An information support system for studying environmental aspects of the economic development of border regions

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Abstract. The present research aims to develop a scientific basis for information support system for studying environmental aspects of the economic development of border regions. The relevance of this goal stems from the peculiarities of the Chinese Belt and Road Initiative' border regions in Russia, China and Kazakhstan in terms of various aspects of economy-environment interaction in specific territories. Based on the generalization of analytical materials and scientific publications, we propose the ways to form a system of information support for the studying, which can be used to develop an ecological and economic integration policy of border regions. Approbation of the approach proposed by the authors was carried out within the framework of the scientific research program of the Baikal Institute of Nature Management SB RAS.

1. Introduction
In the regions adjacent to the territory of the Chinese Belt and Road, there are complex political and economic problems, many environmental problems are of a border nature (water, air pollution, degradation of ecosystems, etc.). The availability, timeliness and quality of relevant information are a solid basis for their solution and the development of an ecological and economic integration policy.

Measuring of ecological and economic information is an important tool for monitoring and assessing ecological resources and their correlation to economic indicators. There are many examples in numerous scientific publications, reports on the state of the environment and on progress in the development of a green economy, etc., published annually by national and international environmental agencies [1-4]. Information support for collecting, processing and analysing of economic, social and environmental indicators for the development of border regions is a complex scientific task, usually associated with the information gaps due to a high degree of data uncertainty, imperfect knowledge, inconsistent data or malfunctioning data flow mechanisms.

The present study aims to provide a scientific basis for information support for studying the development of border regions in terms of various aspects of economic and environmental interactions at regional and local levels.

2. Materials and methods
The research is based on analytical materials of various levels, available in the public domain and commissioned by international organizations (UN, UNEP, OECD, etc.) [1-5], as well as scientific articles by foreign and domestic scientists and a number of authors’ own developments [6-12].
3. Results and discussion
Based on the study and generalization of analytical materials and scientific publications, the authors have developed a scheme for information support for the study of environmental aspects of economic development of border regions (hereinafter – information support) (Figure 1). The upper part of Figure 1 presents the goal, basic principles, requirements and functions of information support. According to the experience of creating the Shared environmental information system (SEIS) [5, 6], information should be accessible to all its users, it should be comparable at the appropriate geographic scale and supported by common and open software standards, it is necessary to ensure that data collection and presentation is localised (“managing as close as possible to their source”).

We formulated the following main tasks to be solved for provision of information support for environmental and economic research:

- Developing and forming a set of indicators that correspond to various national, regional and international standards, and allowing comparison of the state of model areas. Indicators that reflect regional characteristics and measurement capabilities, as well as the selection of appropriate methods, can be used to assess progress in achieving the set management goals [7];
- Defining functional diagrams to describe the cause-effect relations between environmental, economic, social, technological indicators, reflecting various aspects of the nature management process. Measuring, processing, interpreting and communicating information is expensive, so the choice of approaches and indicators for its measurement must be tailored to the specific needs and conditions of a particular country [2, 8];
Developing an infrastructure, by which we mean “an efficient web-enabled technical infrastructure”, that takes full advantage of advanced information and communication technologies, including the creation of specialised data banks, web services to provide easy access to a wide range of information and data flows. A priority for the authors in this context was the development of the concept of an information system to automate the process of analysing the environmental aspects of the development of border regions’ economies.

In the process of forming the information support system, the authors distinguish the following main stages:

- **Stage 1.** “Defining the object of study based on the provision of data and the formation of information on the socio-economic, natural-resource and environmental development potential of the model areas”;
- **Stage 2.** “Data management based on collecting, measuring and processing of information, and the formation of theoretical provisions on changes in the characteristics of model areas”;  
- **Stage 3.** “Enabling the use of the obtained information by creating databases and developing information systems based on digital information”;
- **Stage 4.** “Modelling the characteristic of the study objects, and making forecasts for the development of model areas, elaborating scientific and practical recommendations”.

In addition to statistical materials and monitoring studies data, the present research proposes to use the methods of comparative econometric and cluster analysis; selection of priorities based on the analytic hierarchy process; methods for assessing ecosystem functions, assimilation potential, anthropogenic load and economic damage; building composite indexes; structuring information based on the DPSIR concept; development of cartographic materials, etc.

**Table 1.** Initial indicators for assessing the socio-economic potential of model areas.

| Potential       | Baseline indicators                                                                 |
|-----------------|--------------------------------------------------------------------------------------|
| Social          | - average monthly income of the population;                                         |
|                 | - life expectancy at birth;                                                          |
| Production      | - the volume of industrial production per 1 person employed in industry;             |
|                 | - investment in fixed assets in industry per 1 rouble of industrial production;      |
|                 | - the cost of fixed assets per capita.                                               |
| Economic        | - GRP per capita;                                                                   |
|                 | - GRP for “mining operations” per capita;                                            |
| Investment      | - investment in fixed assets per capita;                                            |
|                 | - FDI per capita.                                                                   |
| Labour          | - the share of the economically active population of the region in the total population of the region; |
|                 | - the unemployment rate;                                                             |
|                 | - population migration.                                                             |
| Innovation      | - the volume of shipped innovative products.                                         |
| Infrastructure  | - coefficient density of roads;                                                     |
|                 | - railways density factor;                                                          |
|                 | - the value of fixed assets;                                                        |
|                 | - depreciation of fixed assets.                                                     |
| Foreign economic| - foreign trade turnover per capita;                                                 |
|                 | - tax revenues per capita.                                                          |

An integral part of information support is the creation of specialised data banks and an information system, which include economic and social indicators, characteristics of integration processes and institutional factors, indicators of resource and environmental efficiency, parameters of natural assets and environmental quality of life, etc.
Approbation of the approach proposed by the authors to the development of information support for studies of environmental aspects of economic development of border regions was carried out within the framework of the scientific research program of the Baikal Institute of Nature Management SB RAS. At the Stage 1 of defining the study object, several databases were created:

1. Database of economic and social indicators, which includes 2 large blocks:
   - assessment of the socio-economic potential of the model areas (Table 1);
   - assessment of the development and use of tourist and recreational potential, which includes a system of criteria and an assessment algorithm for 7 assessment elements: tourist and recreational resources, transport, information and border infrastructure, regional tourism policy, investment projects, tourism market development. The assessment algorithm is based on the analytic hierarchy process, which allows to compare the values of tourist and recreational potential based on a system of criteria describing the availability, characteristics, state, degree of development and further use of resources and conditions for tourism development.

2. Database for assessing the ecological state of model areas, formed on the basis of a set of specific indicators of pollution of various components of the natural environment (emissions, discharges, waste), reduced to a single mono-pollutant (per unit area and per capita);

3. Database of ecological and economic indicators (GRP and investment in fixed assets per capita, environmental current and capital costs per unit area, per capita and per unit of GRP of model areas) (Figure 2).

The approach to identifying regional features is based on the construction of matrices for assessing the level of ecological and economic development as a result of comparing specific indicators of the ecological state and environmental investments and costs, the main indicators of economic development of different regions, the subsequent ranking and grouping of regions [9].

![Figure 2. Indicators for the environmental and economic measurement of regional growth.](image)
At the Stage 2 of data management, the following results were obtained:

2.1. A methodological toolkit has been developed for assessing the social capacity of territories on the basis of an index method for ranking indicators of social capacity, which makes it possible to carry out a typology of territories at the regional and local levels in terms of the availability of healthcare and education services, and also forms qualitative indicators of infrastructure development of territories.

2.2. An integral indicator of ecosystem services of territories has been developed, showing the availability and use of resources (the eco-capacity of the forest ecosystem of the regions, the calculation of the carbon balance in the forests of the model areas, the cost estimate of the annual use of hunting, tourist and recreational resources, etc.).

2.3. The methodology for determining the ecological-economic index of territories, which characterizes the social and ecological “quality” of economic growth, has been adapted, i.e. economic growth while ensuring social development and preserving the environment [10].

2.4. On the example of model areas, the method of ranking territories for assessing the ecological capacity of the components of the natural environment and anthropogenic load has been tested.

2.5. A methodology for constructing a composite index has been developed, which makes it possible to comprehensively characterize and consider the links and interactions between the economy and the environment in specific local areas. The choice of 5 directions of assessment and 16 indicators has been substantiated (Figure 3). An algorithm for the quantitative assessment of the composite index has been developed, consisting of 6 stages: the choice of directions and the calculation of the initial indicators, the normalization of indicators, the calculation of entropy as a measure of the uncertainty of the system of indicators, the calculation of multiple estimates for each group of indicators, their normalization and quantitative assessment of the composite index. The composite index is calculated for 9 regions of Russia, China and Kazakhstan [10].

2.6. In order to structure various indicators of the composite index from a unified point of view, conceptual model of DPSIR has been proposed, adopted by many national and European institutions as a method of systematizing information and establishing cause-effect relations between driving forces, pressures, states, influences and reactions of society. Figure 4 shows the distribution of composite index scores across DPSIR categories [11].
The following types of work were carried out in Stage 3 of the development of the decision information support system:

3.1. An automated system for assessing economic damage from negative anthropogenic impact and comparing quantitative estimates of economic damage for emissions of pollutants with the amount of environmental investments and payments for air pollution has been developed [12].

3.2. A methodology for calculating the ecological capacity based on accounting the assimilation potential and the characteristics of each component of the natural environment in specific territories has been adapted. The assimilation potential of a territory consists of: the calculation of the assimilation potential of the atmosphere, the assimilation potential of water resources, and the assimilation potential of the soil [12].

3.3. For the procedure for automating calculations, a methodological toolkit for an automated system of project analysis was developed (Certificate of state registration of a computer program No. 2018610966 “Regional features of the implementation of investment projects”). The created information system supports the input, calculation and storage of the main indicators required.

4. Conclusion
The authors’ approach to the development of information support for research on environmental and economic interactions allows:

1. to structure the existing flows of socio-ecological-economic information and apply modern methods of its processing and analysis;
2. to assess the environmental aspects of the economic development of the border regions within Chinese Belt and Road Initiative, compare them with each other and identify individual factors affecting their development, as well as determine the directions for development of ecological and economic integration policies.

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