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Changes in the palsa landscapes' components in the West Siberian northern taiga 10 years after wildfires

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Abstract. The reconnaissance exploration of the palsa landscapes' components in the Nadym-Pur interfluve of the northern taiga of Western Siberia, devastated by wildfires 10 years ago, was carried out to compare with an undisturbed area.

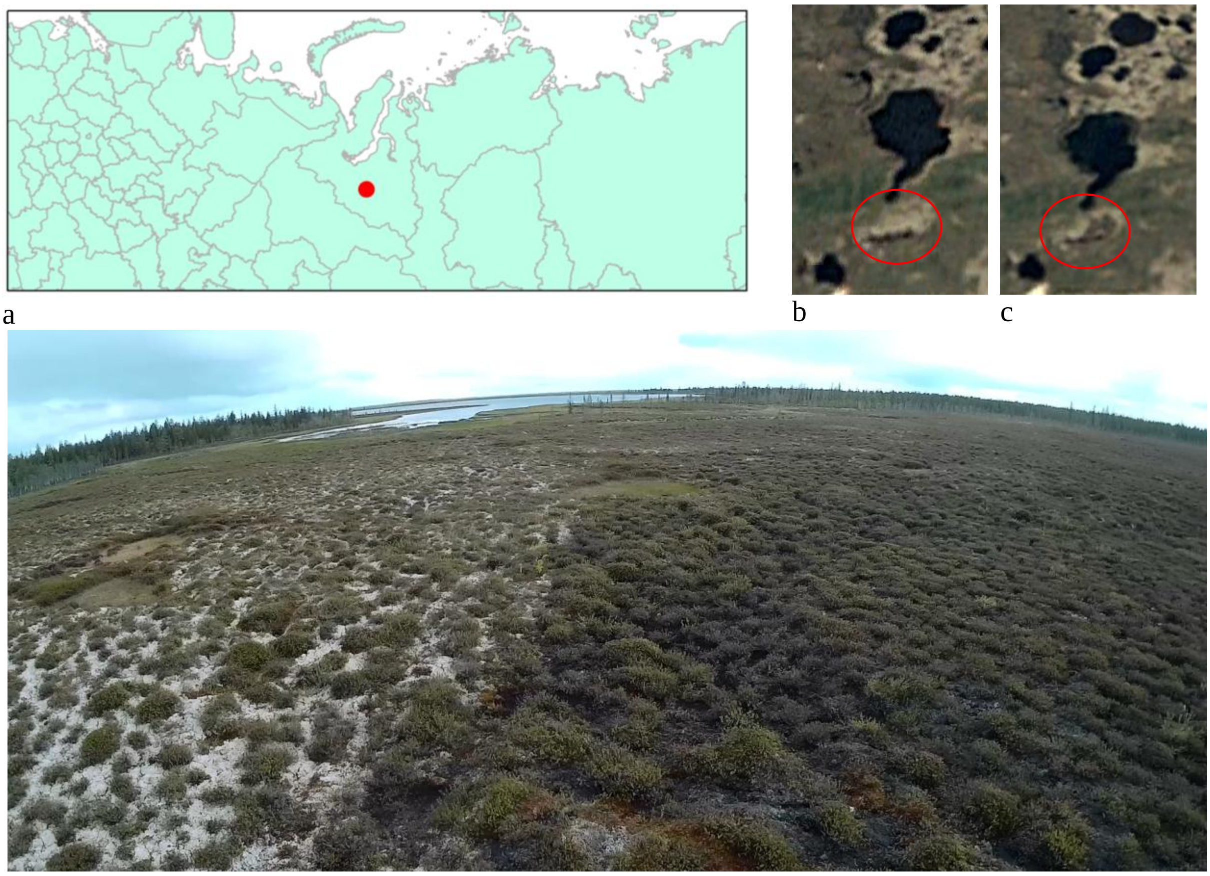
1. Introduction

The response of terrestrial ecosystems to climate change has been one of the most relevant research areas of the global scientific community over the past decades [1]. Pyrogenesis is one of the main factors determining the dynamics of the plant and soil cover of the cryolithozone [2, 3, 4, 5, 6]. It has been established that the destruction of a plant cover, which protects the soil from warming up, by a fire contributes to an increase in its temperature, and lowers down the upper boundary of the permafrost [7, 6]. Fires, accelerating the rate of permafrost thawing, can determine the dynamics of palsas' emergence and disappearance [8]. Sometimes wildfires result in permafrost thawing; permafrost peatlands are often completely destroyed after fires and small water bodies or swamps appear in their place [9, 6].

However, in the Russian cryolithozone, the effects of wildfires on landscape components and post-fire successions were rarely studied. Some general information can be found in researchers' works written in the last century [9, 10, 11, 12, 13, 14, 15], the impact on the landscapes in forest areas was mainly investigated, the information about fires on palsas is rare [7].

2. Materials and methods

The area under study is located in the Nadym-Pur interfluve, in the northern taiga of Western Siberia (Figure 1a). The average annual temperature is -5.3 ° C, the average temperature in January is -25 ° C, the average temperature in July is 16.7 ° C, the relative air humidity is 75.6%, the snow cover thickness is 52 cm (NASA. RETScreen). A detailed description of the area and geochemical properties of natural environments under study is in Loiko et al. [14].



a b c

d

Figure 1. a) Study area location, b) Space image snippet, Landsat, 2006, c) Space image snippet, Landsat, 2007, d) The palsa under study (on the right - the area affected by the wildfire, on the left - an undisturbed area)

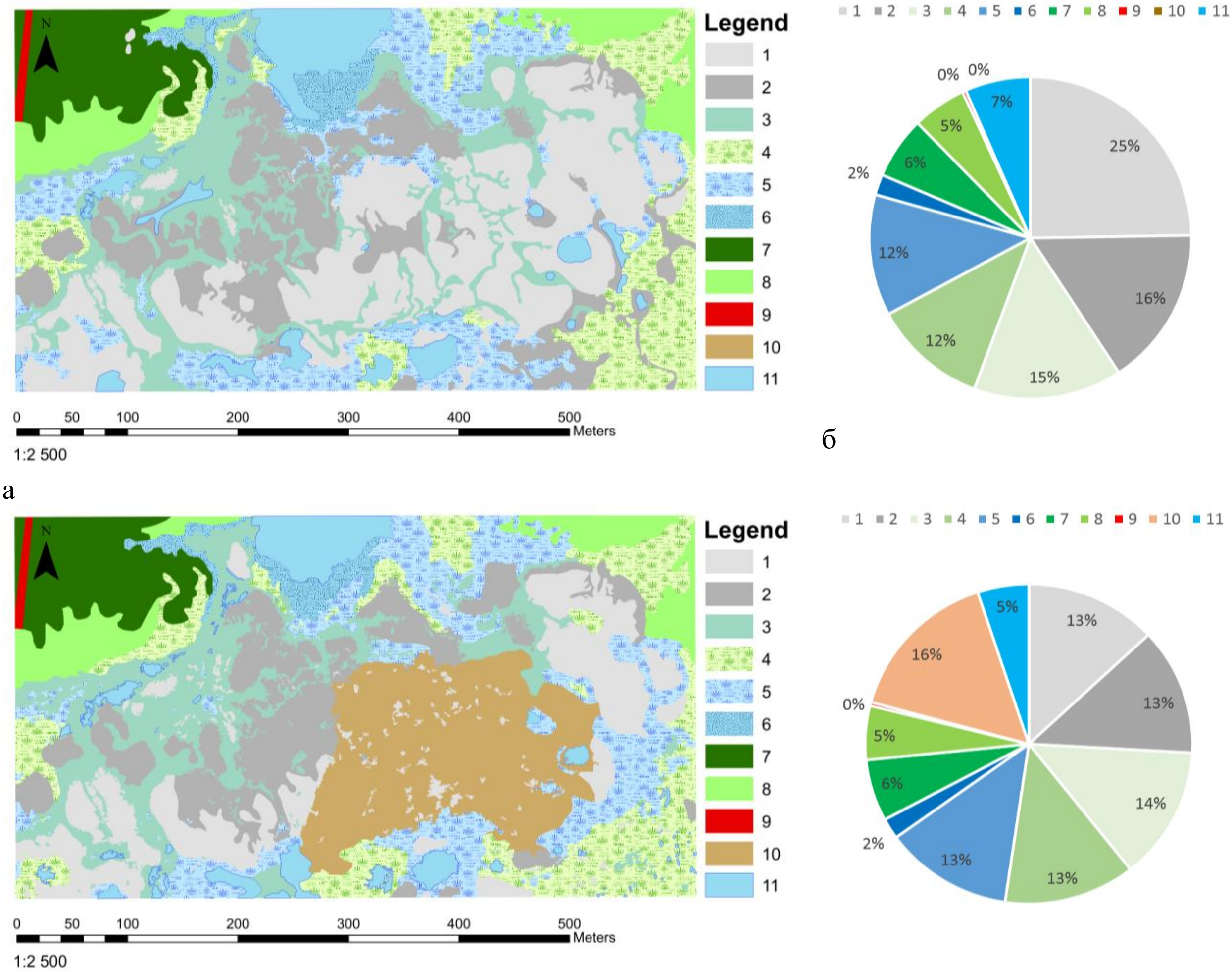
In 1989, a field party of the Research Institute of Biology and Biophysics of Tomsk State University investigated the landscapes of the Nadym-Pur interfluve to provide the environmental support for oil and gas field projects. The study of the territory was carried out employing aerovisual methods combined with a detailed soil-geobotanical survey of key sites. The micro-landscapes were mapped. The maps were accompanied by a detailed explication and an album of annotated aerial photographs, with an indication of the interpretive signs. We analyzed the multi-temporal (1989-2018) satellite images of the average spatial resolution, the interpretation of which made it possible to clarify the data on the changes that have occurred in recent years. We used both an automated interpretation with the help of the software package ArcGIS based on the classification with training, and the “manual” interpretation.

In palsa we found a site in which a part of the active layer of permafrost was destroyed by fire. We consider this site to be a large-scale experiment in nature. By comparing Google Earth images made at various periods of time we managed to determine the date of the fire – it took place in 2007 (Figure 1 b, c).

In 2018 reconnaissance studies of this site were carried out using standard soil and geobotanical methods and SIR-2000 gaoradar, which allows working with both shielded (from 100 MHz and higher) and unshielded (up to 100 MHz) antenna blocks.

3. Results and discussion

When comparing aerial photographs of 1989 with modern satellite images of close resolution, we found significant changes in the landscapes of the previously surveyed areas: a decrease in the areas of hollows and large thermokarst lakes, the descent of lakes into the drainage network, the emergence of new lakes near the fire site (Figure 2).



a б c d

1- lichen palsa, 2 - lichen-shrub palsa, 3 - hollows, 4- sphagnum-dwarf shrub bog, 5- sedge-cotton grass fen, 6 – cotton grass-sedge-sphagnum quagmires, 7- coniferous forest, 8- lichenaceous - suffruticose coniferous sparse forest, 9- cutting down, 10 – burnt palsa, 11- lake

Figure 2. Decoded remote sensing materials and landscape structure of the territory: a, b - 1989, c, d – 2018

The vegetation in the undisturbed part of the palsa is typical for the palsas in the northern taiga (Figure 3), oligotrophic shrubs dominate in the shrub layer including *Ledum palustre* L., *Chamaedaphne calyculata* (L.) Moench, *Andromeda polifolia* L., there are a lot of *Empetrum nigrum* L., *Vaccinium vitis-idaea*. *Betula nana* L. is abundant. On the palsa one can find such herbs as *Rubus chamaemorus* L. From 60 % to 90% of the surface is covered by lichens belonging to *Cetraria* and *Cladonia* genera. In hollows one can find *Eriophorum vaginatum* L., *Eriophorum polystachion* L., *Scheuchzeria palustris* L, *Carex limosa* L., *Carex rotundata* Wahlenb., *Carex chordorrhiza* Ehrh., *Carex globularis* L. The peat moss cover consists of *Sphagnum fuscum* (Schimp.) Klinggr,

Sphagnum magellanicum Brid., *Sphagnum angustifolium* (Russ.) C. Jens., *Sphagnum nemoreum* Scop. In addition to these types of sphagnas in the current vegetation cover there are *Sphagnum lenense* H. Lindb., *Sphagnum jensenii* H.Lindb. and *Sphagnum fimbriatum* Wils., *Sphagnum rubellum* Wils. and *Sphagnum russowii* Warnst., *Sphagnum balticum* (Russow) C.E.O.Jensen. There are also green mosses, for example *Warnstorfia fluitans* (Hedw.) Loeske, *Drepanocladus aduncus* (Hedw.) Moenk.
On the burned part of the palsa, the upper thermally insulating lichen layer was partially destroyed, and partially turned to a baked dark crust, which changed the surface albedo and enhanced the permafrost layer thawing (Figure 4).

Figure 3. Typical natural palsa vegetation

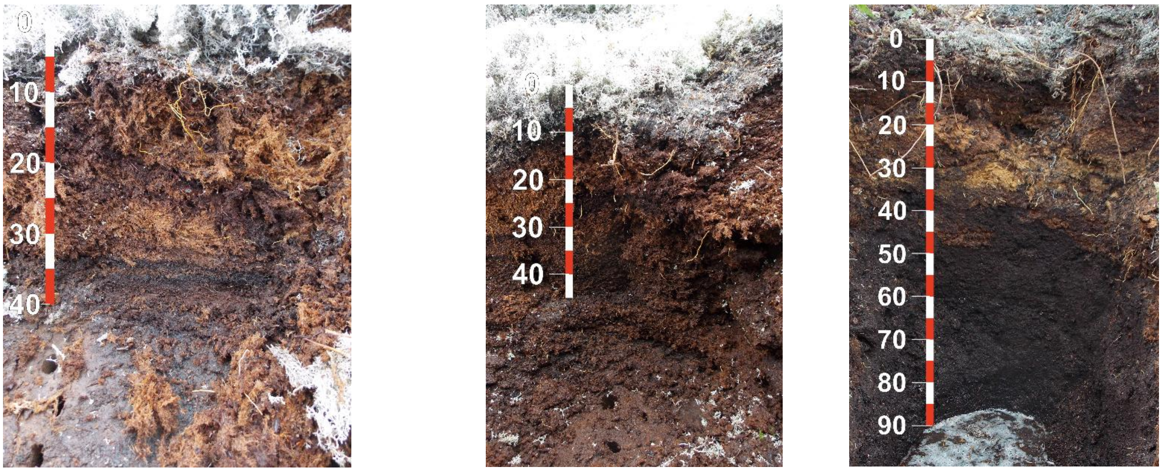
Figure 4. Restoration of vegetation at the fire site

The plant communities of the burnt area are characterized by a low projective cover of the toe-shaped and tubular lichens of the genus *Cladonia*, as well as *Polytrichum*, ericoid shrubs, which was noted earlier for the first stages of recovery after wildfires [15, 16]. In the shrub cover *Ledum palustre* L. dominates, however, *Vaccinium vitis-idaea* starts restoring and *Rubus chamaemorus* L. appears.

It was revealed that after the wildfire, the permafrost degradation processes accelerated, which is confirmed by the data of Tyrtikov and Moskalenko [7, 9], who found out the permafrost upper boundary lowering as the active layer reduced. In addition, the degradation of permafrost is influenced by a change in the surface albedo, and, accordingly, the temperature of the underlying layers, and the change in the thickness of the snow cover in the burnt area [7].

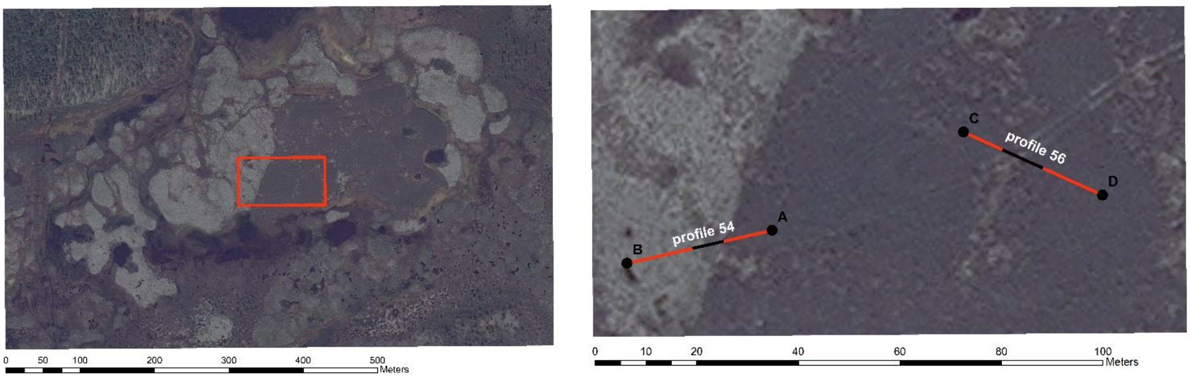
In the soil cover of the undisturbed palsa area, peat oligotrophic permafrost soils (Cryic Fibric Histosol (Turbic)) prevail on the mounds, their active layer being represented by the alternation of sphagnum and shrub peat of various decomposition degrees [14]. The upper limit of permafrost is at a depth of 40-50 cm (Figure 5 a, b). In the area devastated by wildfire, the permafrost boundary is shifted to 80-100 cm, with a significant part of the active profile layer represented by thawed peat (Figure 5 c).

During the georadar survey, we found out that lowering the upper boundary of permafrost rocks is not typical for the whole territory, but only for its particular sites (Figure 6).



a b c

Figure 5. Soil cuts in the study area a, b) Cryic Fibric Histosol (Turbic), c) thawed Cryic Fibric Histosol (Turbic)



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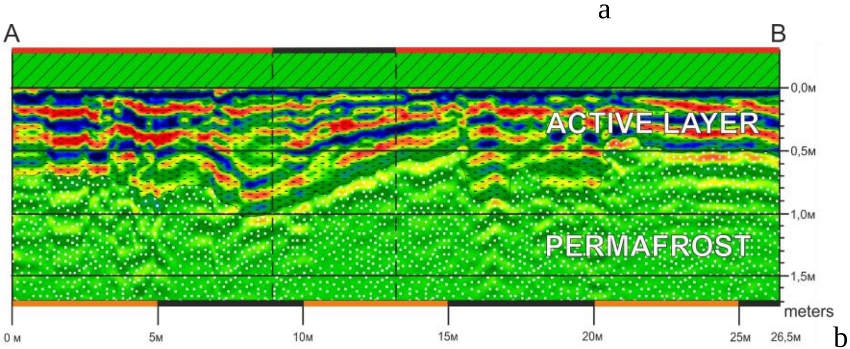

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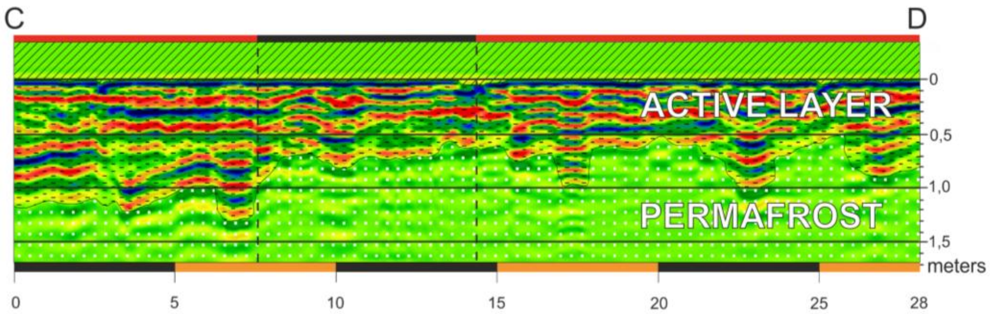

c

Figure 6. GPR survey of the site a) Routes geolocation b) Profile 54 c) Profile 56

4. Conclusion

Thus, on the burnt part of the palsa, the degradation of the permafrost is revealed, due to the fact that, firstly, the thickness of the insulation layer decreases, secondly the surface albedo and the temperature of the underlying layers change, and thirdly the thickness of the snow cover changes. However, the degradation of the permafrost is heterogeneous in different parts of the burnt palsa.

In the future, this area may be considered not only from the point of view of the influence of pyrogenesis on permafrost peatlands, but also from the point of view of the future perspective. If we assume that permafrost thawing will continue, then this experiment in nature can be viewed as a physical model of the future state of the landscape over a fairly large area.

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