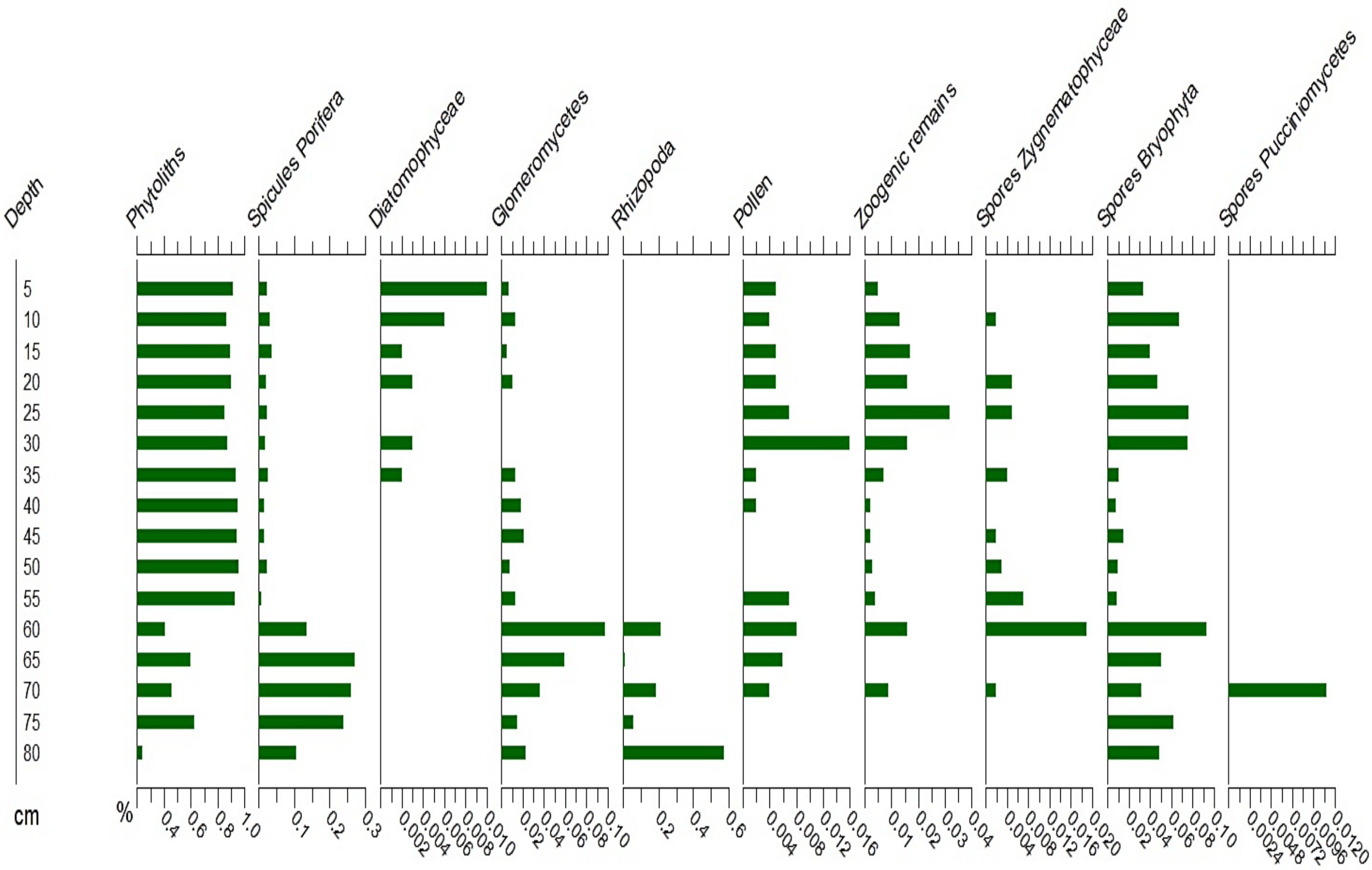

Figure 1. Microbiomorphic profile of a swampy meadow.

The shells of diatoms algae (Figures 2I-2M) are indicated among other silicon forms in the upper layers of the profile. These are the largest group of unicellular eukaryotic microalgae that are present in almost any aquatic environment (Gordov et al., 2013). Their presence corresponds to the presence of the present swampy phytocenosis.
Silica is also formed in freshwater and marine sponges (Figures 2N and 2O) (Gordova et al., 2013). Most types of the ordinary sponges class (Demospongiae), most representatives of Homoscleromorpha class, and all representatives of the glass sponges class (Hexactinellida) have the silicon skeleton (Drozdov, Karpenko, 2013). Sponge spicules are found over the entire depth in the investigated profile. Their largest number (from 10 to 25%), as expected, is concentrated in the lake sapropel. The Demospongia class in the continental reservoirs of Western Siberia predominantly represents sponges; freshwater bodyagy and several other species are ordinary for modern ecosystems, (Sharapova et al. 2014). Remains of the sponges skeleton are often found during paleobotanical investigations the archaeological sites of Western Siberia located in floodplains of rivers and lakes (Sharapova et al. 2014).
Rhizopoda shells (Figures 2H and 2P) are noted among the zoogenic residues in the profile. The amoeba shells are found in the wide variety of natural conditions: in moist mosses, soils, including fresh water (Imankulova et al., 2013; Imankulova, Lukyantseva, 2014; Zaidov, 1991).

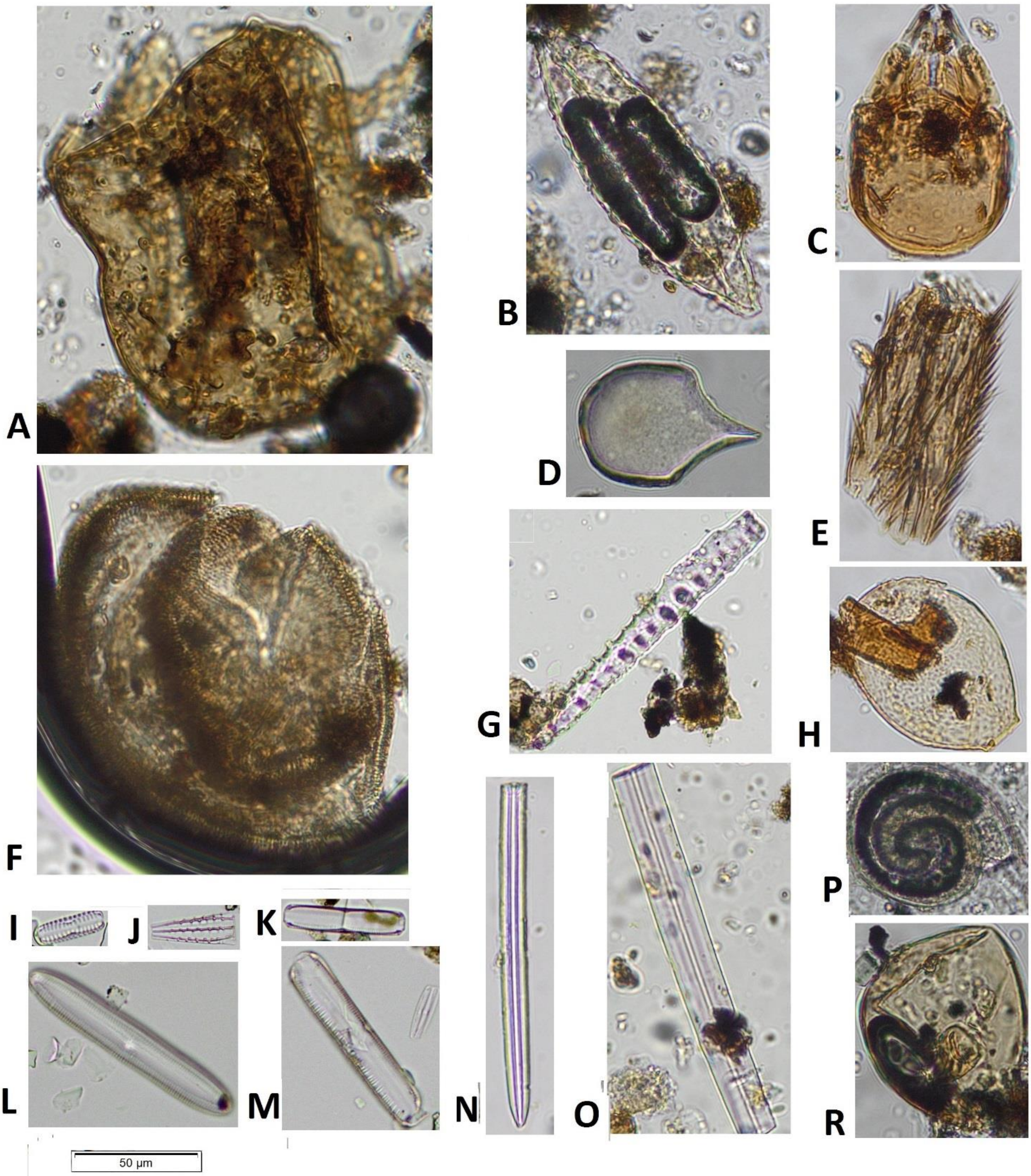

Figure 2. A – Rotifera oocyte; B – Zygnematophyceae spores; C, E – Insecta parts; D – Phragmites phytolith, F – Cladocera part; G – grass phytolith; H, P – Rhizopoda shells; I–M – Diatomophyceae; N, O – Sponge spicules; R – Dinoflagellata cyst.

The shells of these protozoa, although they have different degrees of preservation, can persist for long periods in peat deposits and be used for the indication of climatic conditions in paleoecological investigations as well as for reconstruction of the swamps water regime (Booth, 2001; Kuryina, 2011, 2015; Kuryina et al., 2010; Warner, Charman, 1994). The hydrological conditions of the investigated reservoir promoted the conservation of Rhizopoda shells only in the lake sapropel. Their large number in three layers of the profile: 55-60 cm, 65-70 cm and 75-80 cm is noticed. The decrease of shell amoebas in the profile correlates with increase the number of phytoliths. Thus, it should be assumed that the pulsation of the lake occurred in the holocene. In some years, the lake’s mirror increased, in others it decreased and partially overgrown.

Other zoological residues (Figures 2A, 2C, 2E, 2F, 2R), besides the sponges spicules and amoeba shells, are found in the profile: insect fragments, parts of chitinous cover of rotifers and their oocytes, fragments of cladocera crustaceans, tardigrade eggs, which are evenly distributed throughout the profile in small quantities.

Spores of fungus, algae and mosses, as well as pollen represent the botanical material of the soil profile from coniferous and flowering plants. The spores of *Glomeromycota* (Figure 3A), endomycorrhizal fungus, which form arbuscular mycorrhiza and improve the mineral nutrition of plants, are mainly found in the lower layers of the profile. Their formation preceded the overgrowth of the reservoir (Belimov et al., 2012; Tchaikovskaya 2015). The reservoir was polluting at the time of the settlement’s existence. The number of phosphates, which were more accessible to plants growing along its banks, increased (Goleva, Kiryushin, 2015), so, the mycorrhiza formation became less.

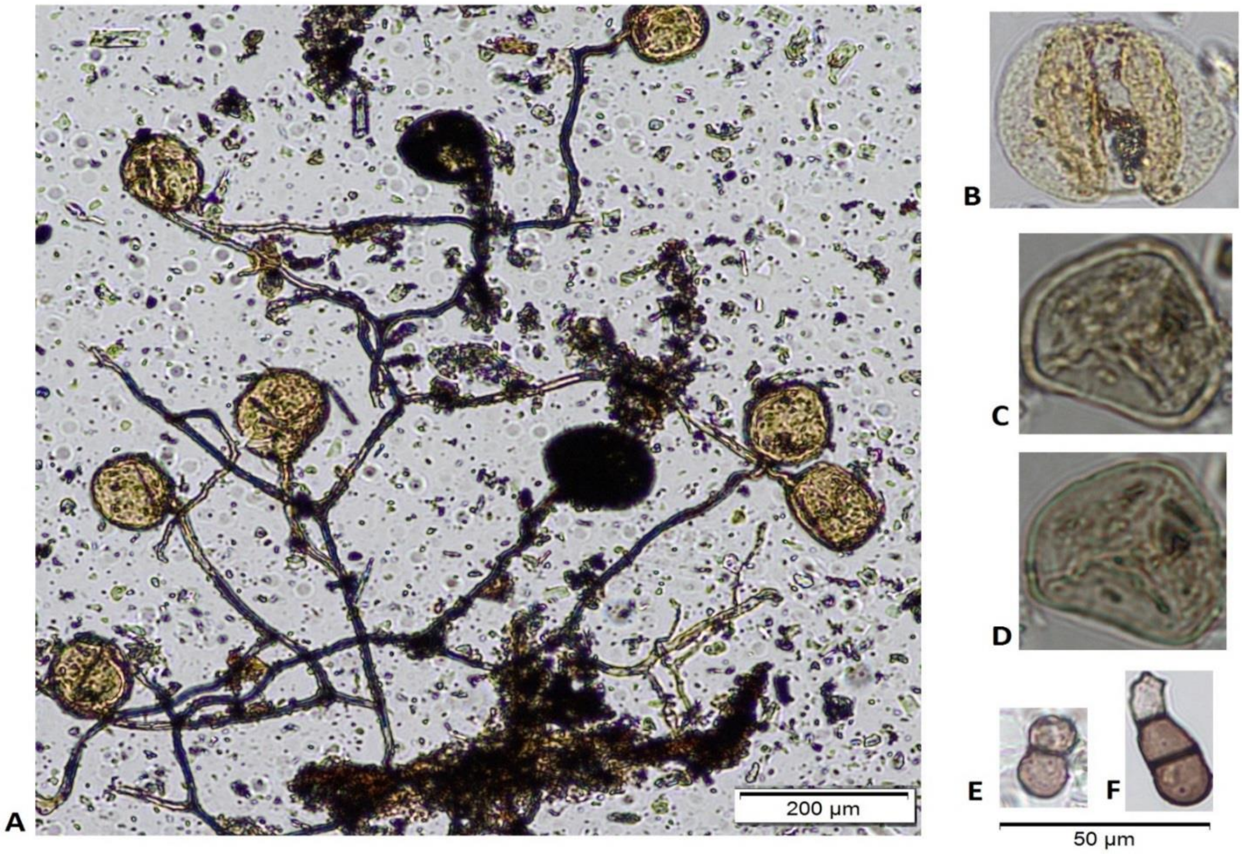

Figure 3. A – Glomus spores and gifs; B – Pinaceae pollen; C, D – Bryophyta spores; E, F – Pucciniomycetes spores.

Among fungus, Pucciniomycetes spores (Figures 3E and 3F) are also noted in small number in one layer. These are parasitic basidial fungus, which development occurs with the change of owners and several variants of sporulation (Rayimova et al., 2015).
Moss spores (Figures 3C and 3D) and pollen (Figure 3B) are found in small numbers throughout the whole profile. Palynological material usually has the high preservation of peat deposits of Siberia. Poverty of the samples by the pollen and spores is probably associated with the high rate of peat accumulation. The conjygat zygospores (Zygnematophyceae) (Figure 2B) with elongated form, which correspond to spores of zignem algae, are found in some layers of the profile. Ornamentation of spores is similar to the structure of Spirogyra, the freshwater alga, which is abundant in standing water (Janse, Vuuren, 2006). The significant number of these microbiomorphs was found in the layer of 55-60 cm, which corresponds to the boundary of lake sapropel and peat. Thus, it was the freshwater standing water.

Conclusion

The microbiomorphic profile correlates with the morphology of the section. Initially, there was the fresh lake on the site, which was confirmed by the set of microbiomorphs. The water level in this pond was not constant and overgrowing was observed in some periods. The eneolithic settlement of people appeared on the shore of the lake approximately 4,200 yeas ago A.A. Goleva and K.Yu. Kiryushin found that people polluted the lake with household waste that led to its overgrowing (Goleva, Kiryushin, 2015). Despite the fact that people left this settlement subsequently, the hydrological regime of the reservoir did not recover. The reasons are the dry climate at the turn of the atlantic and subboreal period and the general tendency of intensification the waterlogging and peat accumulation processes in the subboreal period (Baulin et al., 1989; Rudaya et al., 2012; Zhilich et al., 2016). Waterlogging in the forest-steppe, besides the climatic factors, was caused by the presence of low-drained spaces with various negative landforms (Evseev, Zhilina, 2010).

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