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V.S. Tikunov[1], **O.Yu. Chereshnya**[2]

INCREASING RELIABILITY OF INDEXING SUSTAINABLE DEVELOPMENT USING MULTIVARIANCE: CALCULATION AND MAPPING

Abstract. *This article provides an overview of existing techniques used to improve the reliability of classification. In particular, it focuses on the multivariance as a simple and reliable method of increasing the reliability of estimates. The use of multivariance aythorth consider on an example of the Index of the ecological situation of Russian Regions, that has been designed as part of complex estimation of sustainable development. The index includes three indicators: damage caused by air pollution, amount of discharged polluted wastewater and environmental protection expenditures.*

Key words: *multivariance, indexing, sustainable development, reliability, mapping.*

Introduction. Researchers need to improve the reliability of their estimates in the assessment of complex and multi-dimensional categories such as state of the environment, which include a plurality of factors. An excellent tool for improving the reliability is the multivariance. Multiple aspects of research, improved information support, the availability of a wide range of methods and involvement of modern computer tools allowed to realize multivariable approaches in modelling of geographic systems.

Ways of using multivariance are very diverse and can include all stages of the research, as shown in (Tikunov, 1990). It can be an analysis of different approaches in formulation of the problem and research purposes; using of different datasets to describe the same phenomenon; application of various modelling techniques; processing of the same dataset using different algorithms; visualisation of results in several ways.

Research methods. The use of multivariance we consider on an example of the Index of the ecological situation, that has been designed as part of complex estimation of sustainable development. It was calculated for regions of the Russian Federation. The index includes three indicators: damage caused by air pollution, amount of discharged polluted wastewater and environmental protection expenditures. We proceeded from the following principles in the selection of indicators. Selected indicators should be simple and accessible for comparing both at the regional and international level in the future. They have to indicate anthropogenic pressure on nature, reducing of environmental quality and its impact on human health. Minimum number of indicators allows researchers to concentrate on the most important of them and facilitates interpretation of results.

Method of calculation is following: instead of arithmetic average it uses the evaluative algorithm. It includes normalisation of initial indicators by the formula:

$$\hat{x}_{ij} = \frac{|x_{ij} - {}^{0}x_j|}{|{}_{max/min}x_j - {}^{0}x_j|},$$
$$i = 1,2,3,\dots,n;$$
$$j = 1,2,3,\dots,m;$$

where ${}^{0}x$ is worst value for each indicator occurring over the whole period in time for all three indicators; ${}_{max/min}x$ is the most different from the ${}^{0}x$ values of parameters, *n* is the number of territorial units, *m* is number of indicators used for the calculations.

[1] Lomonosov Moscow State University, Faculty of Geography, Integrated Mapping Laboratory, Head, Full Professor, Doctor of Science; e-mail: vstikunov@yandex.ru.

[2] Lomonosov Moscow State University, Faculty of Geography, Department of Geography of the World Economy, PhD student; e-mail: chereshnya.o@yandex.ru.

Ranking is carried out by comparing all territorial units on a conditional basis, characterised by values of ${}^0x$. This is done using the Euclidean distance (d^0) as a measure of proximity of all territorial units to a conditional basis (a worst-case values ${}^0x$ throughout a range of indicators). Processing of the array using principal component analysis for the purpose of orthogonalisation and a «convolution» system of indicators was then used. In the experiment, all the original indicators have equal weight, although it was assumed that weight meaning can be different and can change through history. To apply the weights, we need a reliable basis, however and today there is no such basis (Tikunov et al, 2006).

The first application of multivariance for this index is the use of different systems of indicators processed by one algorithm, which is described above. The results of such calculations require the same type of visualization. That improves the reliability of the final conclusions.

The first dataset was formed from the absolute values of the indicators. The second included indicators related to the area, population and «ecological gross regional product» (ecological GRP). The «ecological GRP» was developed by us specifically for this study. We excluded from the total GRP those branches which produce the greatest amount of waste, as well as air pollutants emissions. They are following: agriculture, hunting and forestry; mining; manufacturing; production and distribution of electricity, gas and water; building; transport and communications; providing utility services. Unfortunately, Russian statistics do not allow to make it more accurate, for example to separate transport from communication, as in the statistics of GRP they are in same category: transport and communications.

Results and discussion. As a result, two variants of the index of the ecological situation has been received. In absolute values, which characterize the overall pollution and environmental costs (Fig.1). And in relative values, which allow to assess the degree of contamination of the territory, both anthropogenic and industrial load (Fig. 2).

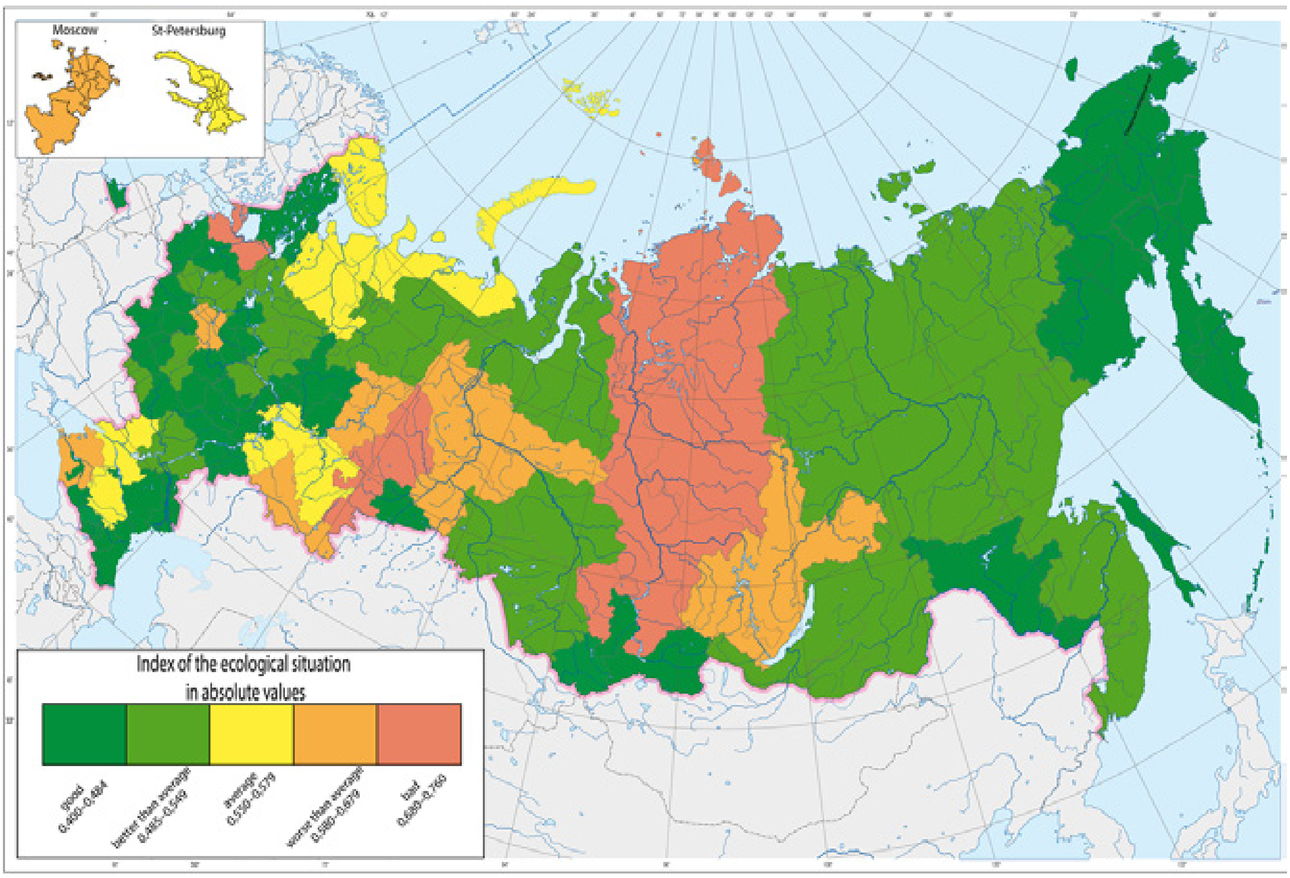

Fig. 1. Index of the ecological situation in absolute values

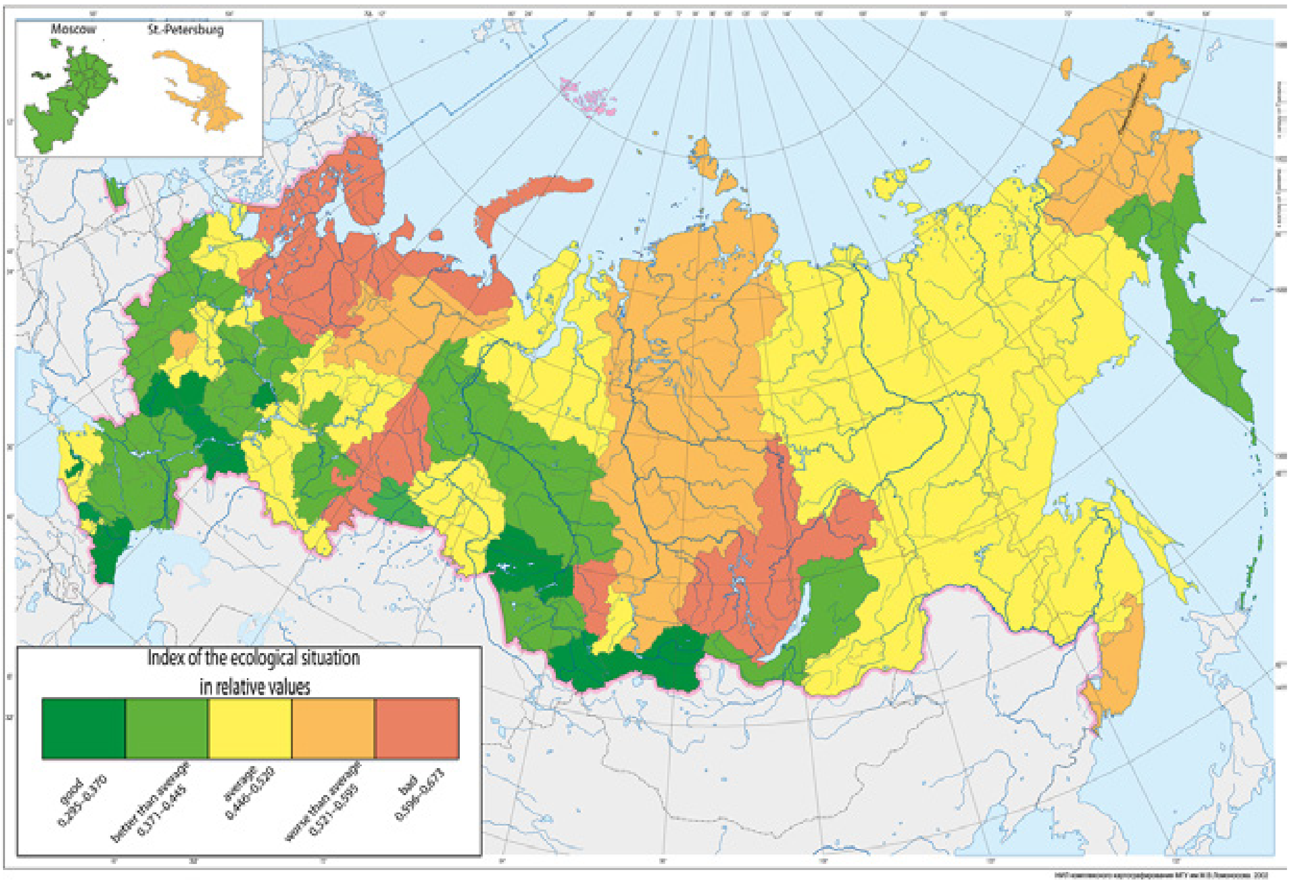

Fig. 2. Index of the ecological situation in relative values

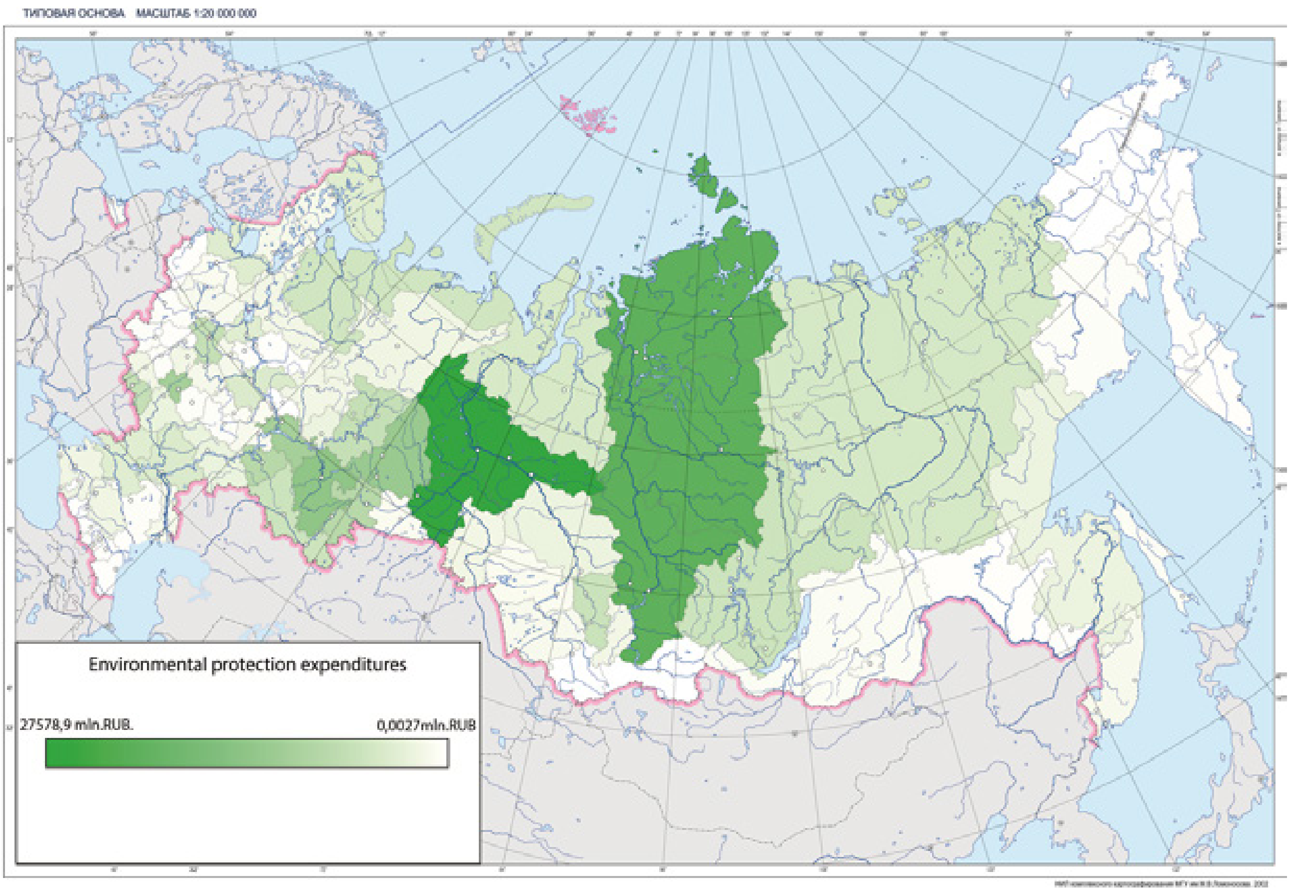

Fig. 3. *Environmental protection expenditures*

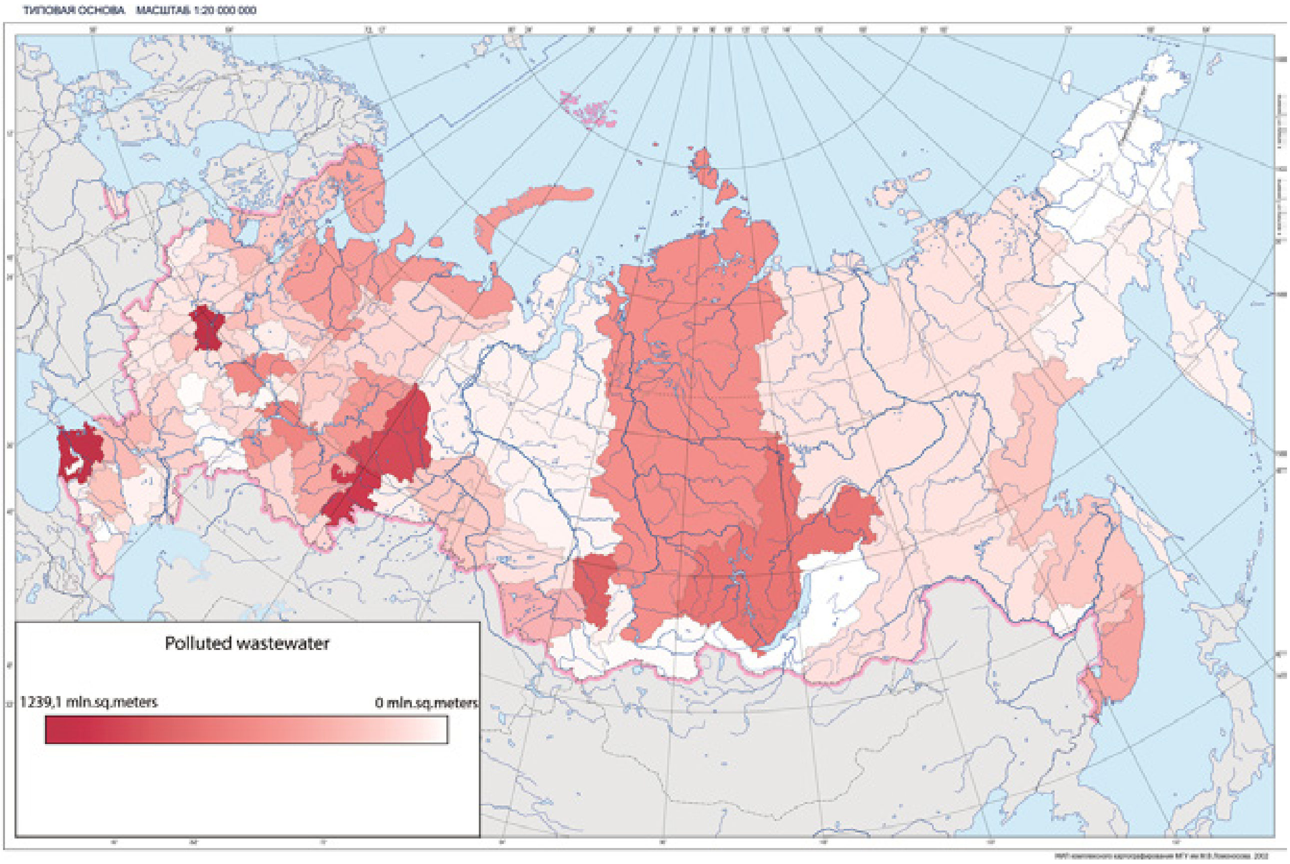

Fig. 4. Amount of discharged polluted wastewater

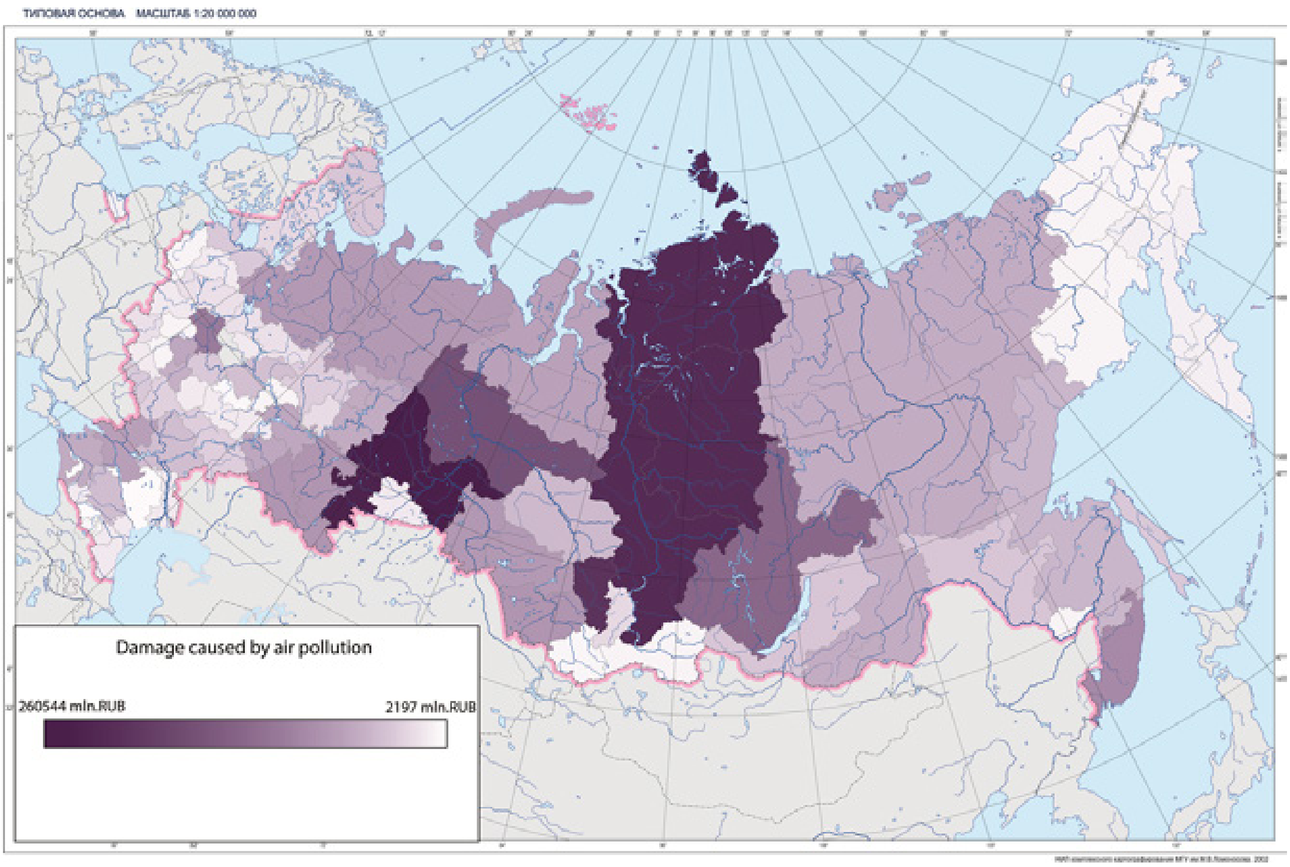

Fig.5. Damage caused by air pollution

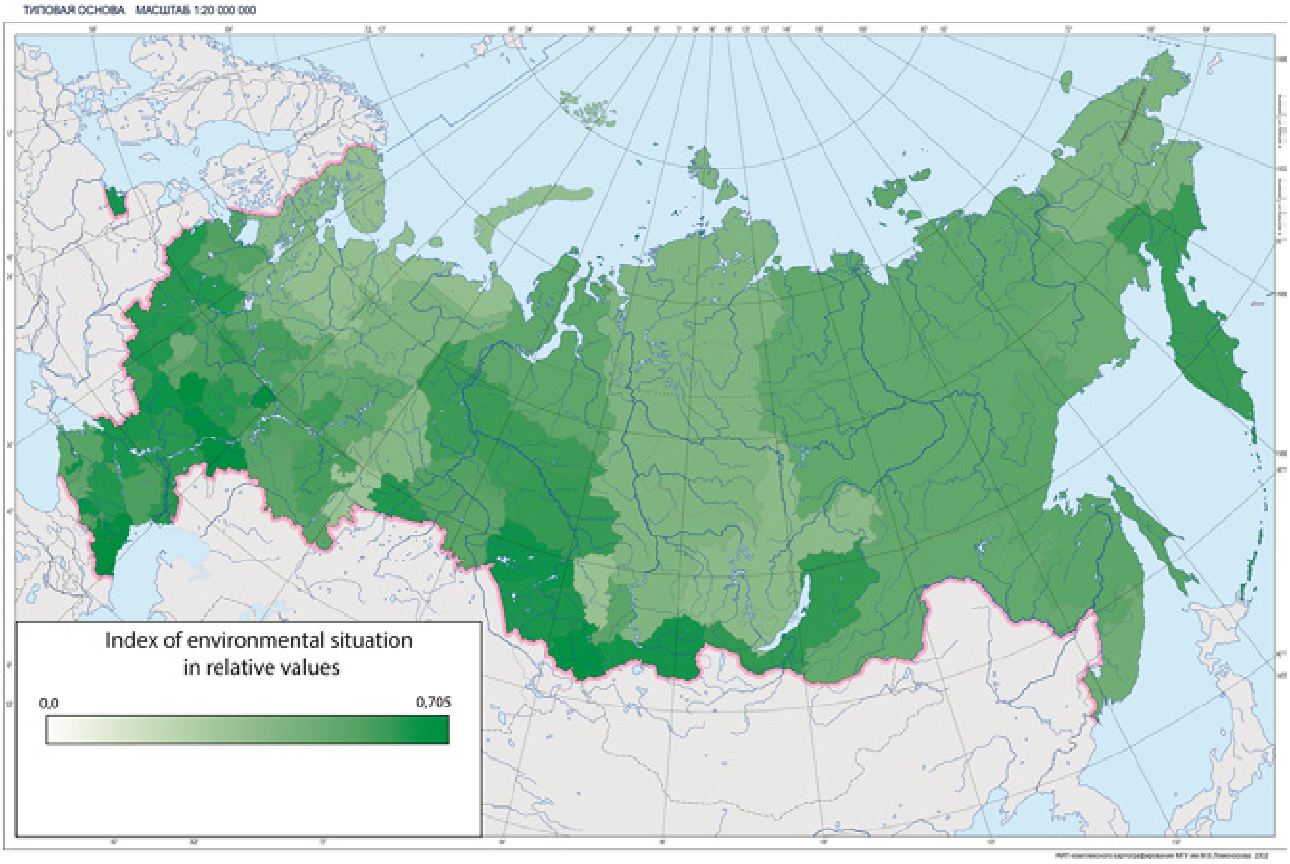

Fig. 6. Index of environmental situation in relat. values

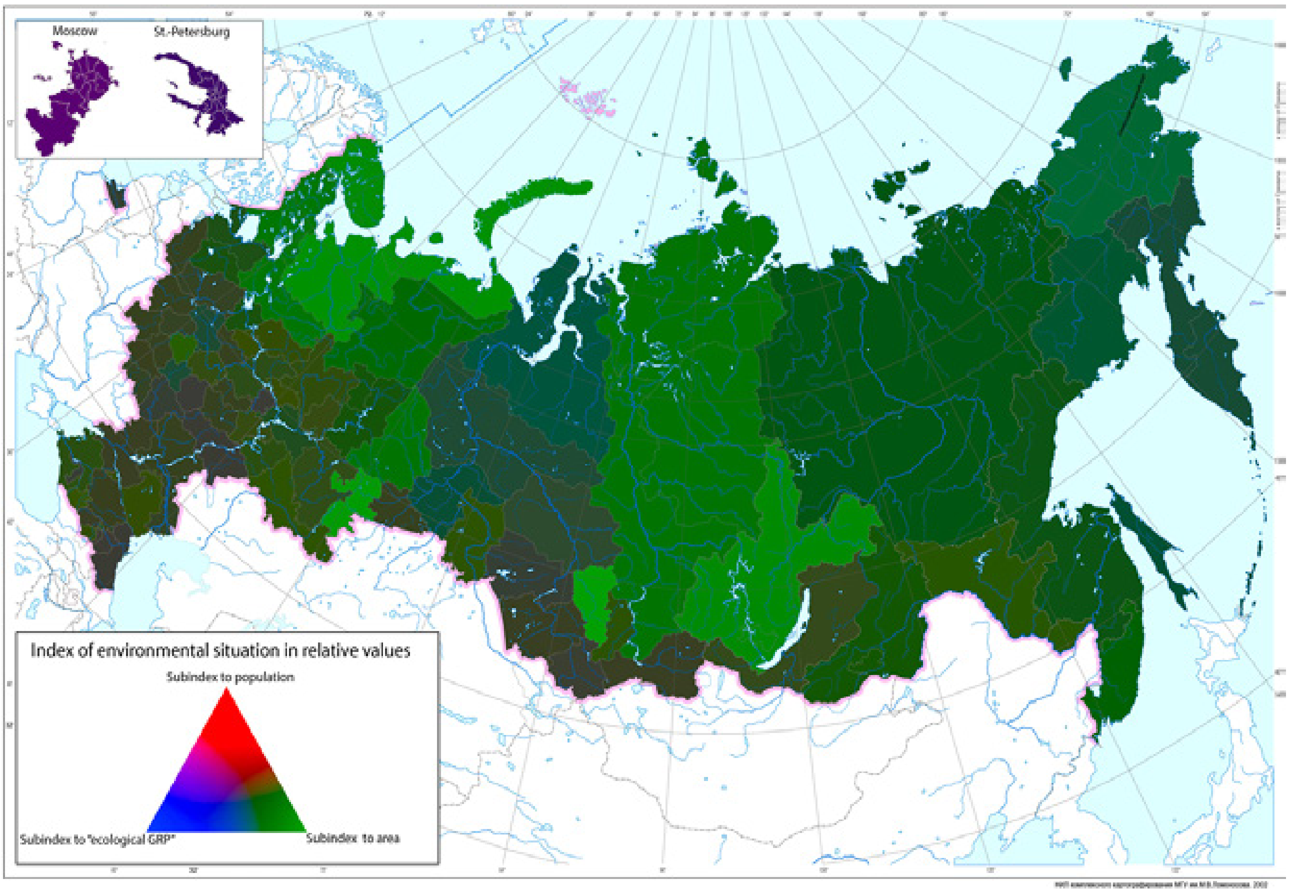

Fig. 7. Components of index of environmental situation

Besides stepless maps, was built a map that illustrates proportion of components of index of the ecological situation in relative values. It was created according to the method of colour triangle where each colour is proportional to its corresponding subindex (Fig. 7).

The second approach for increasing reliability – multivariance of classification methods, which is used on these cards. Selecting of homogenous groups of territories performed by three algorithms (SAS…, 1985):

- selection of similar stages from ranked values of a number of Euclidean distances to the best conditional territorial unit, characterised by values of ${}^{0}x$;
- Ward's method, which minimizes the total within-cluster variance and maximizes it between clusters;
- centroid method, in which the distance between two groups is defined as the square of the Euclidean distance between their averages.

The results obtained in all variants, were similar, indicating high reliability of classification of regions by ecological situation. All received values can be averaged to create single classification. This approach significantly increases the accuracy of the typology.

The third method of multivariance used in the study – the various ways of visualization of results. Diversity of ways to present results of modeling allows to select the final version that convey the essence of phenomena.

Multivariance is the possibility of parallel use of different datasets, mathematical algorithms and methods of visualization of results. Use of multivariance resulting in higher reliability of the final conclusions and allows better analyse all the factors that constitute this or that phenomenon.

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