SUSTENTABILIDADE RELATIVA DOS ECOSSISTEMAS TRANSFRONTEIRIÇOS DE ALTAIE

RELATIVE SUSTAINABILITY OF THE ALTAI TRANSBORDER ECOSYSTEMS

ОТНОСИТЕЛЬНАЯ ЭКОЛОГИЧЕСКАЯ УСТОЙЧИВОСТЬ ЭКОСИСТЕМ ТРАНСГРАНИЧНЫХ ТЕРРИТОРИЙ АЛТАЯ К ВНЕШНИМ ВОЗДЕЙСТВИЯМ

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RESUMO

Os complexos montanhosos naturais do território transfronteiriço de Altai são um objeto único de estudos sobre a sua durabilidade contra um impacto externo, uma vez que representam uma complexa estrutura em mosaico. Os autores utilizaram uma característica integrante como fator de avaliação, o que permitiu determinar a durabilidade da cobertura do solo. Primeiro, a camada do rio foi convertida no padrão de varredura. Em seguida, todas as características foram traduzidas em valores relativos. Durante a pesquisa, estabeleceu-se que os ecossistemas formados em terrenos com declives acentuados eram mais suscetíveis a fenômenos naturais adversos. Foi descoberto que a paisagem é uma unidade ideal para determinar a durabilidade dos ecossistemas. O artigo fornece resultados de uma avaliação integral do grau de durabilidade ecológica do ecossistema contra um impacto externo.

Palavras-chave: Sustentabilidade, ecossistemas, estimativa integral, Altai.

ABSTRACT

Mountainous natural complexes of Altai cross-border territory is a unique object of studies into their durability against an external impact since they represent a complex mosaic structure. Authors used an integral characteristic as an assessment factor, which allowed to determine the durability of their soil cover. First, the river layer was converted into the scanning pattern. Next, all characteristics were translated into relative values, During the research, it was established that those ecosystems that formed on terrain consisting of steep slopes were more susceptible to adverse natural phenomena. It was discovered that the landscape is an optimal unit for determining the durability of ecosystems. The article provides results of an integral assessment of the degree of ecosystem’s ecological durability against an external impact.

Keywords: sustainability, ecosystems, integral estimate, Altai.

АННОТАЦИЯ

Высокогорные природные комплексы трансграничной территории Алтая являются уникальным объектом для изучения их устойчивости к внешним воздействиям, так как представляют собой сложную мозаичную структуру. Авторами, в качестве оценочного показателя, была использована интегральная характеристика, которая позволила определить устойчивость почвенного покрова. На первом этапе, слой рек был преобразован в растровый слой. Далее все характеристики были переведены в относительные величины. В процессе исследования было установлено, что те экосистемы, которые сформировались на круто-склонных ландшафтах более подвержены воздействию неблагоприятных природных явлений. Обнаружено, что ландшафт является оптимальной единицей определения устойчивости экосистем. В статье приведены результаты интегральной оценки степени экологической устойчивости экосистем к внешним воздействиям.

Ключевые слова: экологическая устойчивость, экосистемы, интегральная оценка, Алтай.

INTRODUCTION

One of the geo-ecologic tasks that remain relevant over the last decades is the study of the technogenic processes’ effect on the natural landscapes and the reactive self-compensation of the biogeocoenosis (Dmitriev, 2010; Chapin *et al.*, 2010; Wu, 2013; Peterseil *et al.*, 2004). The definition of the sustainability criteria is highly important to define various changes in the conditions of anthropogenic influence on the natural complexes (Frohn and Lopez, 2017; Bell and Morse, 2012; Morelli, 2011; Renetzeder *et al.*, 2010; Paoletti, 1999).

By sustainability, we mean the capacity of an ecosystem to maintain its structure and functions under the influence of both internal and external factors (Dmitriev, 2010; Chapin *et al.*, 2010; Wu, 2013; Peterseil *et al.*, 2004; Frohn and Lopez, 2017; Bell and Morse, 2012; Morelli, 2011; Renetzeder *et al.*, 2010; Paoletti, 1999; Alekseev *et al.*, 1998; Dmitriev and Ogurtsov, 2013; Dmitriev and Ogurtsov, 2012; Odum, 1986). The estimate of the sustainability provokes an issue on the choice of the territorial estimate units. This role is usually played by the geographic complex formations– landscapes (Armand et al., 1992), or private – geo-morphologic (Proletkin *et al.*, 1999), soil (Glazovskaya, 1997), hydro-geologic (Kudelsky *et al.*, 1998). Consideration of landscapes as complete multi-component geosystems is connected with the following advantages: 1) the entire complex of the interconnected components and intercomponent connections is considered; 2) all the happening and expected changes and consequences are recorded. The peculiarities and conditions of the landscapes also influence the environment- and resource-reproducing functions important for humans and vulnerable to the anthropogenic factors (Chapin *et al.*, 2010; Frohn and Lopez, 2017).

To the full extent, these functions can be performed by the landscapes in the normal and not disturbed state. But in case the natural components are disturbed, the performance of such functions becomes incomplete or is terminated. It naturally leads to the losses (damage): decrease in yielding capacity, deterioration of the natural resources, growth in the population morbidity rate etc. Thus, the extent of deterioration of the natural components of a landscape highly influences on the degree of the human needs satisfaction. It means all the properties of the environment evidencing the degree of its well-being (ill-being), are ecologically significant for humans (Kochurov, 2003).

MATERIALS AND METHODS

When choosing the territorial unit for the sustainability estimate of the geosystems we were focused on the landscapes, as exactly this approach ensures the division of the territory into the sections homogeneous by their response to the environment. As the basis, we used the map by D. V. Chernykh and G.S. Samoylova (Chernykh and Samoylova, 2011).

We chose those estimate criteria for the biota and abiotic environment, which enabled diagnosing the sustainability towards the environment. The sustainability of the geosystems is defined by the complexity of the physical and geographical factors and depends on the properties of their components and the specifics of the environment. The most significant at the estimate of sustainability is the terrain, geological structure, soil and vegetation cover, water balance, drainage network density and climatic conditions. Therewith the maintenance of the sustainability of the territory requires a certain correlation between the states of the abiotic and biotic components. The sustainability of the abiotic components is achieved through the physical and mechanical as well as chemical processes of transfer, dilution, sorption, and migration of the substance; sustainability of the biotic components is defined by the capacity of the organisms to adapt to the environment as a result of both internal resistance of the biochemical organization and due to the capacity of biochemical degradation of the poisons and the change in the specific velocities of the metabolic processes in the ecosystem influenced by the environment (Primak, 2009).

The terrain is one of the most important estimate indicators as it contributes to redistribution of the energy and substance in the system of the natural components interaction. The estimate of potential sustainability of the landscape considers significant such characteristics of the terrain as the depth of vertical differentiation and the steepness of slopes. These characteristics define the direction of the substance flow and the capacity of the landscape to self-purification. As one of the indicators, we used the steepness of slopes, because this parameter generally defines the migration capacities of the pollutants. The more active their distribution along the territory of the natural complex, the more significant will be the destabilizing effect on all its components. The increase in the steepness of slopes causes the acceleration of various slope processes, which may significantly influence the results of the mechanical influence, creating the conditions or preventing from the development of the slope erosion processes, water erosion etc.

As an estimate indicator characterizing the sustainability of the soil we used the integral characteristic because we deemed it insufficient only to record the mechanical composition of the soil under the conditions of the mountain territory. As the basis, we chose the calculation of the point estimate of the soil sustainability to the change in the parameters of natural and anthropogenic regimes according to V. V. Snakin, P. P. Krechetov, V. E. Melchenko, I. O. Alyabina (Snakin *et al.*, 1995) and have insignificantly modified them.

The next parameter, which we considered at the estimate, was the Normalized Difference Vegetation Index. It is a simple quantitative indicator of the amount of photo synthetically active biomass (usually called the vegetation index). In the self-regulation of the geo-systems, it is exactly the biota that plays a great role, because it is the most important stabilizing factor of the territory. Due to its mobility and wide adaptability to the abiotic factors, the capability of recovering and creating an internal environment with specific regimes – light, thermal, water, and mineral – a certain degree of the landscape's sustainability is formed (Herbei *et al.*, 2015).

As one of the indicators, we considered such a characteristic as the type of the agricultural lands. We highlighted several types: tundra, marsh, forest, and meadow. The pollution is potentially dangerous for the marsh and forest lands, considering their role in biological diversity, while for the marshlands the presence of the peat horizon is considered, causing a series of oil contamination consequences that are hazardous for the environment. The same picture is also formed for the mechanical effect, which is the most dangerous for the marshlands due to the effect on the hydrodynamic indicators, dynamics of the geochemical and biological processes.

We also considered the density of the drainage network. It is believed that the higher this indicator, the more active is the transportation of the pollutants. In this case, the watercourses, on the one hand, act as migration corridors, while on the other hand – as potential objects of chemical contamination. The mechanical action with the growth in the value of the drainage network density also become more dangerous for the natural complexes and may to a significant extent change both the hydro-chemical (due to the geochemical barriers), and hydro-dynamic indicators (change in the water level due to the creation of the additional hydraulic head) (Kesoretskikh and Zotov, 2012).

The work on the calculation of relative

sustainability was performed through such geo-information systems as Quantum GIS and GIS GRASS. To obtain the calculation characteristics we used the tools of the map algebra, which allows conducting the complex analysis of the estimated indicators considering their geographical localization.

The reference material of the research is a series of the following geo-based data sets:

1. To estimate the drainage network density we used the vector map of the drainage network with the scale of 1 to 500 000;

2. The vegetation biomass amount, as already mentioned, was estimated based on the NDVI, which is good at reflecting regional differences. The grid-data products of the NDVI are available on the website of the US Geological Service (EarthExplorer) posted by the owner of this data - NASA. We used the MOD13Q1 version 6 (MOD13Q1: MODIS/Terra…), the composites of which are formed on the basis of the 16-day shooting period out of the pixels characterized by the best indicators of the geo-botanical index, the least cloud coverage and the least vision angle of the shooting system. The spatial resolution of the MOD13Q1 data is equal to 250 meters, which is feasible for the purposes of the territory research.

In general, we used ten sets of the grid-data – by two sets per each of the five 16-day periods covering the time interval from 9 June to 12 August 2016;

3. The analysis of the land surface slopes was conducted on the basis of the SRTM with the spatial resolution of 1 angular second (Shuttle Radar topography mission (SRTM) 1 Arc-Second Global), obtained from the website of the US Geological Service (EarthExplorer).

4. The peculiarities of calculating the soil sustainability quantitative indicators as well as the quantitative indicators of the agricultural land types are considered above. We performed the work on the point estimate of the considered indicators in different kinds of landscapes. The basic map at this stage of the research was the landscape map of the Altai Mountains, scale 1: 500 000 (Chernykh and Samoylova, 2011). The results of the conducted estimates were transformed into the raster layers of the corresponding contents.

The processing of the source data was carried out on the GIS GRASS and included a series of phased works presented in Figure 1.

RESULTS AND DISCUSSION:

At the first stage, the layer of rivers was transformed into the raster layer containing the quantitative indicators of the drainage network density (the number of the rivers' kilometers per square kilometer of the territory) (Figure2).

Next, based on the layers with the NDVI for various days, we formed the single layer with the averaged NDVI values for the period from 9 June to 12 August 2016 (Figure 3). From the layer of the terrain digital model using the module of morphometric analysis, we extracted the indicators of the soil surface angle of slope (Figure 4).

In conclusion, along the layer of landscapes, we carried out the assignment of the point estimate results to their soil sustainability, as well as the assignment of the point estimate to the types of the prevailing agricultural lands. At the second stage, we transferred all the analyzed characteristics into the relative values and conducted the calculation of the relative sustainability of the territory through the following Equation 1:

$$ST=0.3_{(\text{N terrain})}+0.25_{(\text{N soil})}+0.2_{(\text{N vegetation})}+0.15_{(\text{N-type of agricultural lands})}+0.1_{(\text{N drainage network density})}, \qquad (1)$$

Where ST – the sustainability of the territory; N terrain – controlled parameter of the surface slope; N soil – integral indicator of the soil sustainability; N vegetation – NDVI normalized value; N type of agricultural lands – normalized value of type of agricultural lands, N drainage network density – normalized value of drainage network density.

The third stage included the works on the extraction of the spatial and statistical characteristics (areas occupied by the territories with different sustainability), as well as the creation of the resulting map (Figure 5). As a result, it was stated that the prevailing territories are those with relative sustainability equal to over 50 % (Figure 6). This category mostly includes planned areas peculiar to intermountain basins and marsh or steppe and semi-desert landscapes with formed geosystems of low probability of natural transformation (Karanin *et al.*, 2016).

Despite the high specific density of the 'sustainable' territories in the total area of South-Eastern Altai, the share of the vulnerable areas is by no means low. At the same time, the vulnerable geo-systems predominantly occupy the upper height levels represented by the alpine-subalpine meadow, tundra and glacial-nival landscapes (Figure 7).

The ecosystems formed at the steeply sloped landscapes are the most exposed to unfavorable natural phenomena (soil slips, landslides, debris flows etc.) taking an adverse effect on the stability of local geosystems.

CONCLUSIONS:

The quantitative indicators of the high-mountain ecosystem's sustainability estimate perform the most important function of objectification and revealing of the role of some or other kinds of exposure on the environment.

Among the exposure estimate criteria, a great role is played by the natural factors forming the ecosystems, which may accelerate or decelerate the exposure process.

The landscape is an optimal unit for the estimate of the ecosystem sustainability because its structure is caused by a specific combination of biotic and abiotic components playing an important and complex role. Integral estimate of the high-mountain landscape sustainability levels allowed differentiating the transborder ecosystems of Altai according to their response to the environment. This will subsequently enable offering the variants of the spatial location of the business entities, including the recreational ones, minimizing possible negative consequences and degradation of the natural complexes.

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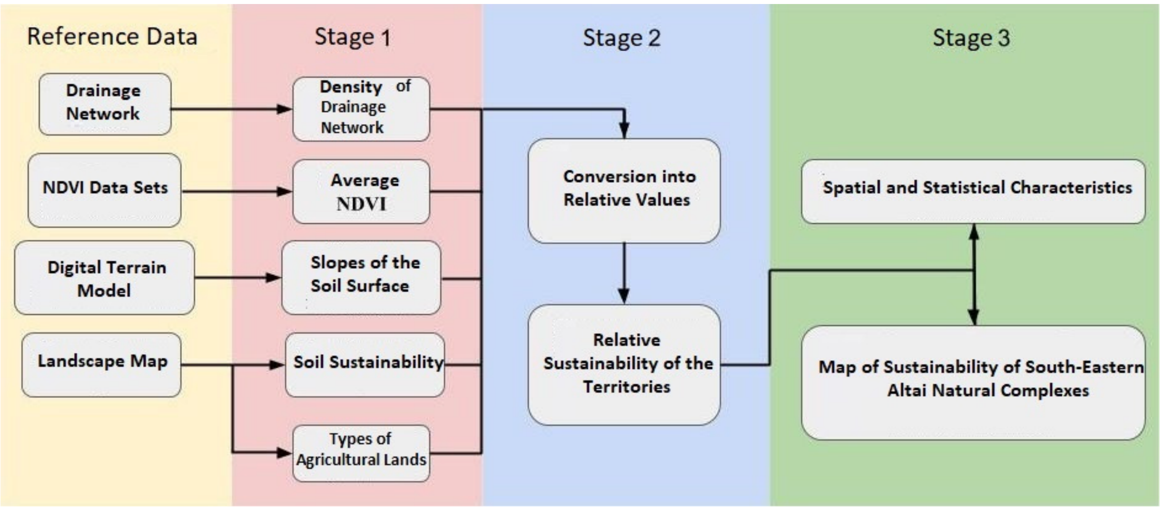

Figure 1. *Block Scheme of the Technical Data Processing*

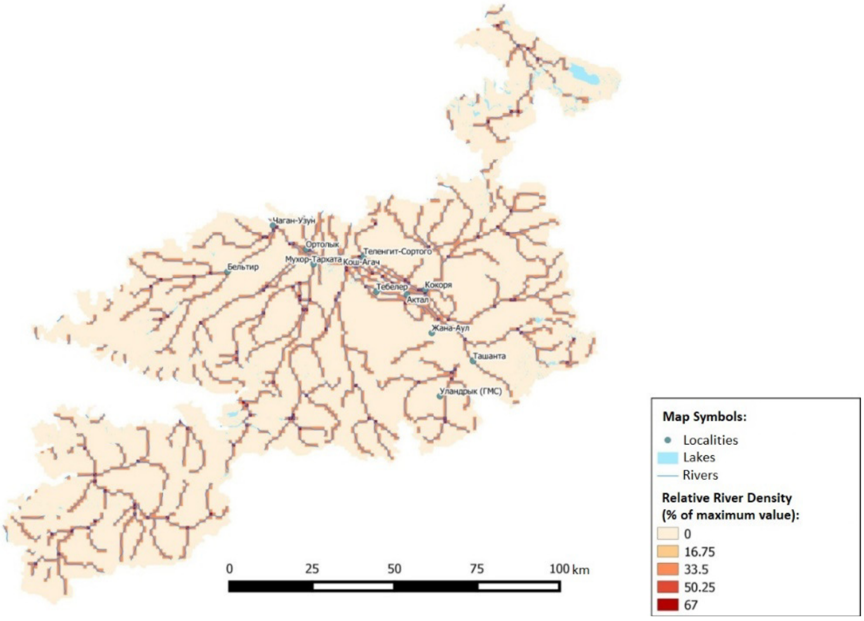

Figure 2. *Relative River Density (Density of the Drainage Network)*

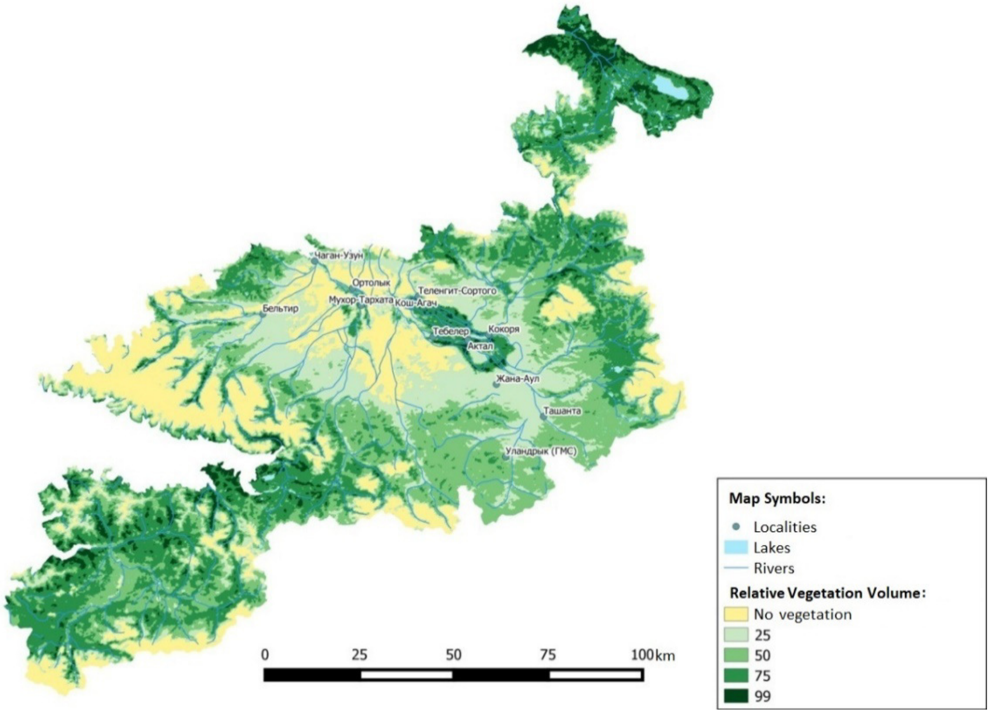

Figure 3. *Relative Vegetation Volume*

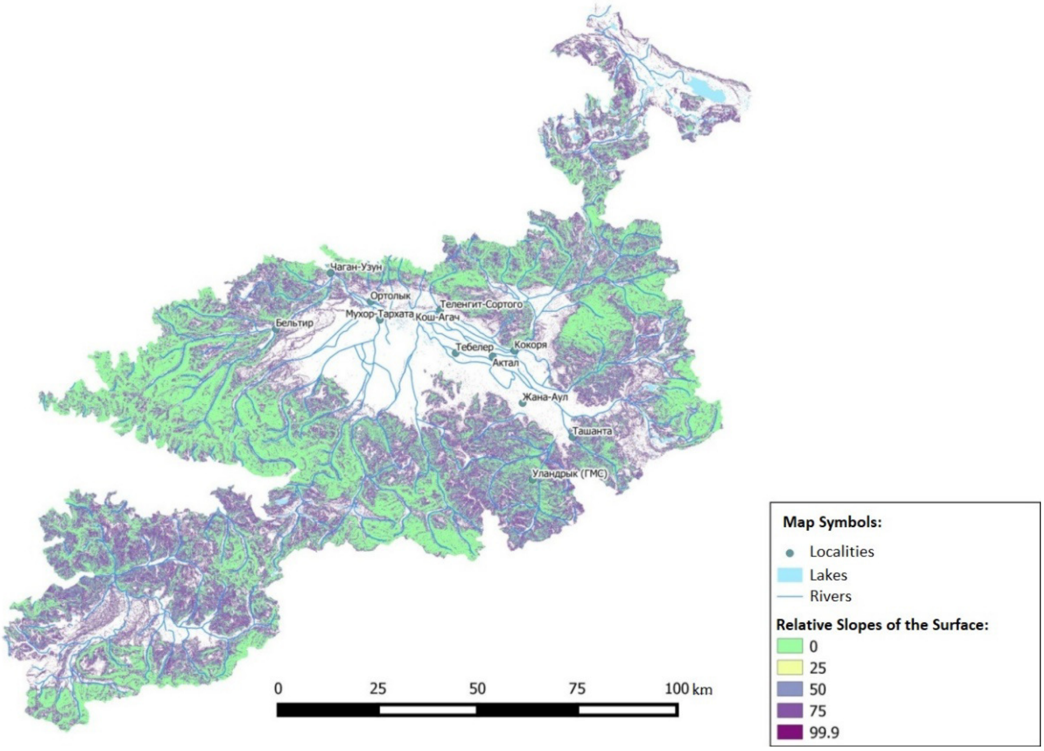

Figure 4. *Relative Slopes of the Soil Surface*

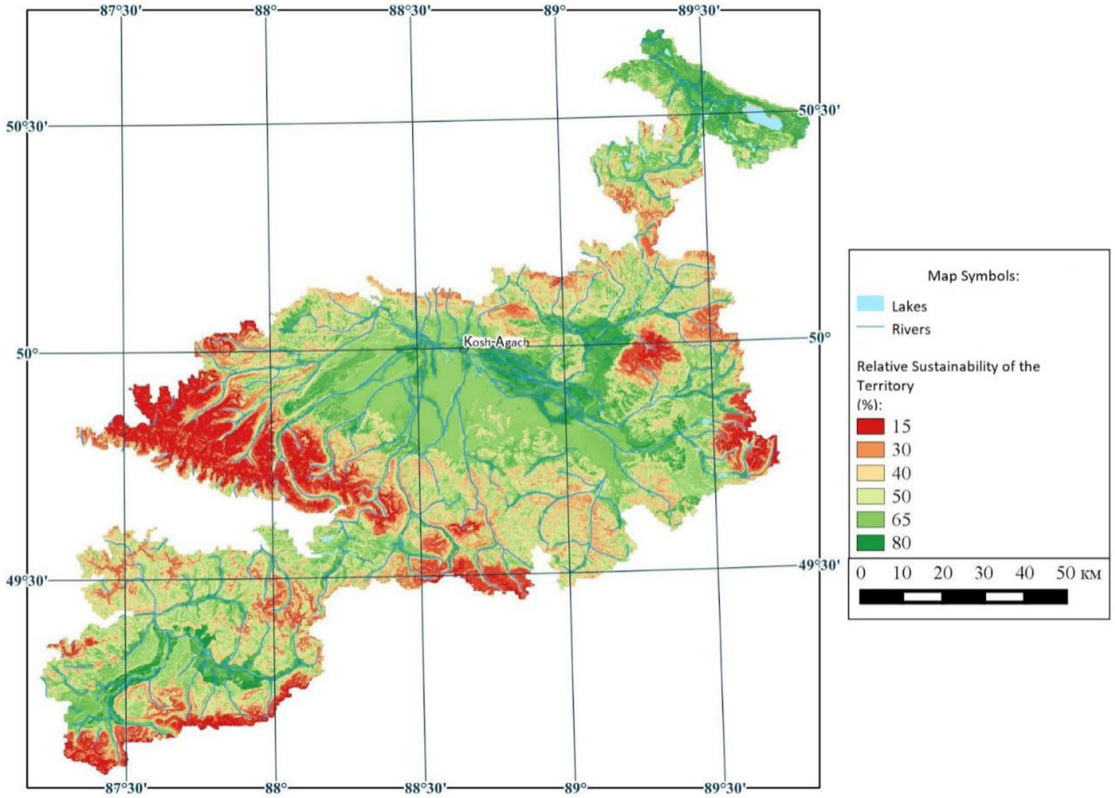

Figure 5. *Sustainability of South-Eastern Altai Natural Complexes*

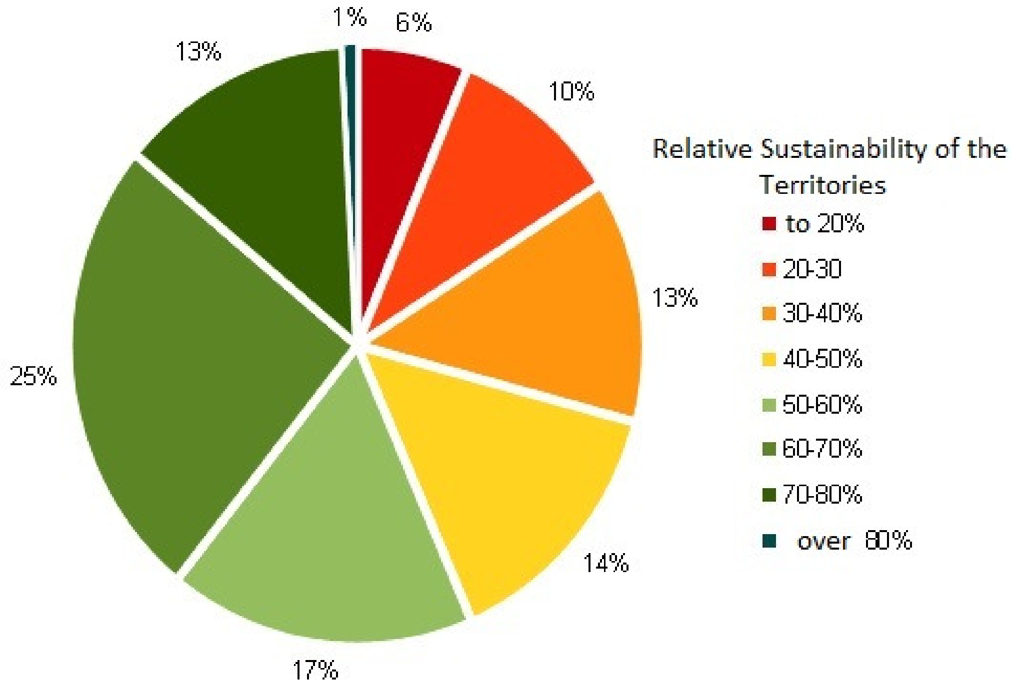

Figure 6. *The Share of the South-Eastern Altai Areas occupied with the Territories of Different Relative Sustainability*

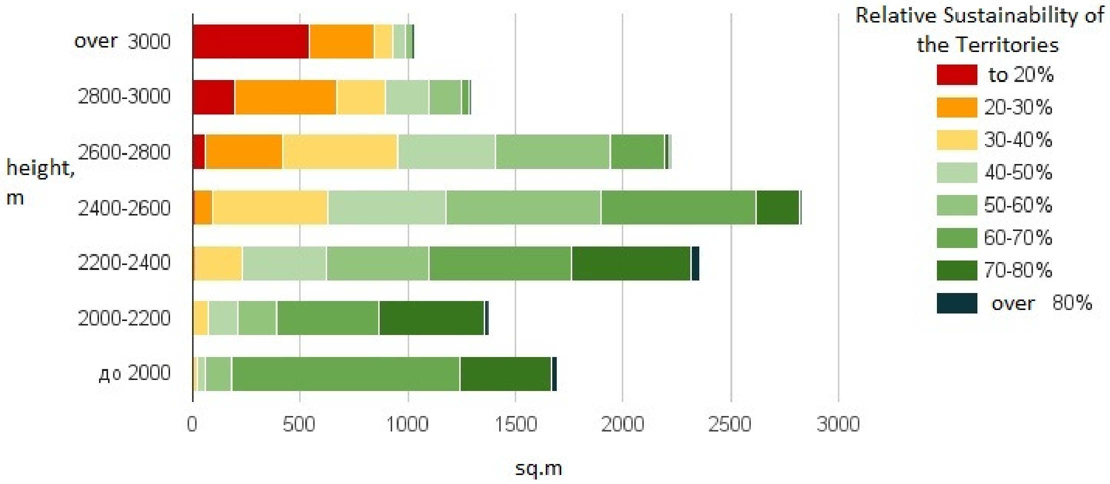

Figure 7. *Area of the Territories with different Sustainability at Different Height Levels of South-Eastern Altai*

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