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Assessment of Environmental Parameters Impact on the Level of Sustainable Development of Territories

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Abstract

The reason for the research is Russia's transition to the model of sustainable development. The environmental component plays the important role in the formation of sustainable development of the territories. This research area enables to estimate the influence of environmental parameters on the level of sustainable development of territories. Indicators characterizing the state of the environment and ecological potential of these territories were used as indicators which have an impact on sustainable development. This research was carried out on the basis of multiple regressions method. For the first time the classification of regions of the Russian Federation for 2013 by the level of environmental safety was made. As a result, the most significant indicators affecting the sustainable development of territories were revealed and decisions for the management of these parameters were developed in order to improve the sustainable development of territories.

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Keywords: Sustainable Development; Environmental Parameters; Environmental Safety; Factor Analysis; Cluster Analysis; Regression Model; Territories.

1. Introduction

The assessment of the impact of environmental parameters on the sustainable development level of territories has paramount importance. This is due to the processes of urbanization: atmospheric air pollution, deterioration of living conditions in regions, pollution of the environment around industrial centers, etc. Therefore, this research has a high degree of scientific and practical significance since it implies the development of methods of assessment of the environmental parameters impact on sustainable development of regions. This method enables not only to identify key environmental parameters, to evaluate their impact on the sustainability of territories, but also to classify them according to the environmental safety level. These results can be used to develop management solutions to ensure the sustainable development of territories taking environmental parameters into account.

The novelty of the research is as follows:

1) The method for the formation of indicators characterizing the ecological safety of territories on the basis of the main factors is developed;

2) The regression model of the correlation between the sustainable development of the territory and environmental safety factors enabled to reveal environmental safety factors which have the greatest influence on shaping the sustainability of the system;

3) For the first time the classification of regions of the Russian Federation for 2013 by the level of environmental safety was made through the use of typological groups method and cluster analysis with the determination of stable groups.

2. Critical review of the materials on the research topic

Since the 20th century in response to the challenges of globalization, international centers, such as the World Bank, the Organization for Economic Cooperation and Development (OECD), the United Nations, Institute for Sustainable Manufacturing, V.B. Sochava Institute of Geography, Russian Academy of Sciences Center for Ecological Safety and others

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developed and offered solutions in the sphere of sustainable development of territories. One of the common methods of the assessment of the sustainability of a territory with regard for environmental parameters is the use of the integrated assessment. It boils down to the reasonable selection of the most informative indicators, the choice of the type and rules of standardization of these indicators, the choice of the form of calculation of the integral indicator. [1]

The World Wildlife Fund (WWF) designed the Living Planet Index. It is based on the estimates of the population size of particular wild species and is calculated for forest, marine and freshwater ecosystems. Besides, WWF developed such indicator as the Ecological Footprint, which measures the pressure on the environment by any person, enterprise, organization, community, country, the population of the entire country.

Yale and Columbia Universities in the United States developed the index of environmental sustainability. This index implies the use of 76 indicators in the calculation grouped into 21 indicators, which are reduced to five components: "ecological system", "reduce of environmental stress," "reduce of the vulnerability of humanity", "social and institutional capacities", "global oversight." [2].

The United Nations developed a system of indicators of the Millennium Development Goals which is aimed to assess the effectiveness of actions to address social problems and human capacity development in the developed countries. Among the objectives of the MDG is the environmental goal, which is aimed to ensure the environmental sustainability of the planet.[3]

Moscow State University under the guidance of I. N. Rubanova, V.S. Tikunova developed an integrated assessment of the ecological state of the environment of regions of the Russian Federation. This assessment involves getting an integral composite index of ecological state of the environment and the ecological state of the individual indices of its components, which take a value on the scale from 0 to 100. [4]

S. N. Bobylev, V. S. Minakov, S.V. Solovyova and V. V. Tretyakov proposed the ecological and economic index of the Russian Federation regions. The development of the integral index was based on the principles of Adjusted net saving index construction. The developed integral estimate considers environmental sustainability in a broad context, including environmental, economic and social factors into account.[5, 6]

The critical analysis of methods of the assessment of environmental parameters impact on the economy has revealed a shortcoming of such research. These works do not study the interconnections between environmental parameters and the sustainable development of territories. To solve the identified problem, factors of environmental safety are proposed to be considered as environmental parameters. By the environmental safety we will mean the state of protection of the environment and the vital interests of a person from the possible negative impact of economic and other activities, from natural and anthropogenic disasters and their consequences. [7]

3. Methodology of the research

Environmental safety is a complex multidimensional phenomenon. By the environmental safety we will understand the qualitative characteristics of social and economic development, which involves the formation of a new type of technological processes, social organization, management etc., which can efficiently solve environmental problems and protect the society and the person from any environmental dangers (emissions of harmful substances, resources shortages, natural disasters, accidents etc.).

This definition of the environmental safety was formulated by N. Vashchekin. [8].

The level of ecological safety directly affects the state of economic development of the system. It is due to the fact that economic development has a negative impact on the environment. Therefore, in our study we used economic indicators reflecting the use of advanced technologies that can help to reduce the load on the environment (reduction of material costs per unit of goods, work and services by organizations, as a percentage of the total; reduction of energy to produce a unit of goods, work and services by organizations, as a percentage of the total; reduction of carbon dioxide emissions (CO2) by organizations, as a percentage of the total). [9, 10, 11]. In addition, the regression equation for 2013 was made for assessing the impact of environmental factors on the level of sustainable development.

This research is based on the data already used in our previous work [12, 13, 14], but the object of study and the methods are different.

This work considers the developed author’s method of assessment of the impact of environmental parameters on the level of sustainable development of territories with the use of multivariate statistical analysis - factor analysis, regression analysis, method of multidimensional average, method of typological groups, index method.

Multivariate statistics techniques enable to establish a quantitative relationship between the studied phenomena (correlation analysis), to investigate the relationship between the variables (regression analysis), to identify the role of individual factors in the change of the analyzed parameter (factor analysis) etc.

The use of the multidimensional average and the method of typological groups ensure the correctness of the results of the conducted research. This is due to the fact that the object under study is heterogeneous and requires prior typology.

These methods has not only strong but also weak aspects. A big amount of original data is required to ensure the credibility of results of a research, and the use of statistic methods is practically impossible without a computer.

Figure 1 shows the methodology of the study.

On the first stage a metrics is formed. It is the key stage of the work because the result of research depends on the correct selection of the original data set.

Therefore, the set of indicators is selected on the basis of credibility, self-descriptiveness, reliability, comparability and quality of information. For matching these criteria the original date set is proposed to be made on the basis of the data of the Federal State Statistics Service. [15]

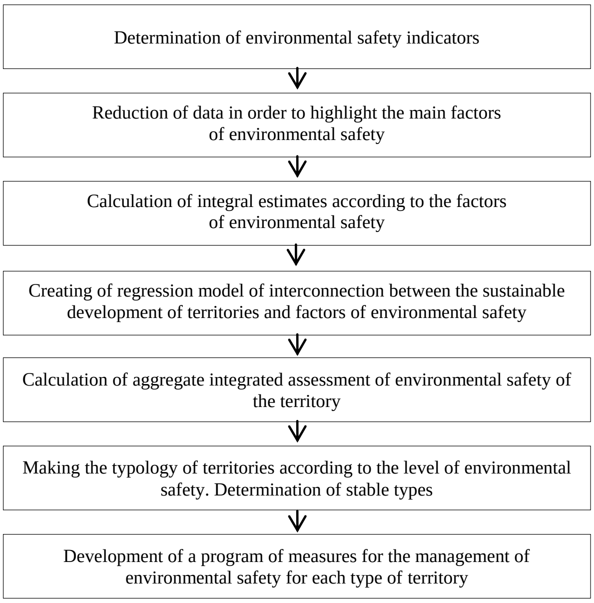

Fig. 1. Method of assessment of the impact of environmental safety level on the sustainable development of a territory.

At the second stage the reduction of the data is carried out on the basis of the factor analysis. Using of the factor analysis enables to reveal unobservable traits that can be estimated during the processing and analysis of primary data. [16]

The Kaiser criterion and the scree test can be used to determine the number of significant factors. According to the Kaiser criterion the factors whose eigenvalues are greater than 1 are selected. A graphic method – the scree test - can be used as well. This method implies finding a place on the chart where the decrease of the eigenvalues from left to right slows down as much possible. For the meaningful interpretation of the factors their number must be small, and their aggregate must explain the main part of the total variance of the primary indicators set. [17]

On the third stage for each selected factor the integral assessment is calculated on the basis of application of multivariate statistical analysis. [18, 19, 20, 21] The advantage of using of multivariate methods is the ensuring of comparability of data by obtaining one-dimensional values. These integral estimates for each selected factor may be the basis for building a regression model, which enables to estimate the interconnection between the factors of environmental safety and sustainable development of territories.

On the fourth stage a regression model which enables to reveal the interconnection between the resulting indicator - the sustainable development of a territory and selected environmental factors – is constructed. When making a regression model, it is necessary to verify the significance of the regression parameters. For these purposes the Student's t test or Fisher's distribution can be used. [16]

At the fifth stage the composite index of environmental safety of territories is calculated. The method of multidimensional medium is used to calculate the composite index.

On the sixth stage the typological grouping of territories by the level of environmental safety is made on the basis of the calculated composite index and cluster analysis, which enables to identify stable types of territories. [12, 13, 14, 22]

The seventh step involves the interpretation of research results, based on which a program of activities for the management of environmental safety for each type of area can be developed.

4. Results of the research

The approbation of the developed method was carried out on the material of 80 regions of the Russian Federation for 2013. The 18 indicators for Russian regions were selected as an initial data set (Table 1).

Table 1. Environmental safety indicators.

Variable	Indicators
x1	Production index of economic activity "mining operations", as a percentage of the previous year
x2	Production index of economic activity "manufacturing", as a percentage of the previous year
x3	Production index of economic activity "production and distribution of electricity, gas and water", as a percentage of the previous year
x4	Index of industrial production, as a percentage of the previous year
x5	Emissions of pollutants into the atmosphere from stationary sources, tonnes / km2
x6	Trapping of air pollutants from stationary sources, tonnes / km2
x7	The use of fresh water, thousand cubic meters per capita
x8	The amount of recycled and consequently used water, thousand cubic meters per capita
x9	Discharge of polluted wastewater into surface water bodies, thousand cubic meters per capita
x10	Reduction of material costs per unit of goods, work and services by organizations, as a percentage of the total
x11	Reduction of energy to produce a unit of goods, work and services by organizations, as a percentage of the total
x12	Reduction of carbon dioxide emissions (CO2) by organizations, as a percentage of the total
x13	Replacement of raw materials or the less dangerous materials by organizations, as a percentage of the total
x14	Reduction of the air, land, water pollution and noise reduction by organizations, as a percentage of the total
x15	Recycling of wastes, water and materials, as a percentage of the total
x16	The amount of work performed by the kind of economic activity "Construction", in actual prices, thousand rub. per capita
x17	Trucking, mln. Tons
x18	Freighting, mln. ton-km

They describe the state of the environment and the ecological potential of development on the basis on the established criteria of credibility, self-descriptiveness, reliability, comparability and quality of information.

Then the reduction of the data was carried out through the use of factor analysis. The use of the Kaiser criterion and the scree test has revealed that 6 main factors can be selected from the original data set. Table 2 shows the matrix of factor loadings and the eigenvalues of the selected factors.

Table 2. The matrix of factor loadings.

Variable	Factor1 (F_1)	Factor2 (F_2)	Factor3 (F_3)	Factor4 (F_4)	Factor5 (F_5)	Factor6 (F_6)
x1	-0.012	-0.150	-0.082	-0.204	-0.030	**-0.832**
x2	0.165	0.019	**-0.857**	-0.108	0.021	0.118
x3	-0.353	0.067	-0.455	0.002	-0.245	-0.257
x4	-0.005	-0.078	**-0.915**	-0.072	0.075	-0.149
x5	0.067	0.113	0.047	**0.905**	-0.073	0.157
x6	0.040	0.062	0.106	**0.898**	0.095	0.035
x7	0.239	-0.432	0.124	-0.183	-0.664	0.294
x8	-0.062	0.226	0.123	-0.064	0.585	0.134
x9	0.072	0.201	0.369	0.384	0.175	-0.361
x10	**0.752**	0.085	0.320	-0.004	-0.041	0.147
x11	**0.837**	0.082	0.067	0.025	-0.083	-0.033
x12	**0.759**	0.011	-0.152	-0.003	-0.134	0.140
x13	0.644	0.063	-0.167	0.175	-0.244	-0.240
x14	**0.711**	0.147	-0.023	0.031	0.116	-0.073
x15	0.589	-0.038	-0.146	0.021	0.533	0.138
x16	0.100	0.968	0.005	0.017	-0.007	0.024
x17	0.034	**0.898**	0.014	0.026	0.141	-0.013
x18	0.120	**0.826**	0.041	0.212	0.115	0.102
Expl.Var	3.360	2.160	2.147	1.947	1.312	1.189
Prp. Totl	0.187	0.120	0.119	0.108	0.073	0.066

Factor loadings in the interpretation of the results are of great importance since they enable to assess the closeness of the relation of a particular attribute with the considered factor. Bold font highlights factor loadings, symbolizing the high degree of direct or inverse relation between the studied parameters and factors.

Table 3. Factors of environmental safety of the Russian Federation regions for 2013.

Factors	Number of factor	Indicators
Factor of ecological properties of production in region (eigenvalue 3,36)	F_1	x10, x11, x12, x13, x14, x15
Transport and construction factor (eigenvalue 2,16)	F_2	x16, x17, x18
Production factor (eigenvalue 2,15)	F_3	x2, x3, x4
Anthropogenic factor (eigenvalue 1,95)	F_4	x5, x6, x9
Water resources factor (eigenvalue 1,31)	F_5	x7, x8
Factor of natural resources (eigenvalue 1,19)	F_6	x1

On the basis of the matrix of factor loadings the classification of the set of indicators to the factors of ecological safety was held (Table 3). The results of the factor analysis were used for calculation of the integral estimates for each selected factor through the application of multivariate statistical analysis - the method of multidimensional average.

Integral estimates were calculated for 80 regions of the Russian Federation for each formed factor: the level of ecological properties of production in region (F_1); the level of transport and construction state (F_2); the level of production state (F_3); the level of anthropogenic safety (F_4); the level of consumption of water resources (F_5); the level of consumption of natural resources (F_6).

The results of the research for the Siberian, Ural and Far Eastern Federal Districts of the Russian Federation are presented in Table 4.

Table 4. Integrated estimates of environmental safety of the Russian Federation regions for 2013.

Russia Federation regions	F_1	F_2	F_3	F_4	F_5	F_6
Altaisky Krai	0.600	0.081	0.157	0.671	0.033	0.970
Zabaykalsky Krai	0.167	0.101	0.268	0.646	0.106	0.675
Irkutskaya Oblast	0.524	0.312	0.159	0.510	0.114	0.678
Kemerovskaya Oblast	0.500	0.167	0.119	0.616	0.194	0.627
Krasnoyarsky Krai	0.433	0.330	0.286	0.567	0.121	0.717
Novosibirskaya Oblast	0.521	0.122	0.184	0.651	0.040	0.722
Omskaya Oblast	0.524	0.112	0.214	0.647	0.077	0.470
Republic of Altai	0.833	0.059	0.153	0.666	0.506	0.565
Republic of Buryatia	0.500	0.048	0.357	0.649	0.028	0.641
Republic of Tuva	0.000	0.022	0.236	0.648	0.033	0.662
Republic of Khakassia	0.333	0.106	0.309	0.627	0.081	0.776
Tomskaya Oblast	0.630	0.182	0.171	0.645	0.075	0.610
Kurganskaya Oblast	0.333	0.041	0.218	0.631	0.096	0.586
Sverdlovskaya Oblast	0.577	0.264	0.190	0.713	0.259	0.634
Tyumenskaya Oblast	0.550	0.976	0.268	0.615	0.302	0.615
Chelyabinskaya Oblast	0.602	0.206	0.157	0.651	0.275	0.636
Amurskaya Oblast	0.445	0.115	0.299	0.596	0.106	0.657
The Jewish Autonomous Region	0.167	0.123	0.244	0.612	0.020	0.419
Kamchatsky Krai	0.500	0.112	0.191	0.597	0.011	0.508
Magadanskaya Oblast	0.583	0.289	0.163	0.585	0.315	0.646
Primorsky Krai	0.436	0.129	0.217	0.597	0.107	0.620
Republic Sakha (Yakutia)	0.375	0.200	0.276	0.606	0.162	0.659
Khabarovsky Krai	0.500	0.182	0.217	0.566	0.113	0.641
Chukotka Autonomous Okrug	0.000	0.034	0.284	0.592	0.352	0.754

These indicators enable to study the environmental situation in a region, to identify problems. So, it is obvious from Table 4 that the level of consumption of water resources (F_5), the level of transport and construction state (F_2) and the level of production state (F_3) in the Russian regions have low values, it shows the lack of development of these spheres. The level of anthropogenic safety (F_4) is characterized by high values due to the creation of additional capacity for trapping air pollutants.

The results of the calculations for each integral indicator were used to develop the program of activities for the management of environmental safety at the level of subjects of the Russian Federation to ensure the sustainability of their development.

On the basis of the calculated integral estimates (F_1, F_2, F_3, F_4, F_5, F_6) for 2013 the regression model was made. The growth rate of GRP per capita in 2013 (*Y*) was used as an indicator of the level of sustainable development. It shows the change in the result of economic activities of business entities of a territory.

The linear regression Equation (1):

$$Y = 0.105 + 0.08F_1 - 0.56F_2 + 0.07F_3 + 0.09F_4 - 0.11F_5 - 0.02F_6 \qquad (1)$$

The findings led to the following conclusions:

- The level of transport and construction state (F_2) has a negative influence on the formation of the resulting indicator - it indicates that the use of environmental technologies in this field is still underdeveloped;
- The level of consumption of water resources (F_5) also has a negative influence on the formation of the resulting indicator - it testifies that the application and implementation of the technologies of recycling and reusing of water supply in the Russian Federation remains underdeveloped.

The influence of other factors on the growth rate of GRP per capita has a negligible effect. It should be noted that such indicators as the level of ecological properties of production in a region (F_1), the level of production state (F_3) and the level of anthropogenic safety (F_4) have a positive influence on the formation of the resulting indicator. This means that the development of industrial production still creates a further opportunity for trapping air pollutants and for using of environmentally friendly technologies in production processes.

Also we consider it appropriate to classify the regions of the Russian Federation by the level of environmental safety through the use of the original data set. For the classification of regions cluster analysis and typological grouping for determination stable groups were used. This classification identifies environmentally unsafe and safe territories. The rating of regions according to environmental safety level is necessary as it enables to develop complex management programs of environmental safety factors. The method of typological groups with an artificial division into three classes gave the most accurate classification of regions. The results of determination of groups by the level of environmental safety are presented in Table 5.

It was revealed on the basis this research. Only one third of all regions has a level of environmental safety above medium. These include regions such as Moscow, St. Petersburg, Republic of Tatarstan, Krasnoyarsky Krai and others.

Table 5. The classification of regions of the Russian Federation by the level of environmental safety for 2013.

Interval value	Type	Russian Federation regions
0.000-0.333	Low (unsafe)	Jewish Autonomous Region, Zabaykalsky Krai, Republic of Karachay-Cherkess, Kurganskaya Oblast, Orenburgskaya Oblast, Pskovskaya Oblast, Republic of Ingushetia, Republic of Kalmykia, Republic of Tuva, Republic of Khakassia, Chechen Republic, Chukotka Autonomous Okrug.
0.000-0.667	Medium (turbulent)	Altaisky Krai, Amurskaya Oblast, Astrakhanskaya Oblast, Bryanskaya Oblast, Vladimirskaya Oblast, Volgogradskaya Oblast, Voronezhskaya Oblast, Ivanovskaya Oblast, Kabardino-Balkar Republic, Kaliningradskaya Oblast, Kaluzskaya Oblast, Kamchatskaya Oblast, Kirovskaya Oblast, Kostromskaya Oblast, Lipetskaya Oblast, Murmanskaya Oblast, Nizhegorodskaya Oblast, Novgorodskaya Oblast, Novosibirskaya Oblast, Omskaya Oblast, Orlovskaya Oblast, Penzenskaya Oblast, Permsky Krai, Primorsky Krai, Republic of Adygea, Republic of Buryatia, Republic of Dagestan, Republic of Karelia, Mari El Republic, Republic of Mordovia, Republic of North Ossetia - Alania, Ryazanskaya Oblast, Stavropolsky Krai, Tambovskaya Oblast, Tomskaya Oblast, Tulskaya Oblast, Republic of Udmurtia, Ulyanovskaya Oblast, Khabarovsky Krai, Republic of Chuvashia, Yaroslavskaya Oblast
0.667-1.000	High (safe)	Arkhangelskaya Oblast, Belgorodskaya Oblast, Vologodskaya Oblast, Irkutskaya Oblast, Kemerovskaya Oblast, Krasnodarsky Krai, Krasnoyarsky Krai, Kurskaya Oblast, Leningradskaya Oblast, Magadanskaya Oblast, Moscow, Moscowskaya Oblast, Republic of Altai, Republic of Bashkortostan, Komi Republic, Republic of Sakha (Yakutia), Republic of Tatarstan, Rostovskaya Oblast, Samarskaya Oblast, St. Petersburg, Saratovskaya Oblast, Sakhalinskaya Oblast, Sverdlovskaya Oblast, Smolenskaya Oblast, Tverskaya Oblast, Tyumenskaya Oblast, Chelyabinskaya Oblast

The main part of the region was attributed to the group with a medium (turbulent) level of environmental safety. These are regions, such as Altaisky Krai, Novosibirskaya Oblast, Omskaya Oblast, Kaluzskaya Oblast, Kirovskaya Oblast, Kostromskaya Oblast, Lipetskaya Oblast etc. And only 12 regions out of 80 have a low level of environmental safety.

5. Conclusion

To sum up, the developed method of environmental safety assessment will be adapted for the study of social and economic systems of different levels of management on the level of environmental safety in the Russian Federation. It will enable to distinguish stable groups by the level of environmental safety in the context of management levels and to develop effective management decisions aimed at improving the level of environmental safety. In addition, this technique of studying the territorial units by the level of environmental safety can be used in other regions of the world, taking their specific features and information basis of the study into account. It will provide an opportunity for international comparisons and the formation of complex development programs and strategies in the field of environmental safety. These measures will help to improve the sustainable development of countries since the solution of environmental problems is beneficial to the economic and social development: the use of clean technologies in the production helps to reduce anthropogenic pressure on the environment and a stable ecological situation helps to reduce social tension in the society. The study can be used to form complex programs of measures for the management of environmental safety as well as to make effective management decisions in the field of sustainable development of the Russian Federation regions.

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