Ecological potential of geosystems on the forest-steppe border (Lake Baikal basin)

I N Vladimirov¹, A A Frolov² and D V Kobykin³

¹ Institute of Geography n.a. V.B. Sochava, SB of the RAS, Irkutsk, Russia
² Laboratory of Theoretical Geography Institute of Geography n.a. V.B. Sochava, SB of the RAS, Irkutsk, Russia
³ Laboratory of Geomorphology, Institute of Geography n.a. V.B. Sochava, SB of the RAS, Irkutsk, Russia

E-mail: garisson@irigs.irk.ru

Abstract. The study of the ecological potential of geosystems is one of the current directions in geographical science. There are several approaches to the study. The authors suggested using an integral approach which can maximize the use of parameters of the geographical environment to identify the potential of geosystems. Based on the original method for mapping geosystems, the results of identification of their environmental potential are presented. The selected research areas on the forest-steppe border have a large number of properties that determine the diversity of landscapes. The relevance of the study is emphasized by the location in the transboundary basin of Lake Baikal which requires making informed decisions in international relations. An attempt to change the ecological potential for a relatively long period was made.

1. Introduction
The study of the ecological potential of geosystems is one of the modern integrated areas in geography. The approach to assessing the ecological potential, depending on the research purpose is divided into anthropocentric and nature-centric ones. The first one is associated with the influence of the environment on economic activities and human health. The focus is on creating and maintaining favorable environmental conditions for human life.

The second approach is used if the assessment is aimed at determining the quality of the natural environment; the criteria are indicators of the natural components and their functional relationships. The essence of the nature-centric approach is the need to preserve wildlife as a whole.

In assessing the ecological potential of geosystems, it is necessary to apply two approaches – nature-centric and anthropocentric, which involves understanding the essence of natural processes, studying the object relationships between the components of geosystems and ensuring rational, environmentally-friendly nature management.

The study area is located in the mountains of Southern Siberia in the central part of the Baikal basin (Fig. 1).
2. Methods and materials
The ecological potential is a number of natural properties of natural systems, the features of their structurally functional internal and external relationships formed during the development of the natural environment and determining their further development, as well as meeting human needs while maintaining the maximum possible structural and functional parameters of the geosystem [1].

Each component or element of the geosystem can serve as an object of environmental assessment aimed at determining its positive or negative impacts on humans. However, the significance of natural factors depends on their combination with other properties of geosystems. Consequently, the assessment of natural factors should be comprehensive – encompassing their entire set and mutual relations embodied in the concept of the ecological potential of geosystems.

Unfortunately, the exhaustive coverage of all possible natural factors determining the ecological potential of geosystems is impossible. It is necessary to identify the main factors, i.e. take into account their contribution to the potential value. To determine the weight coefficients when calculating the environmental potential, the Analytic hierarchy process (AHP) was used [2, 3].

The authors suggest determining the ecological potential on the basis of complex geographical studies whose result is a landscape map. Landscape maps are designed to reflect natural factors that shape the geographical environment. For mapping, two approaches were used to determine the boundaries of geosystems.

The first approach to determining the boundaries of landscapes is based on the principles of structural-dynamic classification of geosystems, the doctrine of geosystems [4], which determine the landscape structure of the territory. In order to obtain field data, complex route studies of landscapes were carried out; special attention was paid to landscape characteristics showing the dynamic state of geosystems (factor series, seriality, relief features, rock yield, species and age structure of phytocenosis, succession stages of vegetation restoration, anthropogenic transformations).

The second approach involved the use of geomorphological data. Since the genetic types of relief and vegetation act as the main indicators of landscape formation, the general patterns of landscape formation are shown on the map and its legend. This method is especially important when using Earth remote sensing data (ERS), where the relief and vegetation are identified.

In order to analyze the current state of the landscapes and build a landscape-geomorphological map, we used different information: 1) space-based (satellite images of Landsat satellites, data from the Google Earth Internet service, SRTM data); 2) cartographic (thematic, topographic maps); 3) field research materials; 4) literary sources.
Based on the degree of positive or negative impacts of any component of the geosystem, it can serve as a separate object of environmental assessment [4, 20]. However, natural factors and their importance cannot be considered without a comprehensive analysis. Consequently, the assessment of natural factors should be comprehensive – encompassing their entire set and mutual relations. This opportunity provides an integrated approach used in geography.

The obtained map sections were marked with indices reflecting the value of ecological potential on a six point scale with the following gradations: 1 – very low; 2 – low; 3 – relatively low; 4 – medium; 5 – relatively high; 6 – high. Geosystems of little value for nature management have a low score.

3. Results
The study made it possible to identify the ecological potential of geosystems in various parts of the southern taiga, forest-steppes and steppes located in the central part of the Lake Baikal basin. This territory is characterized by a diverse relief and vegetation. Ranges elongated in the latitudinal direction change the moistening and insolation of slopes. The northern slopes receive the greatest amount of moisture, since they are windward with respect to the main north-west transport of air masses.

The territory is characterized by the high-altitude zoning with a significant influence of exposure. For detailed studies, two representative sites were selected with a different set of geosystems.

The results of landscape differentiation by ecological potential are shown in Figures 2, 3.

**Figure 2.** The map of the ecological potential of geosystems in section 1 (Small Khamar-Daban ridge) a – arable land, b – residential areas. The numbers indicate the potential.
The first section is located on the southern macro slope and the watershed of the Small Khamar-Daban ridge (Fig. 2). It is characterized by elevations of 1700–1000 m above the sea level. According to the scheme of physical-geographical zoning [5], the site belongs to the Dzhidisk-Khamar-Daban mountain-taiga and hollow province and the coniferous Small Khamar-Daban slope with steppe areas.

Three forest geomes belonging to the mountain taiga groups of the Baikal-Dzhugdzhur and South Siberian geomes, and one mountain-steppe geome belonging to the Central Asian steppe landscapes were identified. Geosystems are represented by several classes of facies related to the following factor-dynamic series: subhydromorphic (along river valleys, streams, intermontane and catchment depressions, in swampy areas), sublithomorphic (on slopes with close bedding of rocks), subhydrolithomorphic (on flat watersheds and drive water areas aligned with elevated areas), xerolithomorphic (southern slopes with rock outcrops), cryohydrolithomorphic and cryohydromorphic (in elevated areas and wetlands with permafrost processes). By the degree of seriality, geosystems are subdivided into primary, located on flat watersheds and drive-divided areas, elevated areas, imaginary, confined to gentle slopes, and serial, which are located on steep slopes with outcrops of rocks, as well as in locations with excessive moisture.

The distribution of ecological potential is largely affected by the topography. The geosystems of boggy flat watersheds, as well as exposure mountain steppes have the lowest values.

The second representative site is located at lower absolute heights (1050–1550 m above the sea level) with a relatively flat low-mountain topography of the Selenga-Orkhon basin-mid-mountain steppe province, in the foothills of the Malkhan Range and wide intermontane basins drained by the Chika and Khilok rivers. A feature of this region is aeolian processes. As a result of the combined influence of factors determining the development of aeolian processes, a peculiar landscape structure was formed in the western part of the Malkhan ridge whose geosystems are interconnected with each other through the transfer of matter. The landscapes of the territory can be divided into two groups:

1. Landscapes formed on the denudation relief which are suppliers of loose materials: geosystems of hills and mountains located above the main basis of denudation (with the exception of aeolian landscapes): mountain-taiga and mountain-steppe geosystems of slopes and watersheds of the Malkhan Range, hilly-steep hills and blowing basins, as well as forests, forest-steppes and steppes located on the slopes of river valleys and bottoms of pads located above the erosion basis.

2. Landscapes formed on the accumulative relief which develop as a result of the accumulation of both local loose materials and materials brought from the surrounding territories: geosystems located in river valleys, on foothill plains and in lowlands: meadow-bog areas on floodplains and low floodplain terraces, pine forests and steppes on foothill plumes and drift cones, alluvial-lake plains, erosion-accumulative terraces, piedmont polygenetic plains processed by aeolian processes, as well as mobile unsecured aeolian sands in the form of dune chains with rare grassy and shrubby vegetation.

The ecological potential of geosystems identified depends on modern exogenous relief-forming processes. Geosystems of mobile unsecured aeolian sands in the form of dune chains of the Holocene age with rare grassy and shrubby (willow) vegetation and small birch-pine communities in inter-dune depressions have the lowest potential. Larch and pine forests located on erosion-accumulating terraces with gray forest and sod-forest soils have the highest potential.

The study of the ecological potential of geosystems is a new direction in geography. The research area is well studied in paleogeographic terms [6–8]. The border position at the junction of steppe and forest landscapes in the central part of Eurasia determines an active response to changes in environmental parameters.

Changes in the landscape structure during warming and cooling periods is one of the most controversial issues. During paleogeographic reconstructions, several schemes of landscape changes depending on the paleogeographic situation in the Late Neopleistocene and Holocene were developed [9–12]. The most acceptable scheme is that when during the cooling era, the areas of char and dry steppes expand, during the warming era, the upper border of the forest rises, the steppes are reduced, and the mosaic of landscapes increases. The schematic diagram of changes in the ecological potential of geosystems shown in Figure 4 reflects scenarios for the cooling and warming eras.
**Figure 3.** The map of the ecological potential of geosystems in section 2 (the interfluve of the Chikoi and Khilok rivers)

- a – arable land
- b – residential areas

**Figure 4.** The schematic diagram of changes in the ecological potential of geosystems in the era of cold climate (I) and warming (II),

- a – char
- b – mountain tundra
- c – char and pre-alpine woodland
- d – forest and pre-alpine woodland
- e – Forest on the slopes
- f – Forest on the slopes, the valley bottoms are occupied by light forest, yernik
- g – forest steppes
- h – steppes
- i – dry mountain steppes
- j – semi-deserts combined with dry mountain steppes
- k – meadow-bog plains (compiled using [6])
4. Conclusion
The modern idea of the ecological potential of geosystems based on the combination of nature-centric and anthropocentric approaches should provide rational, ecologically oriented nature management. A single multi-stage process of geographical research reveals the ecological potential of geosystems. The complex transboundary territory of the Baikal basin requires ecological rationalization of nature management based on a scientific approach, one of which is the study of ecological potential.

The features of the structural and functional internal and external relations of geosystems on the forest-steppe border of the forest and the steppe formed during the late Neopleistocene and Holocene determine their further natural development, which reveals the evolution of the natural process as the basis for the formation of the natural ecological potential of geosystems.

Acknowledgment
The research was funded by RFBR according to the research project № 17-29-05089.

References
[1] Vladimirov I.N., Vyrkin V.B., Ilycheva E.A et al 2019 Natural conditions and ecological potential of geosystems in the central part of the Oka plateau (Eastern Sayan) Geogr. and Natural Resources 3 95–105
[2] Saaty T L 1980 The Analytic Hierarchy Process: Planning, Priority Setting, Resource Allocation (New York; London: McGraw–Hill International Book Co) pp 149–53
[3] Vladimirov I N 2018 August The ecological potential of Baikal region’s geosystems IOP Conf. Ser. Earth and Environmental Sci. 2
[4] Sochava V B 1978 Introduction to the doctrine of geosystems (Novosibirsk: Nauka) 319 p
[5] Plyusnin V M and Sorokovoi A A 2013 Geoinformation analysis of the landscape structure of the Baikal natural territory (Novosibirsk: Geo) pp 55–69
[6] Antoshchenko-Olenev I V 1975 Cenozoic of Jida district of Transbaikalia (stratigraphy, paleogeography, neotectonics) (Novosibirsk: Nauka) pp 76–7
[7] Kalmykov N P 2002 Nature and ancient man in the lake basin Baikal (Ulan-Ude: BNC SB RAS) 130 p
[8] History of Buryatia: Antiquity and the middle ages vol I 2011 (Ulan-Ude: Publ. house BNC SB RAS) 328 p
[9] Kalmykov N P 2003 Paleogeography and evolution of biocenotic cover in the lake basin Baikal (Rostov-on-Don: Publ. house of RSU) 240 p
[10] Bazarov D-D B 1986 Cenozoic of the Baikal region and Western Transbaikalia science (Novosibirsk, Nauka) 182 p
[11] Imetkhenov A B 1997 Nature of the transition zone (on the example of the Baikal region) (Novosibirsk, Nauka) 234 p
[12] Antoshchenko-Olenev I V 1982 History of natural conditions and tectonic movements in the late Cenozoic of Western Transbaikalia (Novosibirsk, Nauka) 156 p