Landscape and mapping support of regional geoecological analysis

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Abstract. The aim of the study was to develop a methodology for geographic synthesis of knowledge based on the polygeosystem concept and the idea of interpretative landscape-ecological mapping using GIS technologies, ranging from the study of general principles and logic of research to solving specific problems of geographic information mapping. The mapping strategy is to display the natural landscape as a complex of human living conditions in comparison with anthropogenic impact and possible consequences. The methodology for creating an outfit of landscape maps represents a combination of traditional mapping methods and geo-information methods for organizing thematic spatial data and their modification using GIS technologies. The basic principle of the creation of the cartographic information system (CIS) is the principle of complexity, which presupposes the existence of a system of landscape classification that is uniform for all thematic electronic layers of the CIS, and which can combine their natural and anthropogenic components. Such an approach provides a means of presenting a series of conjugated landscape-ecological interpretation maps of the Baikal region in the form of a holistic CIS consisting of an outfit of thematic layers, united by a common concept and created on a single landscape basis.

1. Introduction
Information support of regional geoecological analysis (GEA) is one of the priority scientific directions of geography and geoecology in connection with the issues of climate change and globalization. The main goal of the GEA is to obtain information which is necessary to prevent or minimize adverse environmental impacts of human activities, to maintain specified socio-economic functions of landscapes and optimal living conditions of the population [1]. Landscape-cartographic support of the GEA is a scientific process of translating interdisciplinary research materials into a constructive cartographic model, which requires clarification of goal-oriented theoretical issues to be studied; as well as determination the criteria for selection of empirical data and methods for their investigation; development of cartographic modeling methods based on the research results. In this context, a purposeful cartographic research procedure is being developed, which requires a consistent form for its implementation. The most pressing issue is the evidentiary standard presented by the final evaluation and forecast results of the study.

Creating a landscape cartographic information system (CIS) to ensure the environmental safety of human interaction with the natural environment and develop strategies and tactics for nature conservation that will work to solve the most important task - sustainable development – which is a current pressing issue. In geosystem mapping, sustainable development is considered as an important systemic quality that determines the existence of geosystems in a constantly changing environment.
The essence of sustainable development lies in the structural conformity of components of the geosystem as a whole and in accordance with the process of changing this whole to the whole complex of environmental properties, under the influence of which they experience constant spontaneous or anthropogenic changes, both reversible and irreversible. Therefore, applied landscape maps made with the use of structural-dynamic classifications by means of their “geoecological interpretation” are of great importance for GEA. [3, p. 223].

In the framework of the electronic atlas “Baikal Region: Society and Nature”, we developed an outfit of thematic maps “Landscape Environment”. It is known that over the past fifteen years in the V.B. Sochava Institute of Geography SB RAS, regional atlases “Ecological Atlas of the Irkutsk Region: Ecological Conditions of Development” (2004) [4], “Ecological Atlas of the Lake Baikal Basin” (2015) [5] and electronic “Ecological Atlas of the Baikal Region” (2017) were created [6]. The content of the atlas “Baikal Region: Society and Nature” differs from the above-mentioned atlases by its managerial interdisciplinary orientation, which is implemented, first of all, in the information support of the programs of ecological safety of interaction of society and nature [7].

The aim of the study was to develop a methodology for geographic synthesis of knowledge based on the polygeosystem concept and the idea of interpretative landscape-ecological mapping using GIS technologies, ranging from the study of general principles and logic of research to solving specific problems of geographic information mapping. The mapping strategy is to display the natural landscape as a complex of human living conditions in comparison with anthropogenic impact and possible consequences. In practice, these maps are designed to provide a comprehensive description of the properties and state of the natural environment, as well as prospects for its use and management, and geographical expertise of economic and other activities.

2. Models and methods

The methodology for creating an outfit of landscape maps for the Atlas represents a combination of traditional mapping methods and geo-information methods for organizing thematic spatial data and their modification using GIS technologies. The basic principle of the creation of the CIS is the principle of complexity, which presupposes the existence of a system of landscape classification that is uniform for all thematic electronic layers of the CIS, and which can combine their natural and anthropogenic components. Such an approach provides a means of presenting a series of conjugated landscape-ecological interpretation maps of the Baikal region in the form of a holistic CIS consisting of an outfit of thematic layers, united by a common concept and created on a single landscape basis.

By using the polygeosystem concept, it is possible to study geosystems as an outfit of combined spatial-temporal natural and natural-anthropogenic structures, to solve problems about the relationship between natural and social in the study of interaction of society with the natural environment and the patterns of its spatial-temporal differentiation. The theoretical basis for the interpretational study is the concept of the functioning of landscapes, developed by A.A. Grigoriev and M.I. Budyko and advanced by V.B. Sochava and his followers [2, 8]. For the ecological interpretation of geosystem characteristics, the concept of “geosystem-environment” was improved [2, p. 126], which allowed to give a new, more capacious content to the object of study, which differs from that in private geographical disciplines. Taking into account the human biosocial essence, geosystems are considered both as an ecological (natural) environment, and as a human habitat (biological species), and as a resource base for its economic activity (figure 1).

By using the methods of geosystem display it was possible to provide the development of indicators of environmental conditions and state, as well as regulatory restrictions of environmental management. In our case, systematization equips us with the idea of self-regulation, hierarchy, structure, internal and external interconnection of the components of geosystems, ways of determining their boundaries, functioning and economic use. The environmental concept can consider the natural conditions of a particular geosystem in comparison with larger regional categories, and the entire hierarchy of geosystems as an environment for the formation and development of its natural conditions. At the same time, a geosystem is a medium with respect to its components, therefore, it is
considered as a polysystem (natural-ecological, economic-ecological, social-ecological, etc.).

Dynamic and functional categories of geosystems are indicators of their ability to withstand anthropogenic loads (sensitivity, or vulnerability), as well as to respond to an imbalance (environmental sustainability). Self-regulation of geosystems “as an integral indicator of their stabilizing dynamics” [2, p. 70] is used in forecasting changes in geosystems and possible environmental risks (ER). Self-regulation is largely dependent on the structural and functional features of the geosystem: as a rule, self-regulation is most effective in optimal conditions of heat and moisture. Thus, due to the research methodology used, each geosystem selection is considered as a spatial cell of actual data concentration for GEA [9].

As the initial information, the materials were used earlier published in the V.B. Sochava Institute of Geography, such as maps and text materials on spatial and temporal differentiation of geosystems of the Baikal region and their hydroclimatic, orographic, and phytotypological characteristics, reflecting the basic geographical patterns of the ecological structure of natural background and defining the characteristics of functioning. Spatial allotments of thematic layers correspond to the regional hierarchical divisions of geosystems developed for the “Landscapes and Their Use” map [6].

3. Results and discussion

Structure of an outfit landscape maps for the electronic atlas "Baikal region: Society and Nature" has been developed. The subject of CIS maps is presented in three sections: 1 - basic inventory and information basis of geosystem content (M 1: 5000 000); 2 - derivative landscape interpretation map of geoecological content (M 1: 5 000 000); 3 - interpretational derivative maps of estimated and forecast content (M 1: 5 000 000; 7 500 000). The outfit of the most representative and differing complexes of natural conditions was determined, which describes the entire complex range of natural situations of the Baikal region. Established is a specific empirical level of their research and a specialized classification system for the landscape-cartographic module of the atlas “Baikal region: society and nature”, is developed, which includes a comprehensive classification of the base map and numerous derived generalizations from derivative maps developed for solving interface environmental problems of society and nature.

The article outlines a specialized classification of the basic landscape map, developed as an information and inventory basis for subsequent environmental interpretations and geo-ecological
Figure 2. Intensity of functioning, self-regulation categories and vulnerability degree of geosystems in the Baikal region.

Landscape-ecological structures (spatial groupings of geom groups of different physical and geographical regions and identical ecological and geographical conditions). Northern-Asian arctic-borreal. 1. Goletz–taiga high mountains of the East Siberian type (alpinotypic, sometimes subalpintypic, goletz, subgoletz and rare forest). 2. Mountain–taiga and taiga larch Baikal-Dzhugdzhurskie; mountain–taiga dark coniferous South Siberian; larch Middle Siberian; larch Amuro-Sakhalinskie (larch-mare, permafrost-marsh). 3. Mountain–taiga and taiga larch Baikal-Dzhugdzhurskie; mountain–taiga dark coniferous South Siberian; mountain–taiga light coniferous South Siberian; middle–taiga larch Middle Siberian. 4. Mountain–taiga and taiga larch Baikal-Dzhugdzhurskie; mountain–taiga and taiga dark coniferous South Siberian; southern taiga Middle Siberian; southern taiga Amuro-Sakhalinskie, mountain–taiga pine South Siberian. Northern-Asian semiazarid. 5. Mountain and submontane subtaiga Baikal-Dzhugdzhurskie; South-Siberian, Middle-Siberian and Amuro-Sakhalinskie. 6. Meadow-steppe South Siberian; southern taiga pine; pine forest and plain of Middle Siberia. Central-Asian aridis. 7. Mountain-steppe and steppe geosystems are herbage-turf-grass and turf-grass Dauro-Mongolian. 8. Mountain-steppe and steppe turf-grasses Dauro-Mongolian.

Intensity of functioning. Geosystems: 1 – extreme conditions of development with a significant lack of heat; 2 – reduced conditions of development with a lack of heat; 3 – limited development conditions moderately warm moderately humid; 4 – optimal conditions for development warm humid; 5 - optimal development conditions warm with some lack of moisture; 6 – limited conditions warm insufficiently humid; 7 – reduced conditions very warm and dry; 8 – extreme conditions hot dry with a significant lack of moisture.

Self-regulation categories of geosystems: 1 – lowest possible; 2 – very low; 3 – relatively low; 4 – relatively high; 5 – high; 6 - relatively low; 7 – low; 8 – very low.

Degree of sensitivity (vulnerability): 1 – highest possible; 2 - very high; 3 - relatively high; 4 - relatively low; 5 - low; 6 – relatively high; 7 – high; 8 - very high.
zoning of the territory (figure 2). By specializing, we examined classification units of geosystems of a regional hierarchical level through the functional integrity of systems of various ranks in accordance with their landscape-ecological and socio-economic role: the classification contains regional-typological, morphotypical, and structural-dynamic characteristics of geosystems.

A polygeosystem interpretation of the contents of the landscape-base map has been carried out and the ecological diversity of the landscape structure of the Baikal region has been determined, having natural, user and economic significance. The thematic load of the landscape-ecological map in general is reduced to three positions: structural content, elements of anthropogenic load and characteristics of the state of the environment, allows geo-ecological integration, or combining several layers of information and developing evaluation and forecast recommendations. It allows us to consider the use of each individual resource as the exploitation of a particular landscape system of a certain rank. The main form of integration of various layers of geographic information is geo-ecological zoning of the territory.

Figure 2 represents the developed content of evaluation and forecast maps of geo-ecological zoning of the territory. The geosystems are grouped by factors of formation, structure and dynamics, as well as by use, by environmental categories, identifying relationships that are part of providing specific tasks for a specific purpose (degree of suitability of a geosystem for a particular type of use, degree of stability of geosystems to environmental protection measures, etc. During the thematic integration of information, a target system of classifications is developed. The list includes the following thematic layers.

The map of the stabilizing dynamics of landscapes reflects their ability to maintain their state over time, despite numerous external influences. It is of great practical importance in the forecasts of changes in natural conditions arising under anthropogenic influences. The categories of landscape sustainability reflect the potential capabilities of a territory, because their ecological potential is embodied in their invariant, which determines the state variables observed in nature and their possible changes in order to rationalize the use.

The geosystem vulnerability map reflects areas differentiated by the degree of variability or susceptibility to the ER. The main natural factors of geosystem variability are climatic (climate warming and aridization); orographic (slope geomorphological processes, sand movement, etc.); structural and lithological (salinity, stony, etc.); fires, etc.

On the map of disturbance of structure, geosystems are divided into categories in accordance to the characteristics of landscape neoplasms on the following categories: derivatives, relatively retaining their spontaneous restoration properties; secondary permanent, radically modified, capable of recovery over a very long period; persistently secondary permanent anthropogenically modified, but capable of spontaneous recovery under reclamation; persistently secondary permanent, represented by engineering facilities, and incapable of spontaneous recovery. The geoecological interpretation of this map determines further conclusions regarding the intensity of the use of landscapes. Some assessment frames are distinguished according to the degree of landscape use as a part of these geoecological zones.

The map of the functioning of landscapes characterizing heat and water availability, biological productivity of terrestrial vegetation of geosystems, was developed on the basis of the ecological scale of M.I. Budyko [5, p. 69].

The map of the ecological functions of geosystems has embedded environment-forming, environmental protection, technogenic barrier, and conservation status of geosystems, knowledge about which is used in the development of environmental protection measures and recommendations on the use of landscapes.

The directional map of modern natural processes in geosystems, indicated by phytoindication, was developed using the improved “ecological scale by A.A. Krauklis (stabilization, activation, and stagnation)” [10, p. 58]. Activation is inherent in locations with disturbed vegetation and moderate or insufficient moisture, stagnation occurs in humid and excessively wet conditions, and stabilization phase occurs as a result of the restoration of vegetation.
The ecological potential map (EP) of landscapes reflects their ability to create a specific human environment. The value of EP of landscapes is associated with the types of geosystems and is differentiated into categories (very high, high, medium, relatively low, and low).

The climate comfort map differentiates geosystems by categories based on the integrated intensity of geosystems on the V.B. Sochava’s scale improved by the author: optimal, limited and reduced conditions of development [2, p. 160].

The map of the optimality degree of territory for life activity of people was created by integrating information from several assessment maps and decomposition of their contours. An integrated environmental approach used in creating this map provides an opportunity to determine the environment of a person, how he can use its components and probable consequences.

4. Conclusion
The specificity of the used geosystem geoecological concept has provided mapping of human activity conditions in various types of natural environment. The theme of the landscape map outfit for the atlas “Baikal Region: Society and Nature” made it possible to streamline existing knowledge about the organization of geosystems at the regional hierarchical level in terms of their functioning, value and stabilizing dynamics. Due to the integrated approach, it became possible to display the ecological state of the territory, which was formed as a result of the interaction of society and nature, as well as its managerial and protective aspects. Identification of the current and future state of landscapes, serving as natural conditions of human life, as well as areas which are problematic in environmental respect, provided geosystem geoecological interpretations and regional indicators.

The outfit of maps is a thematically unified, functionally complete fragment of an electronic atlas, designed as an independent product. Structured according to the principle of thematic and structural conjugacy, it further acts as a means for obtaining new knowledge about the properties of natural environment. On its basis, it is planned to search for currently unknown geographic phenomena and patterns, as well as new connections and interactions of society and nature.

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