INTEGRAL ASSESSMENT OF ENVIRONMENTAL QUALITY AND THE QUALITY OF LIFE OF THE POPULATION OF THE ARCTIC REGIONS OF RUSSIA IN THE PERIOD FROM 2003 TO 2015

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Abstract: *The integral assessment of environmental quality and quality of life of the population of 9 regions of the Arctic zone of the Russian Federation in the period from 2003 to 2015 is considered. To build integrated indicators, we used: summary indicators, randomized summary indicators, and "ASPID methodology" (analysis and synthesis of indicators in the information deficit). When calculating weights, incomplete, inaccurate, non-numeric information was taken into account) about the criteria and priorities of the evaluation. To assess the quality of the environment, 8 parameters were used. To assess the quality of life of the population, the state of three subsystems was taken into account: ecological (8 parameters), economic (5 parameters), social (5 parameters). The choice of criteria was made taking into account the information available on the website of the Federal Service of State Statistics of the Russian Federation, in the collections "Regions of Russia" and in state reports "On the state of the environment ..." To assess the quality of the environment in the regions and the quality of life of the population of the regions, five quality classes were introduced (I - high, II - above average, III - average, IV - below average, V - low). In constructing integral indicators, the sum of the normalized values of the indicators within subsystems (blocks) and between them was used as a synthesizing function, taking into account the equilibrium or nonequilibrium setting of priorities. When assessing the quality of the environment, all regions fall into the third class (middle - the right border of the class) with a slight temporal change. In evaluating the quality of life, three groups of regions were identified. In the first group, the quality of life for the period under review improved by 10 percent or more. The second group includes regions with an improvement in the quality of life by 5-10%, the third group includes regions with an improvement in the quality of life up to 5%. For the same time interval, the quality of life of the APR regions was compared with the regions of Central Russia (Tver Region). The forecast scenarios of a possible change in the quality of the environment and the quality of life of the population in the regions are considered. The studies were carried out with the support of the RFBR grant No. 16-05-00715-a.*

Keywords: INTEGRATED ASSESSMENT, QUALITY OF ENVIRONMENT, QUALITY OF LIFE, ARCTIC REGIONS

1. Introduction

The relevancy of the work is accounted for by the necessity to develop the theory and practice of the evaluation of the state of complex systems in nature and society, their non-additive (emergent) properties, and the system simulation of natural and social transformation of eco-, geo-, and socio-systems. The recent recommendations in the sphere of global, regional, economic, and social development are specified in the works of the commission of Stiglitz – Sen – Fitoussi (see www.stiglitz-sen-fitoussi.fr) [1]. The Commission is more known as the Stiglitz Commission, was set up in February 2008 at the initiative of the President of the French Republic under the guidance of the Nobel prize winner in economics Joseph Stiglitz, with participation of the Nobel prize winner Amartya Sen. The commission was authorized to identify the suitability of using the existing national indicators of development and progress, including such indicator as gross domestic product (GDP). It was necessary to validate the economic development and social progress parameters, to study what additional information could be required to form a more adequate picture, to discuss how to present this information correctly, and to check the feasibility of the suggested tools of measurement. The Commission submitted its first report on 14 September 2009 and called upon national statistics authorities under the aegis of international ones to focus their efforts on the development of new indicators of social progress for more adequate assessment of quality of people's life in countries and regions. To arrange its activities, the Commission was broken into three working groups which studied respectively the traditional GDP evaluation issues, life quality and sustainability issues. The working groups submitted recommendations for each of these spheres [1], which have come to be known as 12 recommendations for the fundamental amendment of the state statistics basics in France and the entire world.

The main conclusions of the report E/CN.3/2011/1 of the UN National Institute of Statistics and Economic Studies in 2011 (section B. Basic conclusions of the report) state that "well-being includes both economic resources such as income, and non-economic aspects of people's life (what they do and what they can do, how they feel, in what natural environment they live)". The sustainability of these levels of well-being depends on our ability to pass on to future generations the accumulated assets which are significant for our life (natural, physical, human, social). Therefore it is important to discriminate between evaluation of the current well-being and evaluation of its sustainability in time" [1, p.2].

It is in this connection that the resolutions can be mentioned which were passed by the UN General Assembly on 25 September 2015 "Transforming our world: Agenda of sustainable development for the period until 2030" and "Report of the interdepartmental group of experts for indicators of objective fulfillment in the sphere of sustainable development" at the UN forty-seventh session 8-11 March 2016 [2,3].

The specific feature of the modern stage is not only the validation of the representative criteria or groups of criteria for the evaluation of the state of natural and socio-ecological-economic systems, but also the development of models of analysis and synthesis of indicators taking into account the use of incomplete, inaccurate, non-numerical information on the evaluation criteria and priorities [4].

The article discusses evaluation of the state of socio-ecological-economic systems (SEES) and quality of life of people of the RF regions. The state of SEES is believed to be the characteristic of the system at a certain moment of time. The focus is on the comparative evaluation of the quality of life in the regions of the Arctic zone of the RF (AZR) from 2003 to 2015.

The key point of our publications on the integral evaluation of the state of eco-, geo-, socio-systems and their emergent properties [6-10] is the following conclusion: in the multi-criteria evaluation of the state of the systems with an indicator approach the incomparability of the obtained assessments is revealed when according to one criterion (indicator) or a group of criteria the system is referred to one class, and according to another (others) it is referred to another (other) class (-es). Thus, with the indicator evaluations of SEES states uncertainties arise in the treatment of the obtained results. The authors have to write on what number of criteria a system can be referred to each of the classes, and more frequently, without introducing classes, the results are just ranked for each of the indicators, determining the place of SEES in question in the list of similar national or regional systems. In the same way the SEES state is evaluated by each of the indicators recommended by them or national statistics authorities. The indicators are not generalized, and if they are, it is on the additive (grade) basis, without taking into account the priority of indicators or their trustworthiness. Then, it is often noted that the objective information of national statistics authorities is unsuitable for evaluation, because it does not contain a number of indicators already tested abroad or recommended recently. At that, the indicators taking into account the perception by people of their position in society, i.e. subjective indicators, are often used as the basic ones. We noted that in order to take such indicators into account, it is logical to use non-numerical (ordinal), inaccurate (interval), incomplete information (so-called *nnn-information*) which is necessary to take into account both for specifying the indicators and for determining the evaluation priorities. It was recommended to use multi-criteria and multi-level evaluation accounting for simulation of evaluation priorities inside levels (subsystems) and between them on the basis of "nnn-information". The levels can include groups of criteria based on the data of national statistics authorities, as well as subjective data obtained in the statistical polls of the people. The following is recommended as the methods: a method of consolidated indicators (MCI), a method of randomized consolidated indicators (MRCI) and its modern version named by the author "ASPID methodology", the methodology of analysis and synthesis of indicators in the information deficit [4]. In all cases a possible change in the priorities for evaluation inside the groups and between them is taken into account.

2. Experimental procedure

The modern foreign level of research is characterized by the developed methods of analysis of target indicators used to characterize the state of complex systems (mostly economic or socio-systems and their subsystems) and, to a less degree, their emergent properties. The present time is characterized by accumulation of methodological and practical experience in the research of the state of complex systems in nature and society and their separate subsystems. The method of making up a "web diagram" ("rose diagram" in Russian publications) is often used which units in a single picture the information on a great number of indicators [5]. As a result, there is an analog of the natural Hutchinson niche or socio-ecological-economic niche visually characterizing the aggregate of the conditions of existence of the system. In case of transformation system its visual image, a niche, is also transformed and its GIS-image reflects the result of impact on the system (its area (volume) is changed, the system acquires a new, predominant vector of development which is revealed and visualized graphically).

The other approach [5] uses the method of building a composite indicator that is a union of the aggregate of the used parameters into a single composite indicator (composite sustainability indicator - CSI) in which the parameters are taken into account with their weights reflecting the priority of each of them (Fig.1).

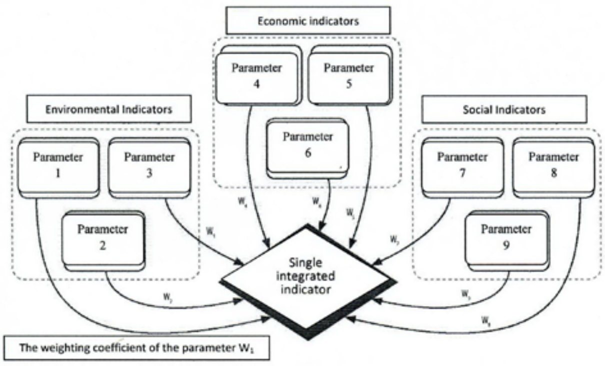


Fig.1 *The structure of the integrated stability indicator (by Noam Lior, 2015)*

Thus, the building of an integral indicator is implemented at one level of convolution of indicators as a sum or product of the characteristics taken with their weights. At that, the author does not consider peripheral issues of the rating of indicators taking into account the type of connection and its non-linearity; simulation of priorities (weighting factors) of the characteristics; creation of the effect of hierarchy on account of introduction of multi-level convolutions; investigation with the use of integral indicators of emergent properties of the systems (stability, well-being etc.).

In our case the building of classification models containing several levels of investigation and convolutions of indicators (Fig.2) is implemented. This figure represents one of the models that we used to evaluate the quality of life in the RF regions [6,7]. These works and Fig.2 give the units, the parameters of each unit and the results of evaluation of the quality of the environment and the quality of life of people of the arctic regions of the Russian Federation. All indicators were sampled from the data of the Rosstat website ("Regions of Russia" collections) for the period from 2003 to 2015. The basic objective of the investigations was to perform a convolution of indicators at the first and second levels and the identification of the situations in which SEES cannot retain its properties and mode parameters with a certain hypothetic influence on it in separate subsystems and the system as a whole [6].

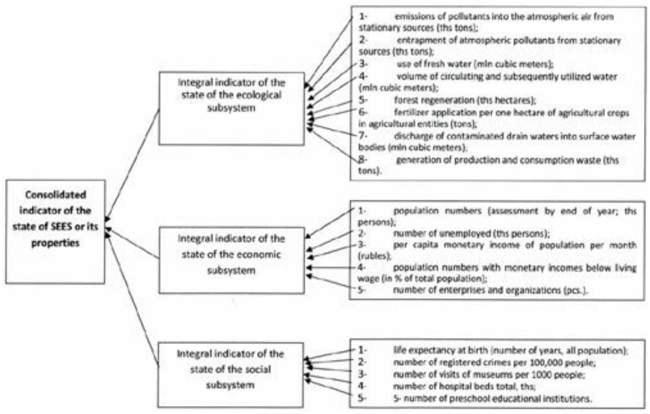


Fig. 2 *Building a model for integral assessment of the SEES state, quality of the environment, and quality of life of the region's population[6].*

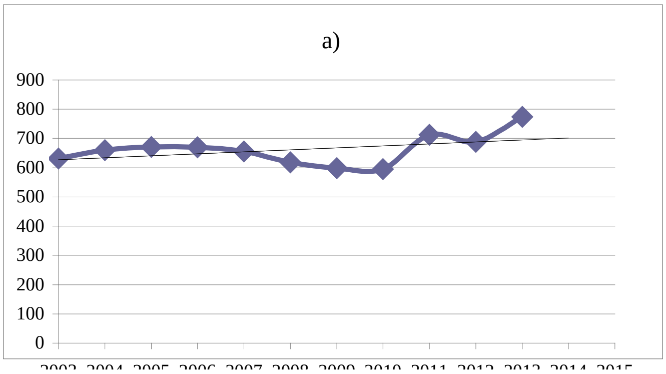
The integral indicator Q_i was constructed so that it depended not only on the rated values of the initial characteristics q_i, but also on their priorities determined by the weights p_i, the sum of which should equal 1.0 ($0 \leq p_i \leq 1$). As an expression for the integral indicator, the linear convolution was used in the form of: $Q_i = \sum_{i=1}^{n} q_i \, p_i$, n is the number of the evaluation criteria. The state of the system and the quality of life of people of the region were evaluated for 5 classes (I – high; II – above average; III – average; IV – below average; V - low). The proximity of the integral indicator to 0.0 evidenced high quality of life of people, the proximity to 1-0 evidenced low quality.

In [6,7] we investigated a change in the quality of life in 9 regions of the arctic zone of the Russian Federation (AZR) for 10-12 years, and the results of the experiments in a hypothetic change of the situations in each of the units and in all units simultaneously were described. As a result, the integral indicators of the quality of life of people for 8 scenarios for the first (inside the subsystems) and the second (between the subsystems) levels of the convolution of the indicators was calculated. The results of the evaluation of the quality of the environment and the quality of life were compared for 2003 and 2013. In these models the liner rating functions were used in the rating of the indicators with the equal weight of the evaluation parameters inside the three subsystems (ecological, economic, social) and between them. In the experiments with loads the results of the options with 30% and two-time deterioration of the situation inside and between the units against the background of 2013 were described.

In general, the subsystem of social conditions was found to be the most sensitive subsystem. The maximum increase in the effect of impact of both on separate subsystems and on the socio-ecological-economic system as a whole (summary evaluation). With low negative changes the ecological and economic parameters provided roughly the same change both at the first level of the convolution and on the second one. It was also noted that after 30% deterioration of the situation the summary evaluation was mostly affected by the economic factors.

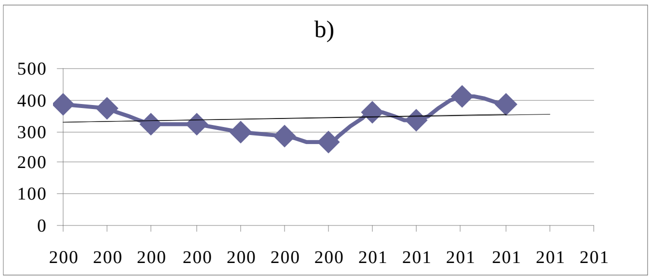
3. Results and discussion

In [7] the main drawback of the experiments with a hypothetical change in the situations in the regions was noted. It consisted in the fact that under real conditions it is not logical to expect a simultaneous change in the load by 30%, 50%, two times, etc. inside one of the units or in all the subsystems simultaneously. Each parameter chosen as a representative criterion will have its rates and direction of the changes. The situation is complicated by the different rates and direction of such changes that may be noted in different regions. Therefore, in the next stage of the investigations it was necessary to study the temporal change of each of 18 criteria and obtain the trends of these changes for the regions. Fig.3 (a,b,c,d) shows the examples of such changes for four parameters of the environmental quality subsystem (ecological unit) for the Republic of Komi for 2003-2013.

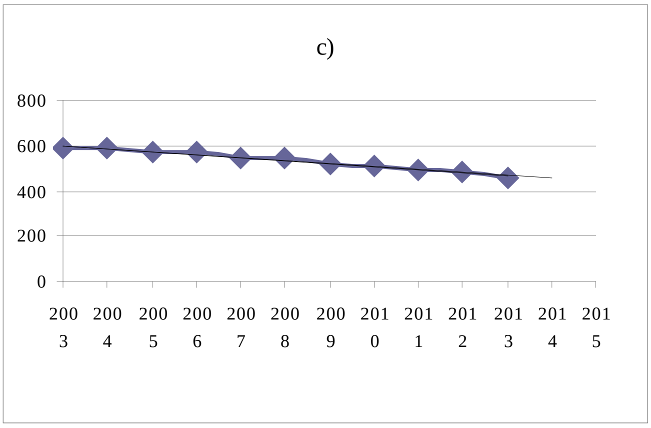


a) Contaminants emitted into atmosphere from stationary sources (ths tons/year)

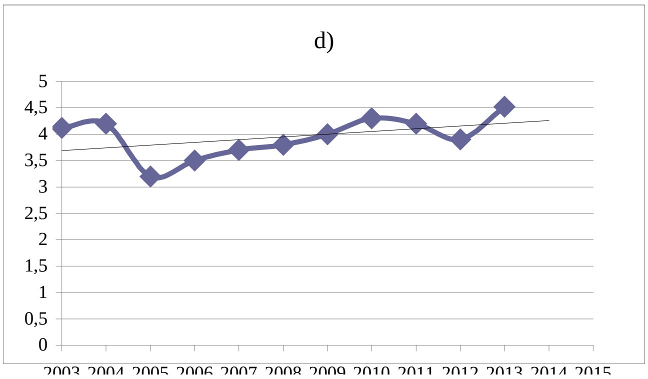
Fig.3 *Tendency of changes in certain parameters of the evaluation of the quality of the environment for the Republic of Komi for 2003-2013.*



b) Entrapment of atmospheric contaminants emitted by stationary sources (ths tons/year)



c) Use of fresh water (million cubic meters)



d) Fertilizer application per one hectare of sowed crops in agricultural crops in agricultural entities (tons)

Analysis of the trends of change of separate characteristics, as was expected, showed that the rates and the direction of their change are different. Thus, for the ecological unit for the region of the Republic of Komi for 5 parameters out of 8 in 2014 a decrease in the indicators in percent compared to 2013 (indicator No. is given in Fig.2) was expected by: 1-9,5; 2-8,3; 4-0,5; 5-5,5; 6-6,0. For the rest of the parameters an increase in the indicators compared to 2013 was obtained by: 3-3,1; 7-1,9; 8-54,9. Thus, the maximum increase in respect of 2013 is noted for parameter No.8, generation of production and consumption waste, by 54.9%, the minimum decrease is noted for parameter No.4, the volume of the recycled and successively utilized water, by 0.5%.

The forecast change of the integral indicator of the ecological unit for 2014 with the quality of the weights yielded the value of the integral indicator Q_1=0,49, which allowed the quality of the environment to be referred to quality class III with the width of the class interval 0.37-0.56. The statistical reporting data (Rosstat website, “Regions of Russia” collections) for 2014 and 2015 confirmed the forecast calculations of the integral indicators for these years. The integral indicators of the quality of life of people in the AZR regions for the period from 2003 to 2015 (the second level of the convolution of the indicators) are given in Table 1. The scale of an integral indicator of the second level of convolution for equal priorities at the first and second levels: I – high (0-0.16); II – above average (0.16-0.36); III – average (0.36-0.56); IV – below average (0.56-0.79); V – low (0.79-1).

As a result, we note that in 8 regions there is a tendency for improvement of the quality of life of people. In Murmask region, the Republic of Komi, Khanty-Mansiysk Autonomous Okrug Yugra, Republic of Sakha (Yakutia) there is an improvement of the quality of life of people by 7-10%. In Arkhangelsk region, Nenets Autonomous Okrug, Chukotka Autonomous Okrug, Yamalo-Nenets Autonomous Okrug the improvement of the quality of life of people is by 10-12%. The unchanged is the quality of life in Taymyr Dolgano Nenets Autonomous Okrug in the period from 2003 to 2005 (Table 1).

To compare the quality of life of the Arctic regions of the RF with the regions of the central part of the Russian Federation, the quality of life of people in Tver region for 2003 and 2013 was examined. By the value of the integral indicator the quality of life of people in Tver region from 2003 (0.64) to 2013 (0.57) was improved by 11%. This indicates the close rates of changes in the quality of life in the regions being compared.

Table 1: Integral indicators of quality of life of people in the regions of the arctic zone of the RF for the period from 2003 to 2015 (the second level of the convolution of indicators).

Region / Year	2003	2005	2010	2013	2015
Arkhangelsk region	0,65 (IV)	0,64 (IV)	0,61 (IV)	0,58 (III - IV)	0,57 (III - IV)
Murmansk region	0,65 (IV)	0,65 (IV)	0,61 (IV)	0,58 (III - IV)	0,60 (IV)
Nenets Autonomous Okrug	0,66 (IV)	0,62 (IV)	0,59 (IV)	0,63 (IV)	0,55 (III)
Taymyr Dolgano Nenets Autonomous Okrug	0,66 (IV)	0,66 (IV)	-	-	-
Chukotka Autonomous Okrug	0,63 (IV)	0,61 (IV)	0,60 (IV)	0,57 (III - IV)	0,55 (III)
Republic of Sakha (Yakutia)	0,62 (IV)	0,61 (IV)	0,59 (IV)	0,55 (III)	0,56 (III - IV)
Yamalo-Nenets Autonomous Okrug	0,63 (IV)	0,65 (IV)	0,60 (IV)	0,57 (III - IV)	0,55 (III)
Republic of Komi	0,67 (IV)	0,67 (IV)	0,62 (IV)	0,60 (IV)	0,61 (IV)
Khanty-Mansiysk Autonomous Okrug Yugra	0,60 (IV)	0,64 (IV)	0,60 (IV)	0,54 (III)	0,55 (III)

Note. 1. The table gives the value of integral indicator; in brackets the class of quality of life; 2 – for Taymyr (Dolgano-Nenets Autonomous Okrug) the data prior to 2005 are given, for by the results of the referendum held on 17 April 2005, from 1 January 2007 Taymyr (Dolgano-Nenets) Autonomous Okrug was abolished, and the municipal Taymyr Dolgano-Nenets Autonomous region was made part of Krasnoyarsk Territory as an administrative-territorial unit with a special status.

4. Conclusions

To conclude, we will note the advantages of using the examined approach for evaluation of integrative properties of complex natural and social systems and the quality of life of people. When building classification models, the investigator introduces the classes of states of the systems and the quality of life; uses the axiological approach and axiometry (ecological qualimetry), validates the type of an integral indicator, solves the problem of rating initial data taking into account the type of communication (direct, reverse) and its non-linearity, takes into account *nnn*-information on evaluation priorities; works with evaluation scales of the necessary and sufficient evaluation criteria, though may also use qualitative scales for evaluation; can introduce several levels of convolution of indicators, specifies or simulates weights (priorities) of evaluation inside groups, subsystems (levels) between them and can change them when necessary.

The use of models in GIS environment allows territories to be divided or zoned by values of integral indicators; the temporal dynamics and spatial differences of integral indicators to be traced, a conclusion on the ability of the systems to safeguard or change the class of state (quality) in time to be drawn. The flexibility of the model algorithms allows a hierarchical system of multi-level evaluation of the state of systems when there is an uncertainty at each level of hierarchy to be organized, and the mapping of integral indicators, division and zoning of territories on this base determines new capacities of the evaluation of states of regions and quality of life of their population.

5. Acknowledgements

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