The ecological potential of Baikal region’s geosystems

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Abstract. The Baikal region is a complex region as regards its natural environment and landscape characteristics; it is endowed with immense reserves of various natural resources, the industrial development of which is steadily progressing, thus posing challenging ecological problems. For assessing the ecological potential of geosystems, the landscape-typological map of the Baikal part of Siberia was generated. The classification of geosystems was carried out on the basis of the taxonomic system of hierarchical units of natural environment as developed in the Sochava Institute of Geography SB RAS. Cartographic analysis determined the most informative units of geosystems of regional dimension, which made it possible to carry out a classification separation of the landscape structure of the Baikal part of Siberia. The investigations into the ecological potential, the factors and the conditions having influence upon its formation used: SRTM data, WorldClim global climate data; data on Net Primary Production; Normalized Difference Vegetation Index, Enhanced Vegetation Index. The main principles of GRID modeling and the Analytic Hierarchy Process technique were used to assess the ecological potential of the Baikal region's geosystems which made it possible to represent the set of natural conditions needed to satisfy the requirements of the population for all the necessary primary means (merely ecological, unassociated with production). The evidence obtained concerning the ecological potential provide a natural scientific basis for a reasonable regional ecological policy, an improvement of the population distribution pattern and the social sphere, a rational organization of labour and recreation, and for the protection of human health.

1. Introduction
The Baikal region is directly connected with the world-famous Lake Baikal, and lies in the middle of Asia. The Baikal region includes three subjects of the Russian Federation, united by belonging to the basin of Lake Baikal; they are the Irkutsk region, the Republic of Buryatia and the Zabaikalskii krai.

The relief of the Baikal region is highly differentiated, due to tectonic processes in the Baikal Rift valley, formation of mountain ranges and valley incisions. The Primorskii and Baikalskii Mountain Ranges stretch along the western coast, whereas the Barguzin Range rises in the northeast, and the Khamar-Daban Range limits the Baikal basin in the south. The largest inflowing rivers are the Upper Angara from the north, the Barguzin from the northeast, and the Selenga from the southeast. The Selenga River constitutes the main inflow from a catchment area extending into the trans-Baikal region and northern Mongolia. It forms a large delta area in the southeastern part of Lake Baikal. Numerous minor rivers may also influence sedimentation in the lake.

The regional and altitudinal distribution of landscapes and modern vegetation is controlled by the relief as well as by temperature and precipitation gradients across the region. Generally, Scots pine
(Pinus sylvestris) and larch (Larix) taiga prevails on dry east-facing mountain slopes, whereas Siberian pine (Pinus sibirica), fir (Abies sibirica) and spruce (Picea obovata) taiga is widespread on moister north- and west-facing slopes of mountain ridges. East of Lake Baikal Larix sibirica is replaced by L. dahurica, and birches (Betula) and poplar trees (Populus tremula) may replace Scots pine- larch -taiga. Steppe and pine forest-steppe (Pinus sylvestris) as well as elm (Ulmus pumila) occur within the Selenga catchment area in the trans-Baikal region. Further north steppe areas are limited to the Barguzin River basin, Olkhon Island and the Priolkhon region. However, within the whole region patches of steppe and rock-steppe vegetation occur on east- and south-facing slopes.

The Baikal region is a complex region as regards its natural environment and landscape characteristics; it is endowed with immense reserves of various natural resources, the industrial development of which is steadily progressing, thus posing challenging ecological problems.

The low potential for resistance of this region’s landscapes to anthropogenic disturbances, and the retarded self-recovery processes determined by the severity of the natural conditions produce a large number of environmental restrictions on nature management practices, with implications for the environmental quality and ecological safety of the population, for biodiversity preservation across territories as well as for setting the stage for their sustainable ecolego-economic development.

The need for the ecological rationalization of nature management in the Baikal region is also dictated by the fact that most of this region refers to the Baikal Natural Territory for which the ecological regulation of nature management is stipulated by the Russian Federal Law “On the protection of Lake Baikal”.

The issue of the ecological rationalization of nature management, and of the prevention or minimization of negative consequences of nature management in the system of human-environment relationships has always been the subject of geographers’ attention. Russian academician V.B. Sochava called for “co-creation of Man and Nature”, and Academician I.P. Gerasimov defined the scientific and methodological principles of “constructive geography”, based on investigations into the problems of systematic transformation of natural environment aimed at effective exploitation of natural resources [1]. The idea of the ecological rationalization of nature management was developed further by the research efforts made by the V.B. Sochava Institute of Geography SB RAS in the field of landscape planning [2].

Nowadays, the principal objective of the ecologization of nature management is to create favorable conditions for harmonious, balanced development of Nature, society and economy. Special emphasis must be placed on recognition of priority of the life-supporting functions of landscapes in the interests of society in comparison with direct use of natural resources provided that the balance of the requirements of the population for the welfare and ecological well-being is maintained. An optimization of nature management involves taking into account the ecological potential of landscapes, which would make it possible to take into consideration the balance of the ecological and economic interests of society, and to create the scientific preconditions for developing the legal environmental regulations.

There are several definitions of the ecological potential but all of them are largely confined to understanding it as the potential for life sustenance, or as the entire set of natural conditions influencing human life and creating a specific local habitat [3].

Such definitions have their origins in the anthropocentric approach leaning upon Man’s requirements to the quality of habitat and focusing on the potential usefulness of natural objects for humans and satisfaction of their requirements.

A.G. Isachenko emphasized a fundamental significance of the notion of ecological potential and defined it as the “capacity of the landscape to satisfy the requirements of the population for every kind of primary (i.e. merely ecological, unassociated with production) mans of living : heat, air, water, sources of food products as well as for natural conditions of labor activity, recreation, medical treatment, and spiritual development” [4]. Furthermore, he warned against confusing the ecological potential of the landscape and its production-resource potential.
In our view, to assess the ecological potential of landscapes requires proceeding from multifactor estimation implying an understanding of the essence of natural processes, and a study into object relationships between the components of landscapes. The ecological potential itself is recognized as the set of characteristics of natural environment which have influence upon human health, the state and functioning of landscapes, and upon their resistance to anthropogenic impacts. As a matter of fact, it is the state of natural environment that determines the comfort of human habitat.

A comprehensive characterization of the ecological potential of landscapes requires taking into consideration several tens or even hundreds of indicators, but its comparative assessment must be based on few criteria, namely on leading, or determining, ecological factors. Such factors include ecologically mandatory, i.e. irreplaceable and steadily operating qualities of landscapes, the absence of which reduces the potential to zero, because life is altogether impossible without them.

Among the main criteria in the system of criteria for assessing the ecological potential of landscapes at the regional and local level can be the biota (vegetation in particular) when regarded as a complex, integral, evolutionarily independently developing autotrophic system which is an important and, often, critical component of geographical environment [5]. In the case of vegetation, the ecological potential can be more precisely defined via traditional biospheric ecological functions of vegetation, such as its autotrophicity and intensity of primary productivity, and via the involvement in the formation of atmospheric gas composition or an assessment of its role in the hydrologic and mineral cycle, carbon deposition or ecosystem relationships with the fauna, etc. Of course, such significant ecological functions of vegetation are important, and they determine its role in all global, regional and local ecological processes in the biosphere. Actually, they are assessed in current ecological research as “biosphere and ecosystems services” [6]; as practice shows, however, they are still inadequately taken into consideration in the regulatory/legislative practice of nature management in Russia Federation.

2. Materials and Methods
For assessing the ecological potential of landscapes (geosystems), the landscape-typological map of the Baikal region was generated. The map contents were developed having regard to the map “Landslides of the south of Eastern Siberia” by using high spatial resolution remote sensing data (Landsat 5 TM, 7 ETM+), and Digital Elevation Model (DEM) produced on the basis of Shuttle Radar Topographic Mission (SRTM) data, published data on the state of landscapes as a whole and for separate components as well as research results obtained in different areas of the Baikal region [7].

A classification of landscapes (geosystems) was carried out on the basis of the taxonomic system of hierarchical units of natural environment as developed in the V.B. Sochava Institute of Geography SB RAS: class (system of landscapes) - group of geoms - geom - class of facies - group of facies. Cartographic analysis determined the most informative units of landscapes of regional dimension, which made it possible to carry out a classification separation of the landscape structure of the Baikal region.

The investigations into the ecological potential, the factors and the conditions having influence upon its formation used: the DEM generated on the basis of SRTM data, and the set of WorldClim global climate data (http://www.worldclim.org); data on Net Primary Production (NPP); the Normalized Difference Vegetation Index (NDVI), and the Enhanced Vegetation Index (EVI).

3. Results
For processing and analyzing the resulting value, the GRID model with regular steps of 90 arcsec (3 km) was constructed. This GRID model was used to calculate in absolute elevation the slope steepness and aspect.
Figure 1. The scheme for calculating the ecological potential using the used the Analytic Hierarchy Process

Figure 2. The ecological potential of Baikal region’s geosystems
The data obtained in the form of regular grids (absolute elevation, slope steepness and aspect, mean annual precipitation amounts, mean January temperature, mean July temperature, the NDVI, EVI and NPP values) were all converted to a vector form, representing a set of regularly occurring points. The indices were all transformed to dimensionless values: ranked into five categories: minimum, low, medium, high and very high values.

To determine the main natural ecological factors and take into account their contribution to the value of the potential used the Analytic Hierarchy Process (AHP) (figure 1) [8].

The formula of this hierarchic structure is $EP = (0.119H + 0.065A + 0.065S) + (0.129W + 0.129T_1 + 0.129T_2) + (0.232NPP + 0.067NDVI + 0.067EVI)$, where $EP$ - ecological potential, $H$ - elevation (rank), $A$ - aspect (rank), $S$ - steepness (rank), $W$ - mean annual precipitation (rank), $T_1$ - mean January temperature (rank), $T_2$ - mean July temperature (rank), $NPP$ - net primary production (rank), $NDVI$ - the Normalized Difference Vegetation Index (rank), and $EVI$ - the enhanced vegetation index (rank).

Based on the developed methodology, applying GRID-modeling principles and the hierarchy analysis method using calculated data in the form of regular networks, special evaluation maps were constructed and the weight coefficients of the main formation factors of the ecological potential of Baikal region’s geosystems were determined. The result of the calculation of the ecological potential is presented in figure 2.

4. Conclusion
The main goal of environmental management at the present time is creation of conditions for harmonious, balanced development of nature, society and economy. Recognizing the priority for society of the life-supporting functions of geosystems before direct use of its resources should be specially emphasized, regarding meeting the balance of the population's needs for welfare and environmental well-being.

In these conditions, the environmental optimization of environmental management based on the ecological potential of geosystems is the main paradigm of environmental policy in the Baikal region, which will allow to take into account the balance of environmental and economic interests of society, to create scientific prerequisites for the development of legal environmental regulations, economic calculations, scientific and information-analytical support of environmental protection and environmental safety.

The main principles of GRID modeling and the AHP technique were used to assess the ecological potential of the Baikal region's landscapes which made it possible to represent the set of natural conditions needed to satisfy the requirements of the population for all the necessary primary means (merely ecological, unassociated with production). The evidence obtained concerning the ecological potential provide a natural scientific basis for a reasonable regional ecological policy, an improvement of the population distribution pattern and the social sphere, a rational organization of labor and recreation, and for the protection of human health.

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