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HYDROLOGICAL RISKS OF SMALL REGIONS UNDER UNSTABLE CLIMATIC CONDITIONS (BY THE EXAMPLE OF BELARUS)

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New data on the maximum and minimum runoff under the conditions of global climate change and the transformation of the conditions for its formation have been obtained. Fundamental approaches to the hydrological zoning of small regions are proposed. A zoning scheme for the territory of Belarus, adapted to new conditions, is proposed, qualitative and quantitative characteristics of the river regime are obtained.

Keywords: global warming, maximum runoff, minimum runoff, risks, problems, adaptation, hydrological zoning.

Introduction

Global climate changes have affected the conditions for the formation of the runoff of small catchments, including the territory of Belarus. Modern natural conditions of the republic have undergone serious changes over the past 50 years. They are reflected in quantitative indicators of the runoff territorial distribution. As a result of the runoff indicators analysis on the territory of Belarus during the period of instrumental observations, the regularities of the territorial distribution of the runoff of both long-term average and extreme values, i.e. minimum and maximum runoff, changes in hydrological seasons are obtained. The maximum and minimum runoff create risks arising in unstable climatic conditions and the transformation of natural runoff-forming factors.

Materials and methods.

The materials of observations over the runoff of the Belarusian rivers during the period of instrumental observations are used in the scientific work. The method of retroanalysis, runoff mapping, statistical, GIS technologies, complex method of runoff analysis in the hydrological zoning of the territory of Belarus: basin, landscape, hydrological analysis are used.

Findings and conclusions

As a result of the hydrological data processing, analytical and cartographic materials on the territorial and temporal distribution of runoff are obtained, and a new adjusted version of the hydrological zoning of a small territory is proposed by the example of Belarus.

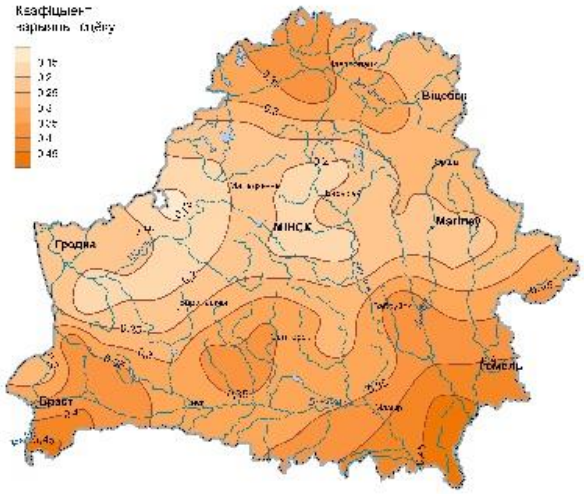

Fig. 1. Long-term variability of the runoff of the territory of Belarus over a long-term period

Statistical processing of the runoff observations made it possible to obtain regional differences in the characteristics of the runoff: the average long-term rate, the minimum summer-autumn module, the minimum winter module, the maximum spring module, which under warming conditions create certain risks of using surface waters.

By contrast with the zonal features of the runoff fluctuations, which tend to decrease from north to south, the coefficient of variation changes from central Belarus (0.15 - 0.2) to 0.3 – 0.45 in the far north of the republic and in the Belarusian Polesie (fig. 1).

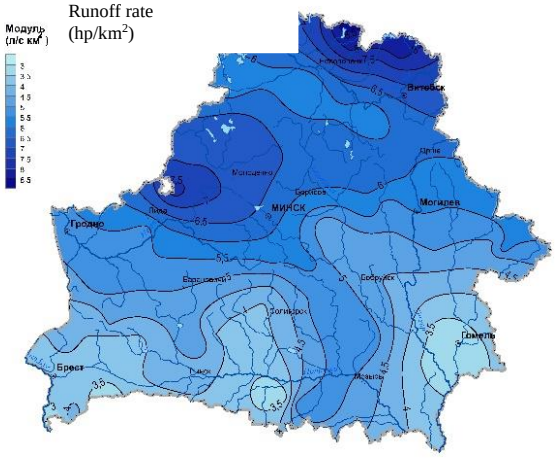

Fig. 2. Average long-term runoff on the territory of Belarus

The territorial distribution of the average long-term runoff is characterized by mosaicity, which is caused by climatic differences and the relief of the territory, the distribution of its moisture content. The runoff rate in the north reaches the highest values. The change in climatic conditions from north to south causes a change in the module from 6 – 8 hp/km^2 in the north, to 3 hp/km^2 or less in the south (fig. 2).

The maximum spring runoff for a long-term period reaches 100 - 120 hp/km^2. The average long-term runoff in the south reaches 20-40 hp/km^2, which is higher than the average annual one (fig. 3).

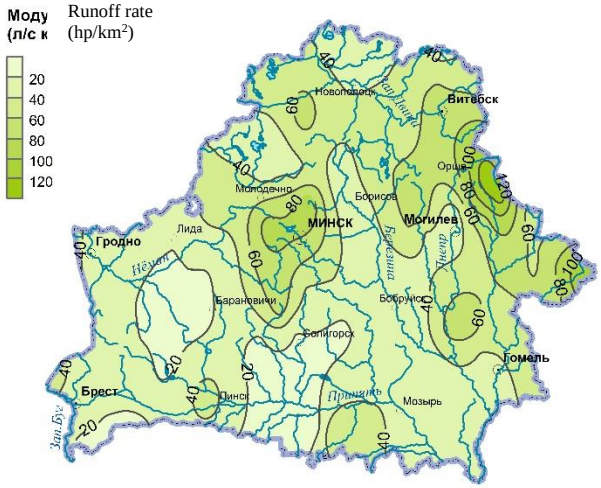

Fig. 3. The maximum runoff of the territory of Belarus

The minimum winter runoff depends on the moisture content of certain districts of the territory and ranges from 3.5 to 1.5 hp/ km^2. The minimum summer-autumn runoff is slightly less than the winter one (1.0 – 1.5 hp/km^2). There is a noticeable increase in the indicator at elevations (up to 3.5 hp/km^2), which is explained by precipitation on the slopes of the elevation (fig. 4).

For the zoning of the territory according to the synchronicity of the runoff fluctuations, hydrological sections with the same observation periods are selected, taking into account the uniformity of distribution across the territory of Belarus. First of all, the correlation matrix is calculated for sections with a catchment area exceeding 4000 km^2, which made it possible to draw approximate boundaries for the proposed districts. After that, the paired correlation coefficients are calculated for all the sections in order to clarify the boundaries in detail. The process of zoning is the unification of the sections into one district in the case when the pair correlation coefficient exceeded the required level (it varied from 0.85 to 0.70). When dividing the territory into districts, the physical, geographical and landscape zoning of Belarus and the position of the watersheds

of the country's river basins are taken into account. The territory of Belarus with the selected districts of synchronous fluctuations of the annual runoff is shown in fig. 7.

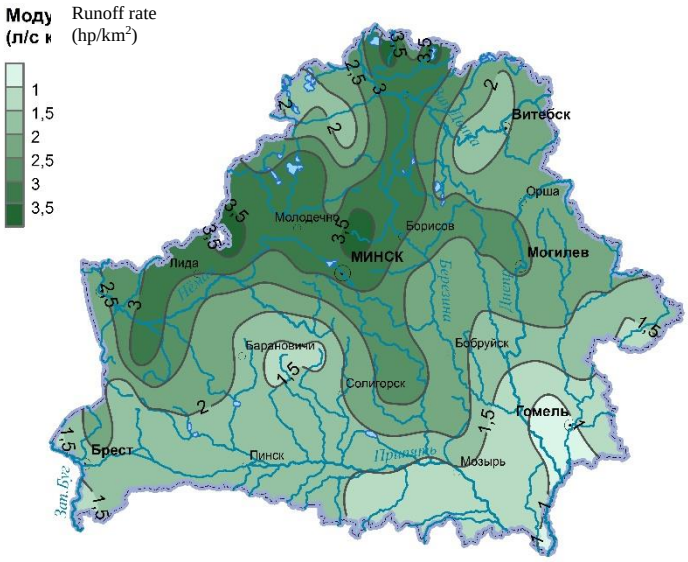

Fig. 4. Minimum winter runoff

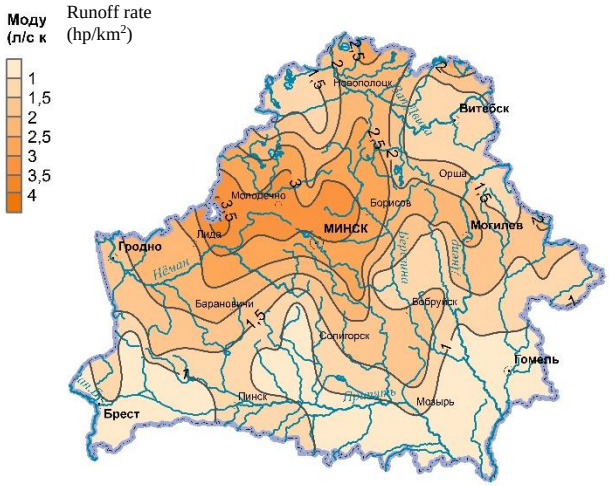

Fig. 5. Minimum summer-autumn runoff

The average correlation coefficients within each of the selected districts and the average correlation coefficients with the remaining districts of the republic are presented in the scientific work. The average values of intra-district correlation coefficients vary from 0.70 to 0.81, which indicates a high level of fluctuation synchronicity of the annual runoff for each group of sections allocated to a

separate district. The average values of inter-district correlation coefficients fluctuate about 0.50 and do not exceed 0.68, which indicates the correct allocation of districts.

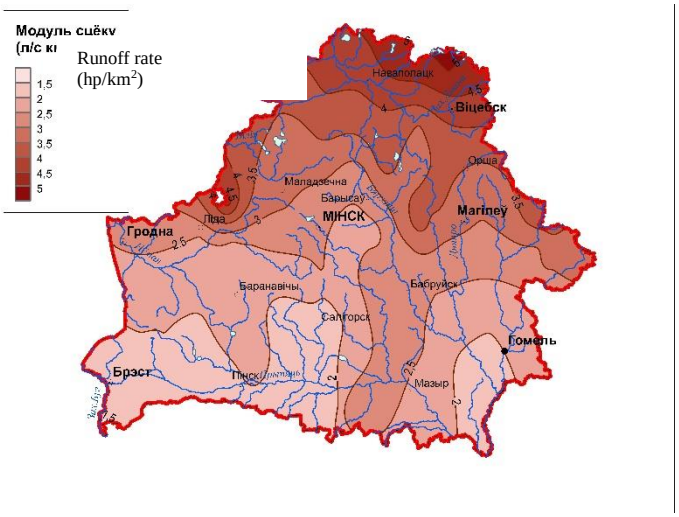

Fig. 6. Average surface runoff

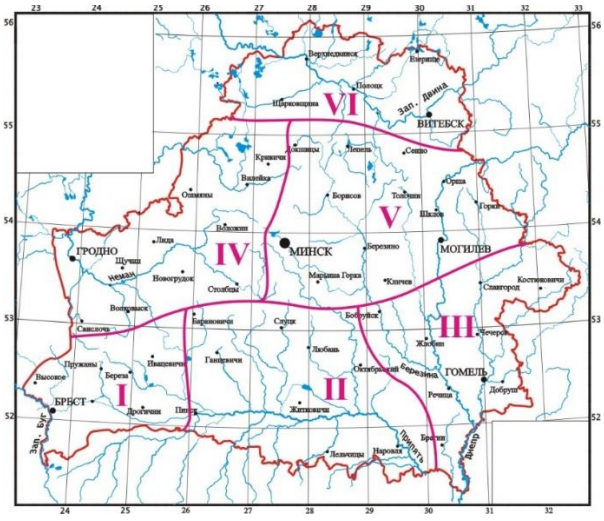

Fig. 7. Zoning of the territory of Belarus by synchronicity of runoff fluctuations
I – South-west, II – Pripyatsky, III – South-east, IV – Nemansky, V – Central,
VI – Zapadnodvinsky

The value of the annual runoff rate has a pronounced tendency to increase from district I to district III, i.e. from the south-west to the north-east of the republic. The coefficient of variation, on the contrary, decreases from the first district to the third one. The autocorrelation coefficient and the ratio of the coefficients of asymmetry and variation do not have similar territorial trends, but in

the central district there is the lowest autocorrelation coefficient and the highest ratio of C_s / C_v annual runoff.

The average number of common years of observation when calculating paired correlation coefficients is at least 20 years. The assessment of the uniformity of the direct correlation function of the annual runoff of the Belarusian rivers showed that the function in question is heterogeneous, so the initial field was divided into smaller districts. In our case, 4 uniform districts have been allocated for the territory of Belarus.

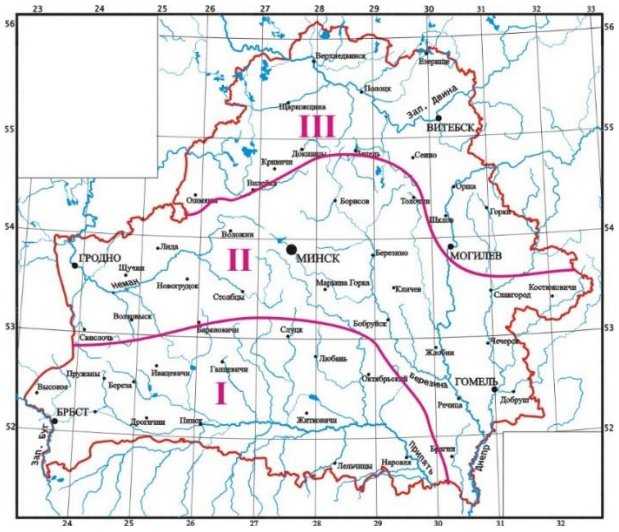

Fig. 8. Diagram of hydrologically uniform districts for the territory of Belarus
I – south-west, II – central, III – north-east

As a result of the conducted research, the hypothesis of four uniform districts for the territory of Belarus is confirmed, depending on the nature of fluctuations in the annual runoff of rivers. The first allocated district includes the river sections of the basins of the Western Bug and the Pripyat, the second area corresponds to the catchments of the Dnieper. District III contains the river sections of the Neman, and the fourth district includes the catchments of the Western Dvina. Zoning of the territory of Belarus depending on the nature of long-term fluctuations in annual runoff is shown in fig. 9.

Based on the analysis of runoff on the territory of Belarus, a variant of hydrological zoning is proposed, taking into account three basic principles of allocation of hydrological districts: basin, landscape and hydrological (fig. 10).

The hydrological district – the hydrological sub-district - is used as the taxonomic units of zoning. In a scientific first, the boundaries of hydrological districts correspond mainly to the boundaries of the largest river basins in the project, which simplifies the conduct of hydrological calculations. Previously performed zoning cut off with the help of borders tributaries of 3-5 orders, which is

unreasonable and very schematic for the territory of Belarus taking into account its small area.

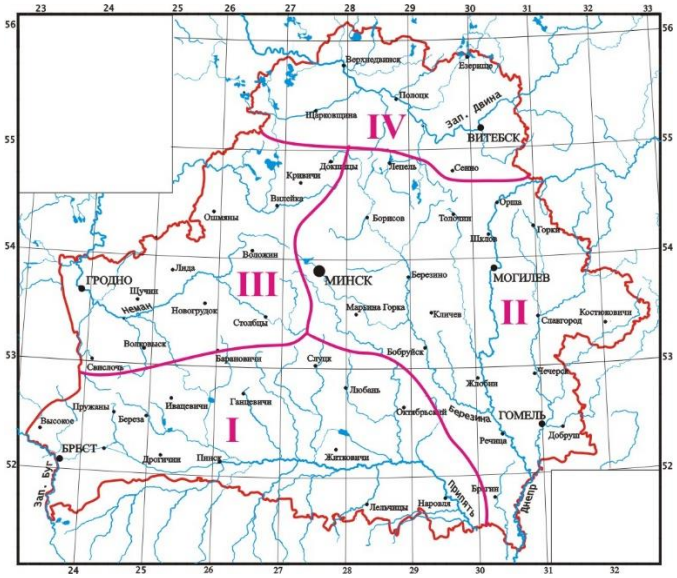

Fig. 9. Uniform districts according to long-term fluctuations in the annual runoff of the Belarusian rivers. I – district No. I, II – district No. II, III – district No. III, IV-district No. IV

In the new zoning, it is proposed to allocate the following hydrological districts: Zapadnobugsky, Nemansky, Vileysky, Zapadnodvinsky, Central Berezinsky, Pripyatsky and Verkhnedneprovsky. The allocation of Zapadnobugsky hydrological district is due to the significant catchment area on the territory of Ukraine and Poland and its compliance with the European scheme of hydrological zoning, the increased water content of the river, the complex trans-border hydrological regime, which is uncharacteristic for Polesskaya lowland. In the previous zoning, it is viewed as a sub-district in Pripyatsky hydrological district. Pripyatsky hydrological district is limited from the north by a conditional line along the water storage basins: Loktyshi, Krasnoslobodskoye, Soligorskoye and Lyubanskoye, which corresponds to the boundary of uniformity in long-term fluctuations in the annual runoff of the rivers of Pripyatsky district.

Verkhnedneprovsky hydrological district includes the basins of the Dnieper river, its right tributary of the Drut and the left tributary of the Sozh. Its allocation is due to the high water content of the river, a complex hydrological regime due to the landscape conditions of the formation of runoff within the East Belarusian province, the Pred-Polesskaya and Polesskaya provinces. The hydrological regime in the middle and lower parts of the Dnieper catchment is characterized by a complex hydrological regime, which is uncharacteristic of Polesskaya lowland. At the same time, these parts correspond to the central hydrologically uniform district, which gives reason to allocate them to the southern Verkhnedneprovsky hydrological sub-district.

Scale 1:8,000,000

Fig. 10. Fundamentally new approach to the allocation of hydrological districts

The developed zoning will reduce the risks arising from the use of water resources of such a small territory as Belarus.