Geographic information modeling of Econet of Northwestern Federal District territory on graph theory basis

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Abstract. Based on the landscape-geographical approach, a structural and logical scheme for the Northwestern Federal District Econet has been developed, which can be integrated into the federal and world ecological network in order to improve the environmental infrastructure of the region. The method of Northwestern Federal District Econet organization on the basis of graph theory by means of the Quantum GIS geographic information system is proposed as an effective mean of preserving and recreating the unique biodiversity of landscapes, regulation of the sphere of environmental protection.

1. Introduction

The issue of Russia's environmental safety is considered at the state level within the framework of various projects and programs. Coordination of Econet creation in the territory of the Russian Federation is carried out by the Department of Environmental Protection and Ecological Safety of the Ministry of Natural Resources of the Russian Federation [1]. One of the targets of the program «Environmental Protection» for 2012-2020 and the concept of development of the system of specially protected natural areas of federal significance for the period up to 2020 is an increase in the total area of territories occupied by specially protected natural areas (SPNA) at all levels. The implementation of nature protection measures will help to preserve and restore natural systems, including the number of populations of rare and endangered species of the animal and plant world of Russia.

In this case, the organization of the Econet system [2,3,4,5] or the ecological network becomes the most effective measure. The starting point for the creation and maintenance of Econet becomes the environmental project - the Pan-European Biological and Landscape Diversity Strategy (1995). However, so far, either at the legislative level or in normative and legal documents, such concepts are not formed and regulation does not occur. At the same time, the adoption «Strategic Plan for the Conservation and Sustainable Use of Biodiversity for 2011-2020» by the Russian Federation involves the creation of more coherent and sustainable Econet that protect the ecosystem in the interests of wildlife and people.

It is obvious that it is necessary to improve legal and methodological bases of functioning and development within the framework of SPNA, which will allow one on the state level to secure the Econet status and to offer integrated approaches to formation of Econet in order to preserve and recreate biodiversity of unique landscapes [6] when regulating land protection issues [7].

As part of the study, a methodology for organizing an Econet system in the Northwestern Federal District was proposed as a mean of regulating the sphere of environmental protection. The interest in this region of the country is associated with its high natural and climatic diversity, the uniqueness of natural places, including places unaffected by human activities. Despite the high level of study of Econet in the region [5,8,9,10], it should be noted that there is no unified methodological approach to the issue of its
formation. In addition, the similarity of the landscape and climatic features of the Russian Federation with border states: Finland, Norway, Poland, Estonia, Latvia, Lithuania, Belarus allows one to carry out joint researches with other countries within the Emerald Network [3, 11], Natura 2000 (Natura 2000) [12] and to develop the Pan-European Ecological Network (EECONET) [13].

2. Materials and methods

During conducted scientific researches, different variations of the Econet description have been established; however, they all have a similar structure (blocks): a system of protected territories (cores) that are connected by ecological corridors (landscape, fragmentary, linear) [14] and buffer zones.

The designed network is multilevel. The proposed hierarchical structure of the Northwestern Federal District Econet will make it possible to exclude the possibility to lose cores connections. The cores of the Northwestern Federal District are SPNAs of the federal level - nature reserves, sanctuary, national parks, etc. Among them, separate territories are formed, which are not connected with each other. Protected areas become nodal elements of the ecological network, preserving the most valuable and vulnerable habitats of living organisms. Using the software product Quantum GIS (QGIS), the built-in QGIS geographic processing module and the open data presented in Table 1, a cartographic basis was prepared - a landscape map with Northwestern Federal District SPNAs of different ranks and a layer called «SPNAs polygon centroids» was created.

| Data                      | Resource                        | Format          |
|---------------------------|---------------------------------|-----------------|
| Administrative boundaries | Gis-Lab. OSM                    | Shape-files     |
| Settlements               | CEO Water Mandate               | Shape-files     |
| River systems             | Greenpeace                      | Shape-files     |
| Pools of rivers           | The Federal Agency for Subsoil Use | WMS/WMT(S)     |
| Old-growth forest areas   | Russian reserves                | Shape-files     |
| Physical map              |                                 |                 |

The polygon centroid here is the SPNA (core) located in the central part of cores concentration within a homogeneous landscape or a conditionally chosen core (not SPNA) by the search method of mathematical approximations. To find the values of core coordinates, a macro was written in the Visual Basic for the Application programming language (VBA) is embedded in the Microsoft Office product line [15], which solved the optimization problem - the minimum of the objective function was found - the mean square error (RMSE) of the position of the center of the cloud of polygon points. To set the initial value of the center, the initial, assumed position of the cores along the X and Y axes was set. The coordinate values sequentially changed by a step size of 10 times: from 100 m to 1 mm. The number of iterations is specified in the study. Thus, 9 groups of SPNAs were formed using automated means of geographic information technologies on the basis of the structural-landscape approach [16, 17] (Fig. 1).
Figure 1. Structural-landscape approach to formation of SPNA nuclei

Mathematical centers (conditional projected SPNAs) of the 1st level group were in turn cores of the 2nd Econet level, where groups of SPNA of different landscapes were already linked. To provide more coherent «connectivity» of SPNA’s cores at the 2nd level, the hydrological approach is considered. Large waterways are integral geosystems. The complex hydrological network of the Northwestern Federal District contains information on thousands of small rivers, swamps, lakes based on the data of Table 1. The whole network is forming a «bone skeleton», which allows one to analyze water objects in general terms; water objects include river systems and their basins, which are «a special spatial unit of the biosphere» [18] and the most promising in a multidimensional study of nature for environmental management [19].

Communication between groups of the 2nd Level is carried out linearly - by riverbeds or fragmentarily - taking into account the boundaries of lakes, swamps, and old-growth forests, preservation and reconstruction of which is one of the main activities of Greenpeace Russia [20]. Thus, at this development stage, while creating environmental corridors (EK), both the hydrological and forest-typical approaches are used.

To establish buffer zones (BZ), it is important to take into account the regulatory legal acts which regulate regional documents when allocating restricted use areas (RUA), Source Water protection and other protected zones [21].

While designing a Buffer Zone for Northwestern District SPNA, the results of the studies by Alekseenko N.A. were taken as a basis [22], taking into account the categorical principle, depending on the protection strictness of the territory. The size of the protected zone is determined by the value of the severity factor (Table 2).

Table 2. Coefficients of strictness of the territorial security regime

| Rank  | Nature reserves | Natural park | Zakazniks |
|-------|-----------------|--------------|-----------|
| Federal | 3.0            | 1.5          | 0.9       |
| Regional | 2.0            | 1.0          | 0.6       |
| Local   | 1.0            | 0.5          | 0.3       |

In this article, only SPNAs of federal significance are considered and appropriate coefficients are used. The average protection zone for each section is usually about 1000 m. Applying coefficient of rigor, the authors get the following width of BZ: for nature reserves - 3000 m, natural parks - 1500 m, sanctuaries - 900 m. During a ban on hunting, buffer zones are set from 500 m to 1000 m, which allows one to
preserve and maintain bio-growth. When designing the minimum size of the BZ was applied. All objects for which BZ can be defined are atypical and should be considered individually. The creation question of BZ requires further scientific development and is not exhaustive in this article. Depending on the design scaling, not only external, but also internal BZs can be organized; for example, on the ML territory there is an object of historical heritage.

3. Quality control of modeled Northwestern Federal District Econet

Biodiversity is directly dependent on the number of cores and corridors that form Econet. The projected Econet includes 8 cores and 17 ecological corridors. It is possible to rate structure elements of Econet by calculating the indexes of graphic connectivity proposed by Bednova O.V. [23]. The system of index indicators alpha (α), beta (β) and gamma (γ) as well as the graph deficit index (ε) is used. After calculations, the projected Econet is characterized as capable of performing migration functions; therefore, it is functional and significant in the aspect of solving an environmental problem (Table 3).

![Table 3. Quality indicators of the Econet](image)

According to the data given in Table 3, it is obvious that the projected Econet of the Northwestern Federal District is effective (according to the α-index), has a good degree of network development (α-index) and a sufficient number of ecological corridors (β-index). The graph deficit index - ε-index is usually used if there are isolated cores. In this case, there are no such cores in the projected network and the deficit indicator is the evidence. It should be noted that considered indicators are based on the evaluation of the connectivity of the Econet graph and are topological, which means that they do not take into account its metric features.

4. Conclusion

On the basis of landscape-geographical approaches, main priority areas for SPNA organization have been identified. Furthermore, the structural and logical scheme of the Northwestern Federal District Econet, which can be integrated into the federal and world ecological network, has been developed (Fig. 2). The methodology of Econet modeling in the territory of the Northwestern Federal District is proposed. Based on the results of the study, a number of main conclusions should be drawn:

1. The existing need to expand recreational areas is related to the solution of the problem of preserving the biological diversity. The most beneficial in this situation becomes the creation of an Econet scheme. It is characteristic that the limelight is shifted from the drawing up of a simple SPNA scheme to the formation of complex spatial systems for the reproduction of the natural environment.

2. The main priority areas for the organization of Econet are identified on the basis of landscape-geographical approaches after the initial map data for the Northwestern Federal District territory selection. Such areas include lakes, swamps, riverbeds and river valleys, as well as old-growth forest areas. Preservation of wild forests and maintenance of a sufficient conservation status of water objects generally increases the effectiveness of the ecological system. However, the lack of regulation at the state level complicates the process of Econet creation.
3. Having analyzed the regulatory and methodological support of the issue on the topic of this research, one can speak about the existence of the initial basis for the development. All researchers' actions in this area are regulated only at the local or regional level. In order to attract public attention to Russian environmental development issues, 2017 was declared as the Year of Ecology and the Year of SPNA, biodiversity conservation and ensuring environmental safety within priority areas and Federal Programs.

4. The considered integrated approach to Econet formation will allow preserving and recreating the unique biodiversity of landscapes, to regulate the issue of land protection, which will allow improving the environmental infrastructure of the region (Northwestern Federal District).

![Figure 2. Structural-logical scheme of Northwestern Federal District Econet](image)

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References
[1] Sobolev N A 2008 Pan-European and sub-regional mechanisms for the nature territorial protection and possibility of their use in Russia. Information and analytical materials on the state of conservation of plants, animals and their habitats in Western Europe and Russia Moscow 16-25
[2] Bykova A A 2016 On the formation of the ecological network in Russia. Problems of geology and mining: researches of the XX International Symposium named after M.A. Usov 1 734-735
[3] The Working Group on Environmental Network in Northern Eurasia 2000 Inform. Materials on ecological networks Moscow 4-5 31
[4] Bennett G 1993; Sobolev N A, Shivarts E A, Kreindlin M L, Mokievsky V O, Zubakin V A 1995; Georgia 1997; Prerequisites and prospects of formation of an ecological network in Northern Eurasia, 1998; Aranbayev A M and Kamakhina G L 1999; Bennett G and Pirot J-Y 1999; Biodiversity of Armenia 1999; Melnik 1999; Opstal A J F M Van, 1999

[5] Prigoryanu O M 2004 Biogeographical basis of the ecological network of the Oryol region (Moscow)

[6] Pan-European Strategy for Biological and Landscape Diversity Nature and Environment 74 66

[7] Dale V H, Brown S, Hauber R A, Hobbs N T, Huntly N, Naiman R J, Valone T J 2000 Ecological principles and guidelines for managing the use of land Ecological Applications 10 639-670

[8] Konstiv K V 2011 Formation of a transboundary Econetwork on the territory of the Põlva and Võru counties of Estonia and the Pechora region of the Pskov region Pskov regional magazine 11 84-92

[9] Green Belt of Fennoscandia: state and development prospects Researches of the Karelian Research Center of the Russian Academy of Sciences (2009) 2 3-11

[10] Preservation of valuable natural territories of the Northwestern Russia. Analysis of the representativeness of the SPNA network in Arkhangelsk, Vologda, Leningrad and Murmansk regions, the Republic of Karelia, St. Petersburg Monography Authors under the editorship of Kobyakov K N (2011) 508

[11] Convention on the Conservation of European Wildlife and Natural Habitats 1979 Bern

[12] Natura 2000 Access mode: http://ec.europa.eu/environment/nature/natura2000/index_en.htm

[13] European Ecological Network. Access mode: http://www.ecnc.org/projects/green-infrastructure/indicative-map-for-the-pan-european-ecological-network-in-south-eastern-europe/

[14] Bennett G, Mulongoy K J 2006 Review of Experience with Ecological Networks, Corridors and Buffer Zones Secretariat of the Convention on Biological Diversity 23 100

[15] Walkenbach D Excel 2010 Professional VBA Programming : Trans. from engl. 2012 161-162

[16] Creation of SPNA Access mode: http://www.greenpeace.org/russia/ru/campaigns/forests/valuable-natural-objects/nature-reserve/creation/

[17] Khoroshev A V 2007 Landscape approach to the formation of ecological networks of the Kostroma region Environmental Planning and Management 4-5 19-29

[18] Sobolev N A 2007 The scheme for the formation of the ecological carcass of the Kursk region Explanatory note

[19] Niu X, Wang B, Wei W J 2013 Chinese forest ecosystem research network: A platform for observing and studying sustainable forestry Journal of Food, Agriculture and Environment 2 1008-1016

[20] Sobolev N A 2017 Problems of restoration and maintenance of a natural carcass in a steppe and forest-steppe zone Electronic journal BioDat. Access mode: http://biodat.ru/doc/lib/agro04.htm

[21] Koshim A G, Sergeyeva A M, Abdullina A G, Galimov M A 2014 The contemporary condition of specially protected natural reservations in Aktobe Region of the republic of Kazakhstan Life Science Journal 5 285-288

[22] Alekseenko N A 2015 Analysis of the representativeness of the network of SPNA in the Kamchatka Krai using the cartographic method of research Vestnik of the Far East Branch of the Russian Academy of Sciences 2 126-132

[23] Bednova O V 2013 The concept of a local ecological network in an urbanized area Lesnoy vestnik 6 131-142