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Effect of soil temperature field heterogeneity on soil and vegetation spatial heterogeneity along tundra-steppe catenas in the Mongun-Taiga Mountain

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Abstract. The article discusses the possibility of revealing reverse interrelationship between temperature field heterogeneity and spatial heterogeneity of soil and plant cover of the tundra-steppe catenas in the Mongun-Taiga Mountains. As a result of the studies, the quantitative characteristics, the temperature field inhomogeneities obtained as a result of a joint analysis of the time series of temperature monitoring and satellite data were used for the first time to identify the structural units of the soil cover of the highlands of the Altai-Sayan region. The novelty of the approach is that the cartographic models of temperature fields created on the basis of quantitative temperatures, adequate informati, allowing to establish interchangeable conditions with other characteristics of objects of the natural environment and to approach the solution of isolation problems and the typology of soil-ecological boundaries.

1. Introduction

Temperature regime is one of the most significant environmental factors, together with hydrothermal regime characterizing the general energy level for soil and plant cover formation and functioning. According to results obtained in the last decades, soil temperature field heterogeneity determines the heterogeneity of soil properties, being the leading factor in structuring soil heterogeneity in time and space [1-4]. Recently the broad application of remote sensing methods for soil ecological studies resulted in the use of temperature regime indicators to develop methodological basis to identify structural and functional boundaries within soil and plant cover. Development of typology techniques for structural units of soil type diversity and theoretical justification of criteria for soil contours differentiation are especially actual for objective representation of soil and plant cover of the mountain regions with their significant diversity and heterogeneity. Most studies devoted to soil cover differentiation and thematic maps development based on remote sensing data, both in Russia and abroad, were carried out using the indicative decoding of space images of plant cover, since vegetation as a soil forming factor determines soil cover composition and background soil genesis [5-7]. However, for some areas, especially the mountainous ones, high seasonality of vegetation development impedes its indication potential to determine soil cover composition as compared to the indicative potential of other environmental factors. In such cases natural boundaries due to the effect of soil-forming factors can be used to establish soil unit boundaries – factorial boundaries, according to one or several factors and functional boundaries drawn according to certain soil processes. The aim of the study was to justify the possibility to use quantitative characteristics of soil temperature regime, received as a result of the analysis of time series of temperature monitoring using ground automated



systems to differentiate soil cover structural units in the Altai-Sayan mountain region. The novelty of the approach resulted in obtaining for the first time the integral quantitative characteristics of soil temperature regime which allowed identifying the ranges of their sustainable functioning as well as revealing the effect of other soil processes on the temperature regime.

2. Objects and methods

The key study sites with the most common types of the tundra-steppe complexes were selected on the northern macroslope of the Mongun-Taiga Mountain range according to the altitude gradient principle in geomorphologic classification and the general concept of a catena (Figure 1).

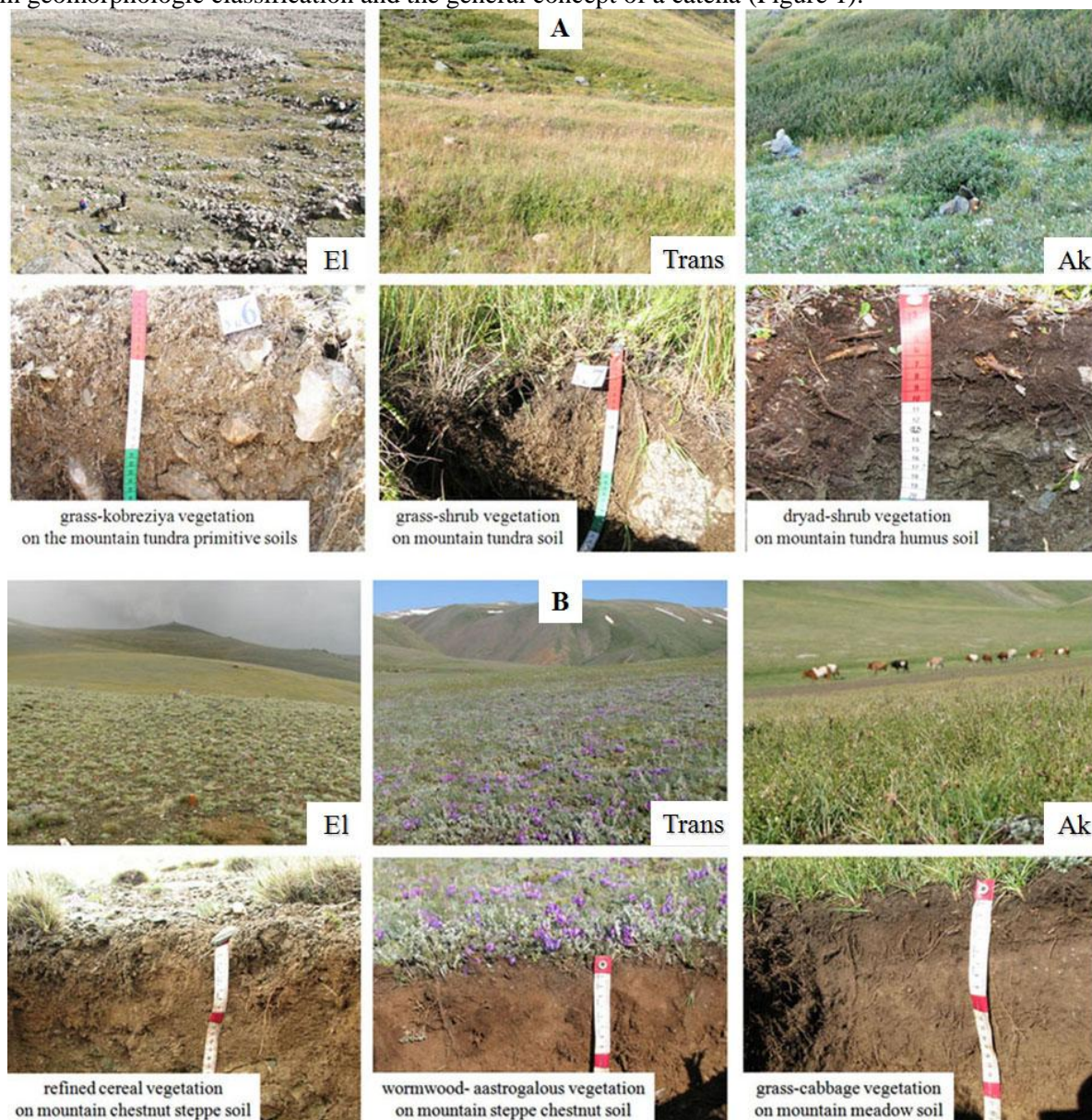


Figure 1. The main groupings of soil and vegetation cover, formed in conditions of eluvial, transition and accumulative positions of the tundra-steppe catenas on the northern macroslope of the Mongun-Taiga Mountain Range. Catena A - East Mugur is located in the zone of direct influence of the glacier; catena B - Shara-Haragai, is located outside the glacier impact zone.

Specific soil-forming processes in the tundra-steppe complexes of the Mongun-Taiga Mountain range resulted in the formation of soil cover structural units where mountain tundra soil immediately neighbored with steppe-type soils. The main differences in tundra-steppe soil formation and functioning result from the accumulation and eluviations processes, which depend on temperature field heterogeneity. Temperature data loggers were placed along two soil geochemical catenas with soil and vegetation associations developed in the area under the influence of a glacier and without such influence. Catena A was located along the East Mugur river valley, including its near-glacier area. The length of the catena is 600 m, starting from its iluvial ecosystem in the immediate proximity of the glacier tongue at 2741 m and ending in the transitional-accumulative ecosystem at 2446 m, while the general sloping was 25°. Catena B was located along the altitude gradient starting from the elevated part of the leveled inter-basin area between the East Mugur and Shara-Haragai rivers at 2886 m and farther down along the stepped slope to the accumulative ecosystem at 2425 m. The slopes of the leveled surface are 5-12°.

To develop the methodical principles to draw soil-ecological boundaries on the basis of temperature regime indicators we registered air temperature and the temperature of the main tundra-steppe soil complexes using the “Thermochron DS-1921” autonomous data loggers. The latter were placed on soil surface or within soil genetic horizons, being programmed to record temperature at 4 hrs increments. Thus 6 data were stored daily in the logger memory. The first data measurement was programmed to be delayed to ensure the simultaneous start of recording on all the key study sites. To register air temperature one logger was placed 2 m above soil surface in such a way as to exclude the effect of solar radiation (Figure 2).

More than 30000 data records were obtained, revealing the temperature annual dynamics and allowing calculating quantitative characteristics of the temperature regime, reflecting the intensity of soil energy turnover and thus the functional soil-ecological boundaries on the catena key study sites.

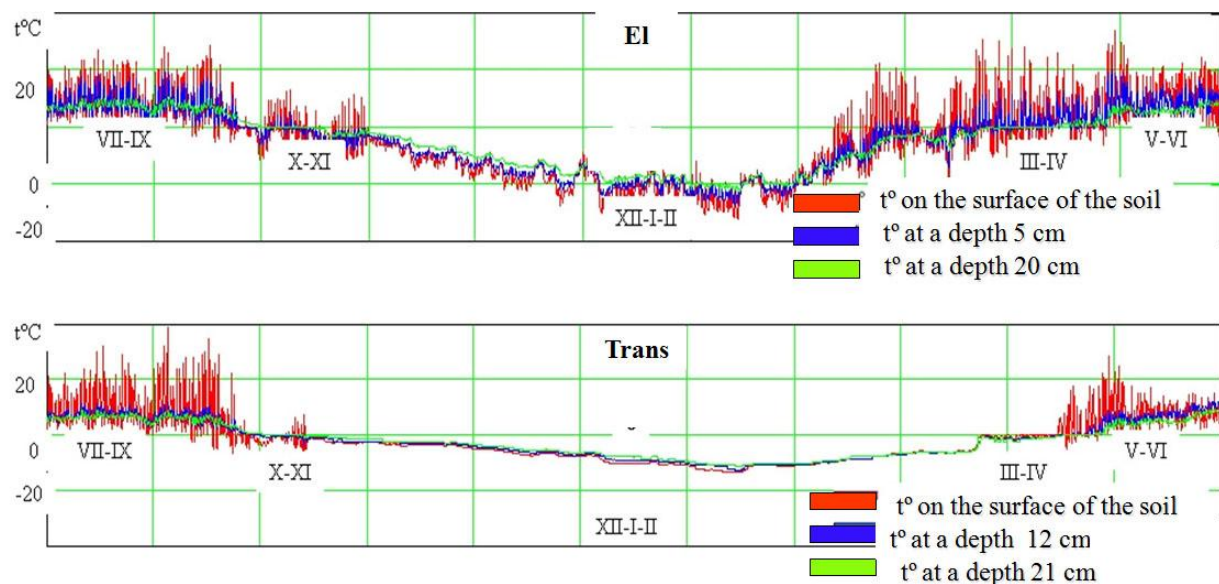


Figure 2. The annual temperature variation along the depths of the soil profile on the eluvial and transit positions of the Shara-Haragai tundra-steppe catena is located outside the glacier impact zone.

3. Results and discussion

Within the catenary altitude boundaries the qualitative differences in soil climate were found in mountain-tundra and mountain steppe soils (Table).

Table. Temperature regime indicators for air and the mountain tundra poorly developed soil

Temperature sum, °C · day	T _{air} , °C	T soil, °C		
		soil surface	at 10 cm depth	at 20 cm depth
annual	-1406.8	-251.8	-129.5	-116.9
>10°	544.3/39*	707.3/54	646/53	549.8/45
>5°	866.5/87	846.5/70	804.4/74	776/74
>0°	962.4/129	937/104	907.8/145	869.3/140
<0°	-2369.2/236	-1188.8/261	-1037.3/220	-986.2/225
Average annual	-4.1	-0.7	-0.4	-0.3

* The number of days

Comparative analysis of the annual temperature dynamics showed that temperature regime of soils developed under environmental conditions of the two catenary complexes studied, differed significantly in their annual, seasonal and daily dynamics of temperature regime. The qualitative difference of soil climate between mountain steppe and mountain tundra soils was also found by integrating soil positive and negative temperature s in soil profiles, annual and seasonal temperature variation, maximal and minimal temperature at various soil profile depths, as well as the rates of soil freezing and thawing. The average annual temperatures, annual and seasonal sums of positive and negative temperatures, freezing-thawing dynamics and thermal resources for biological activity can be used as criteria for soil forming environment assessment and hence as criteria for differentiation of soil cover structural units. Besides the general indicators of temperature regime we justified using indicators of soil temperature regime to group soils as different soil cover structures. As criteria for isolating the types of soil cover patterns the level of heat availability of the biological activity period can be used as a criterion for assessing the ecological conditions of soil formation.

Along with the use of general temperature indicators, the parameters of the thermophysical state of soils were substantiated, allowing soil groups to be grouped as different structural units of the soil cover, which makes it possible to establish the interrelationships of thermophysical characteristics with their soil-genetic indicators and approach the problem of isolation and typology of soil boundaries.

4. Conclusion

As a result of the carried out researches, quantitative characteristics, temperature field, obtained as a result of the analysis of time series of temperature monitoring were used to isolate the structural units of the soil cover of high mountains of the Altai-Sayan region.

The interpretation of typological units of the structural organization of the soil cover is presented on the basis of a statistical analysis of the combination of boundaries and information content of the soil cover contours and the boundaries of temperature fields.

The novelty of the approach is that the cartographic models of temperature fields created on the basis of quantitative temperatures, adequate informatively, allowing to establish interchangeable conditions with other characteristics of objects of the natural environment and to approach the solution of isolation problems and the typology of soil-ecological boundaries.

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