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Spatial-temporal regularities of functioning of river basins on the territory of Belgorod region

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GENERAL DESCRIPTION OF WORK

Relevance of the research topic. Currently, when considering environmental issues de-gradation of more and more attention is paid to the transformation of river systems, which are, on the one hand, "re-serve base", and on the other, - receivers numerous types of pollution. Rivers of Life depends on processes occurring directly within their catchments. Intensive use of a nearby river to river basins economic complex directly or indirectly leads to the degradation of rivers. So, over the past 200 years in the territory of the Eu-ropean part of Russia-length hydrographical network decreased by 30-40% (Chendev, 2008). The origins of many rivers begin well below the position which they occupied in the 18th century.

Spatial features of formation water flow are a direct traction of spatial heterogeneity of land surface and the climatic conditions (Vinogradov, 2008). However, in modern hydrological situation greatly affected the history of economic use of the territory of the river basins and water resources. The solution of the exist-ing ecological and hydrological problems is impossible without taking into account the spatial and temporal patterns of the functioning of river basins.

Science-based assessment and modeling of river runoff is an important condition rd place in deter-mining the current and possible future changes in water resources and water regime of rivers, as well as identify patterns of changing.

The mechanism of self-healing environment where violation of its structure and function has not yet become irreversible is largely unclear (Nefedova, 1977; Dashkevich, 1984; Armand, 1988). This points to the need to assess the stability of geosystems to the effects of anthropogenic load. When you select geo-systems based on a river basin approach area is divided into the catchments of certain orders, each of which is regarded as an independent natural system that includes as elements catchment lower order.

The solution of complex problems of multifactorial assessment and forecasting of geosystems, spa-tial and temporal coordination of information about her, facilitates the use of GIS technologies and remote sensing, as well as the methods of mathematical modeling.

Purpose – to establish spatio-temporal patterns of functioning river basins of the Belgorod region to geo-ecological assessment of their resistance to the appearance of degradation processes.

The main objectives of the study.

1. To characterize changes in the length of the river and ravine network from the end of the 18th century before the beginning of the 20th century in a changing climate and natural and economic condi-tions.

2. Identify the current relationship between the structural organization of watercourses and the rate of change in the extent of the river and the fluvial network for two hundred years to be able to predict the development of these processes.

3. Develop a methodology for modeling and forecasting changes in river runoff in the changing climatic and geoecological conditions by using neuro-technologies.

4. To develop a new methodology to assess the silting of rivers on the basis of the analysis of the distribution of sediment runoff, in their basins and transporting capacity of watercourses.

5. Create a typology of sustainability of river basins to the manifestation of degradation processes on the basis of retrospective analysis of their functioning and the integral evaluation of the existing natural and economic situation.

6. Propose a set of environmental protection measures for the basins of 6th and 7th orders, based on the spatio-temporal patterns of their functioning.

Materials and methods of research.

Theoretical and methodological basis of the research is defined basin environmental management concept (R. Horton, M.I. Maccabees, AD Armand, F.N. Mielke, Yu Simonov, S.J. Sergin, S.I. Zotov , R.S. Chalov, L.M. Korytny, I.P. Kovalchuk, O. Ermolaev, V.M. Smoljaninov et al.), taking into account the basin landscape configuration (Y.G. Simonov, T.YU . Simon, R.S. Chalov, V.N. Votes, V.N. Bevz, M.D. Grodzinskiy et al.).

Methods of assessment of sediment runoff is represented in the works as the Milliman & Syvitski, 1992 foreign scientists; Summerfield & Hulton, 1994; Harrison, 2000; Verstraeten & Poesen, 2001; Aalto, 2006; Molina, 2008; Yan, 2011; Wilkinson, 2014; Shi, 2014, etc.), so and Fatherlandtion (Lisitsyn, 1960. Bobrovitskaya 1972, etc.). Calculation of transporting capacity of watercourses led V.M. Maccaveev (1940), M.A. Giants (1949), E.A. Zamarin (1951), V.N. Goncharov (1954), A.N. Gostunskii (1954), A.V. Karaushev (1961), I.F. Karasev (1965) and others.

We used methods of geoinformation-cartographic display of historical and geographical situations at different time slices and GIS modeling natural and anthropogenic conditions. Evaluation of the intensity of erosion and accumulation processes-owls in river basins were carried out on the basis of hydraulic calculations, calculation methods soil loss and distribute sediment runoff. To create mathematical models with the aim of foresight river runoff changes in the methods used in linear and nonlinear estimation, time series analysis, artificial neural networks.

The study used stock materials on climate, river runoff, underground water, the volume of water consumption and wastewater. Data on the contamination of the surface-waters are derived from the territorial department of water resources of the Don Basin Water Management, Central Black Soil Department for Hydrometeorology and monitoring the environment, Belgorod Center for Hydrometeorology and Environmental Monitoring, Natural Resources and Environmental Department of the Environment, Rosprirodnadzor Belgorod region, Belgorod territorial center of the state monitoring of the geological environment

and water bodies, the Office of the Belgorod reservoir operation manuals "surface water resources of the USSR." These are supplemented copyrighted material of water bodies in the region surveys.

A retrospective analysis is based on the stock material, military maps of the 1880s. (1: 126,000), General Plan Survey Kursk and Voronezh provinces (M 1:84 000), a special map of European Russia (M 1: 420 000), topographic-ray maps (scale 1:50 0000 1:25 000 and 1:10 000), as well as satellite images of high (2 m, Google Earth) and medium (25 m, the Landsat) authorization data on the wooded areas of Bel-urban area (Terekhin, 2013).

Scientific originality of work.

Based on the analysis Variable organization of river network of Belgorod region on topographic maps of 1: 100,000, and other multi-temporal sources, taking into account the set of fractal dimensions of the river and the erosion network, identified patterns of change in the length of the river and ravine network two time card two hundred year period.

The determinacy of the modern geoecological state of basins is determined by the stages of their economic development and the history of the transformation of basin landscape systems from the point of view of their hydrofunctioning. The spatial and temporal regularities of river flow formation in the Belgorod region are determined taking into account the hierarchical levels of the basin organization of the territory.

Taking into account foreign scientists conclusions about the peculiarities of using neural se-children in the modeling of water flows (Thirumalaiah & Deo 1998; Abrahart & See 2000, 2002; See & Openshaw 2000; Cameron et al 2002; Pulido-Calvo & Portela 2007; Makkeasorn et al., 2008) developed a method of neural network forecasting average annual river discharge, including features forecasting for different types of watercourses hydro functioning.

The method of estimation of silting watercourses on the basis of calculation of the ratio of flow of river sediments and conveying capacity of watercourses, based on proven methods of hydraulics, the current understanding of erosion and accumulation processes and the applicability of remote sensing methods, methods of analysis of the relief, allowing to model and predict the ecological tension in the catchment areas depending on the dynamics of the river flow.

A typology of the functioning of river basins stability to the manifestation of degradation processes, based on a retrospective analysis of their functioning and integrated assessment of the existing natural and economic environment.

The author's recommendations for arrangement of river basins, including the spatial and temporal patterns of their functioning.

The practical significance of the work.

The results of the study, including by thematic maps, can be is-to use in the development of the region's rivers to preserve programs, preparation of materials for the design of erosion control and agroforestry activities. Pre-study of water protection zones and coastal protection strips transferred to the Department of Natural Resources and Environmental Protection of the Belgorod region as a basis for monitoring compliance with the water legislation.

The research results are used in innovation for the territory of Belgorod oblast basin projects of nature, as evidenced by a certificate of Department of Natural Resources and Environmental Protection of the Belgorod region of inculcation research work.

Materials of the thesis includes part of the reports in the following research projects: State job "Space and GIS technologies monitoring anthropogenically transformed landscapes and develop a model of ecological optimization of natural resources for sustainable development of the region» (state registration number 114062370006..); RFBR grant "Development of regional models of basin organization of nature-based optimization methods and geoinformation modeling» (state registration number 01201265024..); Russian President Grant "Assessment of agrarian landscapes transformed based on remote sensing data and geoinformation modeling» (state registration number 114121070017..); municipal contracts in 2012-2014. on the development of river basin environmental management projects in the municipal districts of the Belgorod region (sample project is available on Geoportal CCU FRTS NRU "BSU" at maps.bsu.edu.ru/baskra/); grant for activity 1.3.2. within the framework of the Federal Target Program "Research and scientific-pedagogical personnel of innovative Russia" for 2009-2013 "Assessment of spatio-temporal patterns of the functioning of river basins for sustainable management of the environment" (agreement № 14.132.21.1387); RFBR "Spatio-temporal modeling of water erosion of soil by means of GIS technology and assessment of its impact on the state of the small rivers in the complex geomorphological conditions of Central Black Earth region» (№ 16-35-00226).

The provisions for the defense:

1. Spatial and temporal patterns of reducing the length of watercourses, to predict the direction and rate of degradation of the hydrographic network.

2. Methods of modeling and forecasting long-term changes in river runoff using artificial neural networks.

3. Methods of assessing the silting of rivers on the basis of the analysis of the distribution of sediment runoff in their catchments and transporting capacity of watercourses.

4. Typology of the sustainability of river basins to the appearance of the degradation processes, based on a retrospective analysis of their performance and integral valuation of existing geoecological situation.

The reliability and validity.

Mediated techniques generally accepted ideas and built on modern methods of statistical analysis and geoinformational designing, geo-environmental science were tested. The ideas are based on a synthesis of best practices of domestic and foreign scientists. The resulting work conclusions are confirmed by the results of field research.

Personal contribution of the author.

The thesis is a scientific work performed on their own. Research results presented in the thesis, obtained by the author personally. From the scientific laboring, published in co-authorship, the work used only those ideas and positions that are the result of personal work of the applicant.

Testing of work.

The study results were presented and discussed at scientific and practical activities: 21th plenary interuniversity coordination meeting on the problem of erosion, fluvial and estuarine processes (Novocherkassk, 2007); 7th and 9th of seminars of young scientists of universities united Interuniversity Coordinating Council on the problem of erosion, fluvial and estuarine processes (Kursk, 2008, Volgograd, 2012); All-Russian competition of student PR-projects (Volgograd, 2008), the International scientific and practical conference of students, graduate students and young scientists "Region social and geographical aspects" (Kharkov, 2009; 2010); Ukrainian conference with international participation "Young scientists - geographical science" (Kiev, 2010; 2011); International scientific conference of students and graduate students "Geography of research: History, Present and Prospects", dedicated to the memory of prof. G.P. Dubinsky (Kharkov, 2011; 2012); All-Russian show-contest of scientific and technical creativity of students "Eureka-2012" universities; V International scientific conference "Problems of nature management and environmental situation in European Russia and neighboring countries" (Belgorod, 2013), the regional youth contest "Youth Belgorod" (Belgorod, 2014).

Publications. The theme of dissertation is published 45 scientific papers, including 2-mo monograph (co-authored), 4 articles in journals indexed in international databases of Scopus and Web of Science, 9 articles in journals recommended by HAC. 4 obtained certificates of registration databases.

Structure and amount of work. The thesis consists of an introduction, five chapters, conclusions, bibliography of 352 titles (80 of them in English). Fundamentals-term thesis text is presented on 154 pages of typescript and contains 34 tab-persons and 56 drawings.

Thanks. The author is grateful for his guidance D.Sc., prof. F.N. Lisetskii, as well as all the staff of Centre for Aerospace and Ground Monitoring of Objects and Natural Resources of "BSU".

HIGHLIGHTS OF WORK

In the introduction the urgency of evaluating the functioning of river basins, the main aims and objectives of the study, materials, scientific novelty and practical significance of the results, are the main provisions for the defense.

The first chapter is devoted to the research methods used in the thesis.

In section 1.1 the technique of retrospective assessment of the extent of the drainage system, which is based on the coordination of cards 17th-19th centuries., Modern satellite images and other information in a unified geographic information system on the ArcGIS platform. As a single cartographic basis for retrospective studies selected scale 1: 100 000. We have proposed the use of the fractal dimension of the set density of the river network to coordinate these different scales. Fractal dimension has provided an opportunity to assess the dynamics of water availability in the region for two time cards within two hundred years. Assessment of the development of gullies and ravines network over the past two centuries, carried out using the fractal dimension of the erosion network definition-divided on regional research A.G. Narozhnyaya (2012).

The possibilities of GIS and Remote Sensing techniques described in **section 1.2.** The features of the use of digital terrain models (DTM) for the automated isolation Various Orders basin structures. It demonstrates the potential remote sensing data (RSD) high spatial resolution for the analysis of erosion forms. It was revealed that winter images allow most accurately display the hollow structure of the network.

Section 1.3 describes the parameters used to estimate the intensity of erosion-accumulation processes in the river basins. A technique for estimating the soil loss calculation based on the universal soil loss equation is given.

Analysis of hydrological series requires mathematical processing, and therefore in **section 1.4,** a separate method for their statistical analysis by modern methods is given. It includes the method of data normalization, the results of determining the trend components in the temporal processes of changing the water content of rivers. The identification and grouping of rivers by similar river runoff formation conditions using the difference integral curve method are described. The technique of using artificial neural networks for long-term forecasting of river runoff dynamics is presented.

The second chapter assesses the dynamics of the extent and density of the fluvial network of the Belgorod region.

In section 2.1, with the help of GIS analysis, a modern different-order structure of the Belgorod region river network was identified, for which the river network was mapped on a topographic map M 1: 100 000 (state of the terrain for 1982). It is established that 754 permanent and temporary watercourses (excluding order) at a total level of 5004 km (including elderly and sleeves) flow

through the territory of the Belgorod Region at this level of generalization. The entire territory of the region can be represented by basins of 11 rivers: nine of which are 6th order, and two (Severskii Donets and Oskol) – 7th order. In the region there are sources of six large rivers, including transboundary rivers. The river network of the Belgorod region is almost 70% composed of small and smallest watercourses 1st and 2nd order. Analysis of different ordering of watercourses in the basins of large and medium-sized rivers has made it possible to determine the efficiency of distribution of sediments along the links of the river network.

Section 2.2 presents an assessment of the change in the channel network over the last two tables, which made it possible to identify high rates of river degradation in the territory of the present Belgorod region, an average of 15 km/year. It is established that at the end of the 18th century. The length of the river network in Belgorod region reached 7,907 km, but by the 20th century, It decreased by almost 39% - to 4,789 km. The average estimate of the density of the river network of the Belgorod region, obtained by the author, is - 0.18 km/km^2, despite the fact that at the end of the 18th century. It was 0.29 km/km^2.

A significant variability in the change in the total length of watercourses according to basins of 6th and 7th order (22-79%) was determined. First of all, the degradation processes were affected by waterways of the 1st – 4th order (small and smallest rivers), which makes the process of river reduction particularly sensitive for the Belgorod region, where these watercourses account for 90% of the river network.

The use of GIS technologies and the results of fractal analysis made it possible to recreate the picture of the change in the density of the river network over the past two centuries (Figure 1). The intensity of the reduction of watercourses increases in the direction from west to east (in the same direction, the modern density of the river network also decreases). Annual precipitation amounts within the region vary from more than 600 to less than 550 mm in the direction from west to east. Since the end of the 18th century until the end of the twentieth century there was a decrease in the water availability of the territory. This is more clearly reflected in more arid areas.

The investigated basins were divided into two main groups according to the nature of the change in the extent of the river network in the periods from the end of the 18th century. Until the end of the 19th century. And from the end of 19th century. At the end of the 20th century. In the eastern part of the region there are five basins of 6th and 7th order with insignificant rates of degradation, occupying 45% of the region's territory. Six basins of 6th and 7th order with high rates of watercourse degradation are in the west of the region.

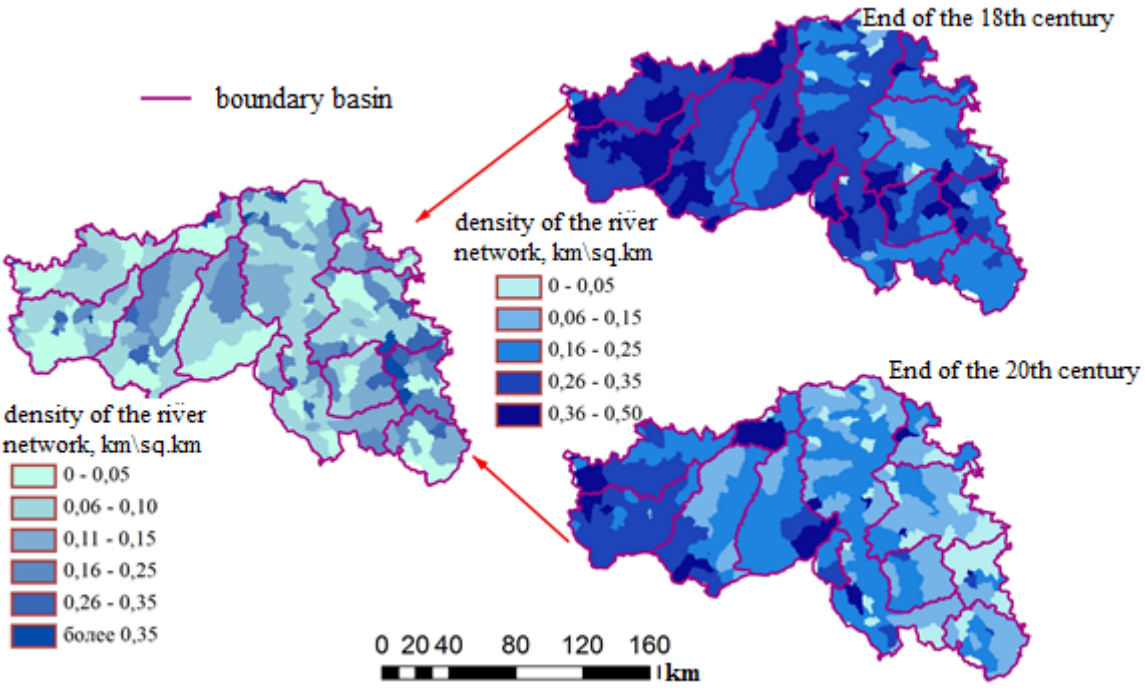

Figure 1 – Territorial features of reducing the density of the river network in Belgorod region for the past 200 years.

Transformation of the channel network in time is reflected in the features of the existing structural organization of river systems.

Section 2.3 is devoted to the analysis of the erosion network from the end of the 18th century. at the end of the 20th century.

The results of the evaluation of linear networks erosion ephemeral streams in southwest of Upland in comparison with the results of other researchers (Petina, 2009; Khrisanov 2011, 2015). The length of the gullies and ravines network domain-sti is 18,064.31 km, the density reaches 0.65 km/km^2. For the past 200 years of its length has increased from 14% to 33% of the initial value for basins of 6th and 7th order, averaging 18%. The increase in erosion network over the past 100-200 years in the basins of small rivers varies greatly. The analysis showed that, the natural features of the territory determine the nature of the development of erosion processes, while the anthropogenic component determines their intensity.

Section 2.4 presents an analysis of natural and anthropogenic factors reduce the length of watercourses in the region.

At the frontier of the 18th-19th centuries the southern half of the Russian Plain was characterized by a great moisture compared with the subsequent period, summer temperatures were significantly lower than today's. There warming and an increase in annual precipitation since the mid twentieth century. (Shiklomanov, St. George, 2002). This trend is predicted and the first

half of the 21th century on the territory of European Russia (Perevedentsev 2006, 2015).

At the end of 18th – first half 19th centuries the integrity of the common woodland finally broken. It was found that the percentage of forest land in the last century has declined slightly (from 9.5% to 7.6% on the scale level of reflection research on maps of 1: 1 500 000). Note that only in the last 60-70 years due to agroforestry increased afforestation area, in some cases by 52% (river basin Vorskla).

Plowing as a factor in the destruction of natural vegetation and soil treatment has been applied in the territory of Belgorod with the 18th century. (Degtar 2005, Chengdu, 2008). The restored picture of the economic use of the territory of the small river basins indicates a high degree of catchment plowing at the end of the 18th century – 69.1%. At the end of 19th century arable land on the territory of the small rivers catchments in most cases was about 80%. For individual basins of the 6th order plowing maximum falls in the middle of the twentieth century – 90%. Over the next 65 years plowed some catchments decreased by more than 15%.

Thus, reducing the river network was due to the decrease in moisture climate since the end of the 18th century until the end of the 20th century. Mass plowing and reduced pools of forest cover in the last two centuries have led to increased erosion and displacement of the sources of the river down the valley. However, since the end of the twentieth century there was an increase in annual precipitation on the territory of the Russian Plain, reduction of arable land area and increase in forest cover river basins of the Belgorod region, which led to a slowdown in reducing the length of watercourses.

The third chapter is devoted to modeling and forecasting river runoff parameters in changing climatic and geoecological conditions. The authors studied the annual river runoff in eight sections of the 5th-order rivers with a catchment area (F) of less than 800 km^2 and 6th-order rivers (1200 km^2 <F <9000 km^2). The duration of the series of observations of river runoff covers the periods from 1930 to 2012.

In section 3.1, an analysis of the dynamics of the average annual discharge in the investigated rivers is carried out. It is established that the hydrological regime of the rivers of the Belgorod region underwent anthropogenic transformation, as a result of which hydrodynamics of the water systems under study are distinguished by qualitative periods differing in trends in the variation of river runoff. On small rivers there is often a complete transformation of the hydrological regime. Large rivers are characterized by a slight manifestation of the negative trend component of the river runoff dynamics. The catastrophic impact of mining production on the hydrological regime of small rivers is shown.

Section 3.2 describes the developed methodology for modeling and long-term forecasting of

river runoff changes using artificial neural networks.

For the territory of the Belgorod region, there are groups of rivers with different types of hydrofunctioning. The hydrological regime of anthropogenically overloaded 5th-order rivers was disturbed to the largest degree. It is predicted to reduce their water content up to 2020 on the basis of the created neural network models. The rivers of the 6th and 7th order are divided into watercourses with disturbed and relatively stable types of hydrofunctioning. The disturbed type of hydrofunctioning is characterized by a tendency to decrease the water availability of the river, including in the forecasted future. The absence of a trend or a weak trend towards a decrease in water availability distinguishes rivers with a relatively stable type of hydrofunctioning.

Section 3.3 presents the results of a statistical analysis of the effect of climatic factors on river runoff dynamics. They indicate non-linear relationships between factors due to the strong spatiotemporal variability of precipitation and the non-linear deterministic nature of river runoff. After anthropogenic transformations, the response of river runoff dynamics to the change in climatic conditions is minimized.

In section 3.4, the quantitative and qualitative characteristics of groundwater in the main bas basins of the Belgorod region, the nature of the use of groundwater and surface water in human economic activities were studied. The change in the quality of water in rivers under the influence of anthropogenic load is analyzed.

Indicators of groundwater resources and their water intake, water consumption from surface sources, the volume of wastewater discharge into rivers were used by us in assessing the impact of natural-anthropogenic factors on river basins. The quality of water in the river is an integral indicator of the anthropogenic load on the water system, the stability of hydrofunctioning. It was used to assess the adequacy and reliability of the obtained results of the impact of natural-anthropogenic factors on river basins.

Section 3.5 provides an objective picture of the current natural and economic situation on the territory of water protection zones (PZ) and coastal protective bands (CPB) based on remote sensing and GIS technologies.

The technological capabilities of the automated isolation of the boundaries of the PZ and the CPB according to SRTM (1 × 1 arc seconds) and vector data of the watercourses are shown. Based on the results of the interpretation of space images (resolution 25 m), violations of economic activities within the boundaries of the PZ and CPB have been established. The specifics of the organization of water protection boundaries, taking environmental problems into catchments, are revealed.

In the **fourth chapter**, the processes of forming sediment runoff on the slopes and siltation of watercourses are considered.

Section 4.1 is devoted to changing the formation of sediment runoff over the past two hundred years.

For the period preceding the twentieth century, the intensity of the redistribution of sediments in the slope-river bed area within the swept catchments is higher, compared with the present. The natural and anthropogenic conditions of the past two centuries have led to a significant reduction in the number of watercourses on the territory of the region and the silting of existing ones. However, since the beginning of the 21th century the situation is somewhat different, causing a decrease in the rates of soil loss and the receipt of sediments in the river network.

Water content and slopes of river beds have a significant effect on the state of small rivers in conditions of strong anthropogenic impact. Assessment of the inclines of the different-order watercourses and the water content of the territory at the end of the 18th century provided the opportunity to assess the distribution of sediments along the links of the hydrographic network in the specified period. The obtained results, along with the assessment of changes in climatic and economic conditions, allowed to adequately predict the rate of reduction of the river network in the basins in the following century.

At the end of the twentieth century the values of slopes in the headwaters of the rivers decreased. The water content of the territory also decreased. This exacerbates the situation on catchments, causing a greater risk of flooding streams of the 1^{st} and 2^{nd} order, other things being equal, compared to the last two centuries. The risk of siltation of different-order watercourses is estimated on the basis of the analysis of the slopes of watercourses and the water content of the territory along with the assessment of soil loss rates.

Section 4.2 presents a methodology for assessing sedimentation of rivers.

In this study it was necessary, first of all, to determine the features and differences of the sediment redistribution for the rivers flowing in a homogeneous and isotropic field of annual runoff. The authors used the formula of E. A. Zamarin (1951) which has been calibrated on the basis of the data about the transporting capacity of watercourses with the sediments (silt and fine sand): common for small rivers.

On the basis of the soil loss values obtained in the basins of the main Belgorod region rivers and the sediment delivery ratio (Golosov, 2006), the amount of sediment in the outfall is obtained (Figure 2) using the ArcGIS mathematical statistics tools. The ratio of the transporting capacity of the rivers in the river from the whole catchment area is a criterion for the vulnerability of rivers to

silting under anthropogenic load conditions and accelerated erosion by catchments (Table 1).

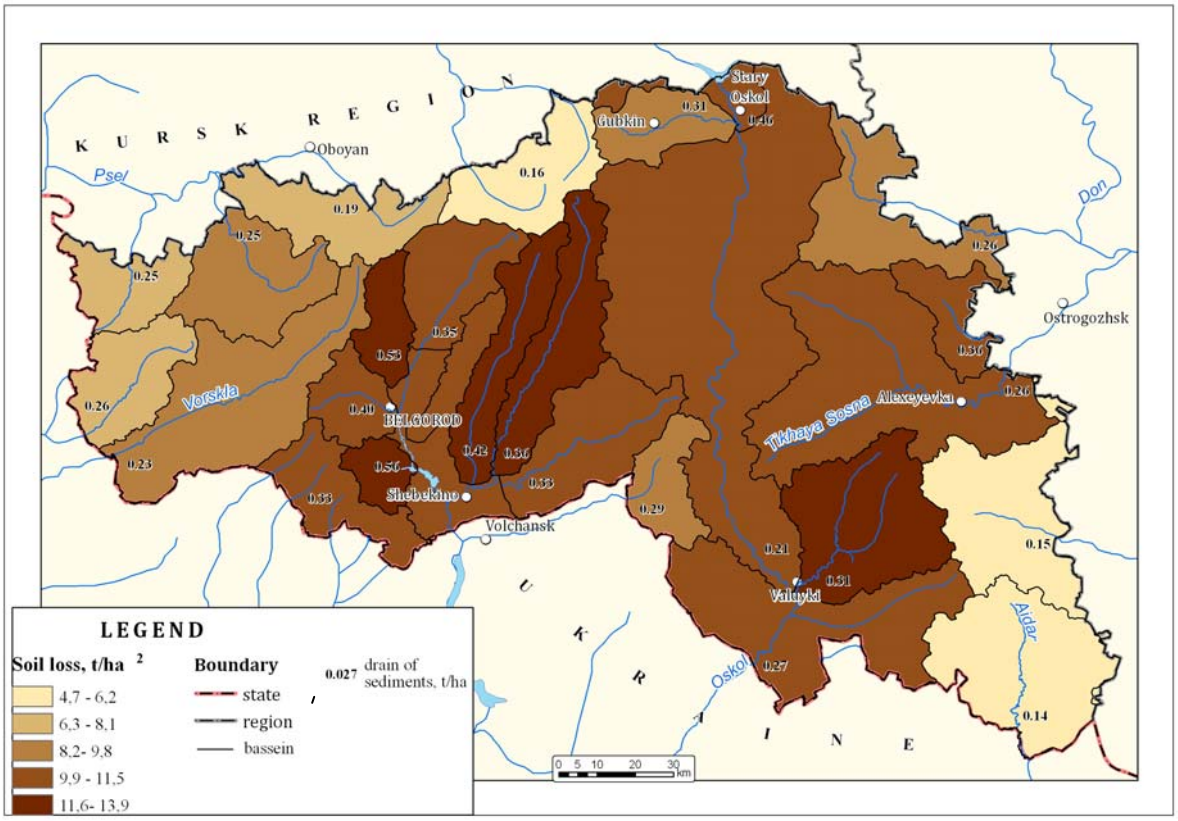

Figure 2 – Average annual soil loss of catchments and estimation of the amount of sediment in the outfall of the Belgorod Oblast rivers

Table 1 – Assessment of the siltation of the rivers of Belgorod Oblast

Indicators*	The studied river							
	Vorskla	Vezelka	Severskii Donets	Tikhaya Sosna	Oskol (source)	Oskolets	Oskol (down-stream)	Valui
Dr	0.03	0.04	0.03	0.02	0.03	0.04	0.02	0.03
Wd	22.25	40.59	34.77	24.92	27.94	31.06	17.50	31.46
M_1	4.84	1.85	4.50	2.39	12.95	9.22	12.79	5.36
RTC_1	0.22	0.05	0.13	0.10	0.46	0.30	0.73	0.17
M_2	50.38	29.17	37.22	28.43	36.61	45.17	73.38	28.69
RTC_2	2.26	0.72	1.07	1.14	1.31	1.45	4.19	0.91
M_3	19.91	9.17	18.07	12.36	27.10	18.23	35.43	13.40
RTC_3	0.89	0.23	0.52	0.50	0.97	0.59	2.03	0.43
M_4	14.88	1.77	7.44	10.39	15.57	9.56	29.17	12.86
RTC_4	0.67	0.04	0.21	0.42	0.56	0.31	1.67	0.41
M_5	17.02	0.55	23.46	11.32	14.48	5.05	38.22	5.90
RTC_5	0.76	0.01	0.67	0.45	0.52	0.16	2.18	0.19

*Dr – sediment delivery ratio; Wd – amount of sediment in the outfall, т/год с км2; M – sediment runoff, т/год с км2; RTC – relative transporting capacity. Indices for Q and R: 1 – dry year; 2 –wet year; 3 – normal flow rate; 4 – 2010; 5 – 2018 (forecast).

It is established that silting processes dominate in the rivers of the Belgorod region. However, in the most high-water years, the situation may change. The most favorable situation is in the mainstream of the most abundant river in the region – Oskol. The accumulation of sediments here occurs only in the very shallow years.

Section 4.3 presents the results of field studies of small Vezelka River, experiencing the maximum revenue from the sediments load slopes in her direction. Describes research the source of the river and its ecological state, state water protection and coastal protection zones. The results of the study of the morphological characteristics of the river bed. Three-dimensional channel model in the areas of artificial expansion.

It was found unsatisfactory ecological condition in the upper echelons of the river network. The depth of the river is constantly changing, often there are muddy areas. An analysis of the state of the water protection zone Vezelka testament to its widespread abuse. In the bottom tier of the river system, its "urban" area, there is a complex pattern morphology of the bottom channel, due to the modern sedimentation. In some parts of the bed there is a formation of islands, some of which are in the process of further expansion completely block the river bed.

In the fifth chapter developed a typology of functioning river basins stability to the manifestation of degradation processes on the basis of retrospective analysis of their performance and integrated evaluation of the existing natural and economic environment.

In section 5.1, assess the sustainability of basins of the main rivers of the Belgorod region, which is proposed to be carried out on the basis of the analysis of the processes taking place on different time cards:

1. assessment of the dynamics of geosystems for a long (200 years) period of time;
2. identifying features pools functioning dynamics at the present stage.

Under the assessment of the dynamics of geosystems means analysis of the dynamics of density of the river and ravine network over the past 200 years. The study established the degree of overall changes in geosystems. Separately estimate the change proposed by characteristics on several time cards. To characterize the dynamics of the operation of swimming pools at the present stage is proposed by analyzing the transformation of the hydrological regime of the water systems. To do this, the results of the study have been parameterized. The basic types of the processes, and then defined pools Group, summarized by the similarities of the dynamics within two hundred years.

Section 5.2 is devoted to assessing the ecological and economic situation in the catchments of the main rivers of the Belgorod region. In our study of selected indicators of the impact of natural and anthropogenic factors: the river network density, ground water resources, forest cover, density

erosion network, erosion, regulation of river runoff ponds, water from surface water sources, groundwater abstraction, wastewater discharge, plowed, the density of the road network, the number of livestock farms, irrigation. A standardization of data so that the best conditions for each criterion corresponds to the value – equal to 0, and the worst – equal to 1. Calculate the overall impact of natural factors, man-made separately and integrated indicator of the ecological and economic burden.

Assessment of the stability of the operation of swimming pools, along with a load acting on them allowed to predict the development of the studied river basins (Figure 3).

It was found that the unstable operation of the pools are characterized by occupying over 24% of the territory of the Belgorod region, and half of them developed an environmentally unfavorable natural and economic situation that affects the rate of degradation of river systems.

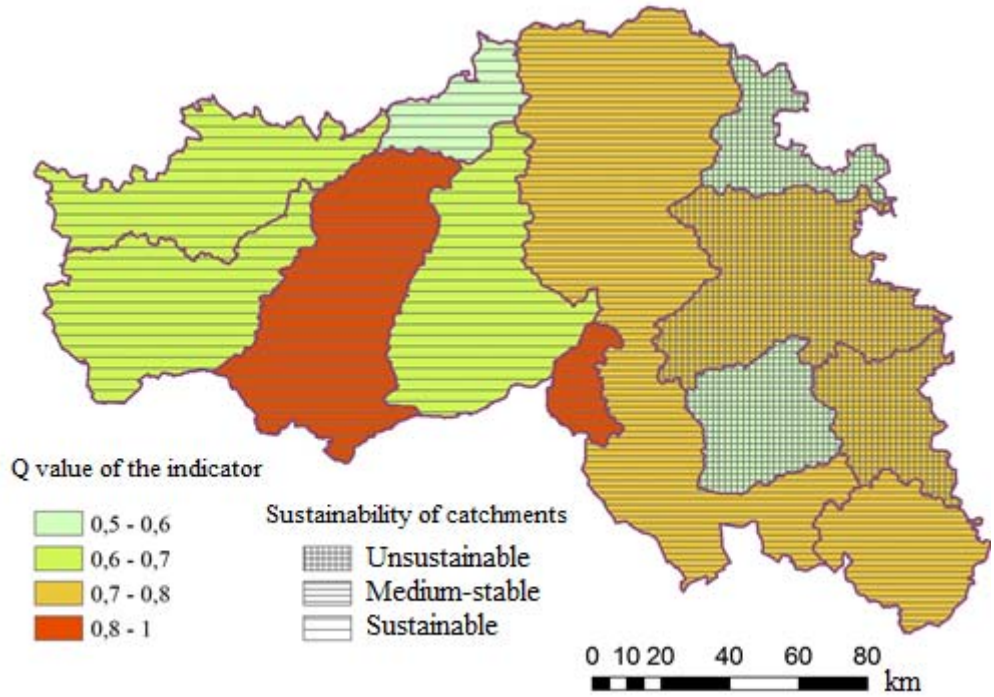

Figure 3 – Integrated assessment of natural and economic situation in the basins of the main rivers of the Belgorod region and the stability of its functioning

Section 5.3 substantiated complex of environmental protection measures, based on the spatio-temporal patterns of the functioning of river basins. Identified the most significant issues of basin-wide environmental management, defined the priority of environmental protection measures.

In **conclusion**, highlights the main results of the study:

1. The picture of the change in the channel network over the past two centuries was reconstructed, which made it possible to reveal high rates of degradation of the rivers in the Belgorod region – an average of 15 km/year. The length of the river network was reduced by

38% in two centuries, that is, by 2,979 km.

2. Cartographic modeling and obtained fractal density values of the river network made it possible to establish the spatio-temporal regularities of its degradation in basins of 6th and 7th orders. It is shown that the intensity of the reduction of watercourses increases in the direction from the west to the east (in the same direction the current density of the river network decreases), which is connected, first of all, with a similar tendency to reduce the moisture content of the territory. The decline in the moisture content of the climate from the end of the 18th century to the end of the 20th century was more pronounced in areas with a lower hydrothermal coefficient. This confirms the zoning of the disappearance of the sources of the river systems of the southwest of the Central Russian Upland.

3. By the nature of the degradation dynamics of the hydrographic network, the river basins studied can be divided into groups roughly equivalent in territorial terms:

- - with a significant degree of change in the extent of the river network (37-78%) over the last two centuries, and the main period of the reduction in the length of the watercourses since the beginning of the 18th century to the end of the 19th century, which is connected with the achievement of a steady-dynamic state by river systems, as well as the reduction of the agricultural load at the present stage;
- - With small changes in the extent of the river network over the last two hundred years (less than 29%), and the main rate of reduction in the length of the watercourses from the end of the 19th century to the end of the 20th century due to the violation of the hydrofunctioning regime of these river systems as a result of anthropogenic impact.

4. Transformation of the channel network in time is reflected in the current structural organization of river systems. For river basins with high rates of shortening of the watercourses, the weak development of the upper link and the predominance of the lower reaches in the structure of the river network for the present period of time are typical. Pools with a low rate of shortening the length of the watercourses are in most cases significantly dissected in the upper and middle links of the river network.

5. The high intensity of the development of a network of temporary watercourses in the territory of the southwest of the Central Russian Upland has been established. Significant territorial differences in the density of the erosion network at all hierarchical levels (regional, basins of 6th and 7th orders and basins of 4th and 5th order) are revealed. The most informative indicator of the assessment of the territory is the erosion of basins of 4th order. The nature of the development of linear erosion is determined by the structural features of the basin, each link of which has distinctive features of the development of erosion forms.

6. A methodology for modeling and long-term forecasting of river runoff changes using artificial neural networks has been developed. For the territory of the Belgorod region, the groups of rivers with different types of hydrofunctioning are distinguished: Group I – the rivers of the 5th order with the radical transformation of the hydrological regime, the presence of a trend for lowering water availability, including the forecasted future (until 2020); II group – the rivers of the 6th order with disturbed type of hydrofunction characterized by a moderate tendency to decrease in river water availability and a forecast for further deterioration of the situation; Group III – the rivers of the 6th and 7th orders with a relatively stable type of hydrofunctioning and a lack of a trend or a weak trend towards a decrease in water availability, including for the forecast period.

7. The peculiarities of the change in the formation of sediment flow from the end of the 18th century to the end of the 20th century in the basins of the rivers of the Belgorod region of the 6th and 7th orders.

The natural-anthropogenic conditions of the transformation of the catchments over the past two centuries have contributed to a significant increase in the amount of sediment entering the small rivers, which has led to a reduction in the extent of the watercourses. Since the beginning of the 21st century, there has been a decrease in the rate of flushing and sediment flow into the river network.

Assessment of water content of different-order watercourses and DEM allows estimating the distribution of sediment along the links of the hydrographic network and, in addition to assessing the changes in climatic and economic conditions, predict the siltation of watercourses.

8. A methodology for estimating siltation of rivers has been developed based on the ratio of the transporting capacity and transporting capacity of watercourses based on hydraulics methods, modern concepts of erosion-accumulation processes and remote sensing analysis of the relief, which allows modeling and predicting environmental tension on catchment depending on dynamics river runoff:

- rivers of the Belgorod region are characterized by predominance of silting processes, but, depending on the water content of the year, the situation changes: from cleansing the channel from sediments to siltation. With the average indicators of the water content of the year, the processes of cleansing from sediments are characteristic only of the most abundant river in the region – Oskol;
- the forecast for the silting of the watercourses in 2018, along with the dynamics of their hydrological regime and the established patterns of functioning, river basins differen-

tiates the stages of development of degradation processes depending on the order of river systems and the natural and economic situation in their basins.

9. The developed river basins typology allowed to reveal the most ecologically unstable basins of the 6th and 7th orders to the manifestation of degradation processes with their differentiation according to the integral indicator of the impact of natural-anthropogenic factors. In practical terms, the analysis of the dynamics of the functioning of basins on short-term and long-term periods and the assessment of integrated indicators of the impact of natural-anthropogenic factors makes it possible to identify the most significant basin-wide problems of nature management, determine priority and the necessary complex of environmental measures.

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