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Algorithm research and evaluation of minimum water flow of mountain rivers using GIS

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SUMMARY

Modern climate change has a significant impact on people's daily lives. They are manifested in various areas of the economy in the strengthening of environmental problems. However, the issue of monitoring hazards resulting from climate change remains essential. According to the WMO classification, there are several types of droughts: meteorological, hydrological, agricultural and economic. The onset of any of these can lead to catastrophic consequences.

For a long time, geographic information systems (GIS) have significantly improved the ability to assess and monitor all geographical processes. The use of their tools is gaining momentum, especially in hydrological research.

Moisture shortages caused by climate change can lead to hydrological droughts, which affect water consumption and drinking water supply, water use in various sectors of the economy, protection of water resources from pollution and depletion.

According to the algorithm for estimating the minimum water runoff of mountain rivers, calculations of the Tisza basin's minimum runoff within Ukraine using GIS were performed. As a result, methodological approaches to constructing the spatial distribution of hydrological characteristics of mountain rivers have been developed.

Introduction. Modern climate change has a significant impact on people's daily lives. They are manifested in various areas of the economy in the strengthening of environmental problems. Today, there are entire programs to adapt to cities and human life to climate change. However, the issue of monitoring hazards resulting from climate change remains essential. Increasing air temperature and reducing rainfall worsens water runoff, especially during low water periods on rivers, which can cause droughts. According to the WMO classification, there are several types of droughts: meteorological, hydrological, agricultural and economic. The onset of any of these can lead to catastrophic consequences (Grebin et al., 2015; Snizhko et al., 2020).
For a long time, geographic information systems (GIS) have significantly improved the ability to assess and monitor all geographical processes. The use of their tools is gaining momentum, especially in hydrological research.
Moisture shortages caused by climate change can lead to hydrological droughts, which affect water consumption and drinking water supply, water use in various sectors of the economy, protection of water resources from pollution and depletion.

Methods of investigation. The use of GIS in the study of the minimum runoff of mountain rivers makes it possible to respond to fluctuations in the runoff, to calculate its magnitude in any section of rivers, taking into account the mountainous terrain.
Accordingly, the work aims to develop an algorithm for calculating the minimum water runoff of mountain rivers using GIS on the example of rivers of the Tisza basin.
Based on previous research on minimum runoff (Pochaievets, 2019; Zhovnir et al., 2018; Obodovskyi et al., 2019), current areas have been identified that require more in-depth study and assessment of the possibility of using GIS. Essential conditions for the overall evaluation of the minimum runoff are:
- taking into natural account conditions and the impact of economic activity on the processes of its formation;
- establishment of intra-annual distribution of runoff to allocate limiting periods and seasons for zoning;
- performance of the minimum runoff assessment taking into account modern methods and approaches for the whole period of observations;
- establishment of long-term fluctuations of the minimum runoff;
- identification of the links of the minimum runoff with the determining factors;
- create maps of the isolines of minimum water runoff modules by 30 and 7 days of 80% exceedance probability and calculate transition rates to determine the water discharge of different exceedance probability.

The set tasks can be presented in the form of a block algorithm on the sequence of estimates of the minimum runoff of rivers of the Tisza basin within Ukraine (Figure 1).
Output data. According to the algorithm of research of the minimum runoff (Figure 1) use of GIS tools gives the chance to carry out any calculations. It is incredibly convenient to use them to visualize research results. The study used data from water runoff observations from hydrometric stations both within Ukraine and from countries adjacent to the study basin, respectively 48 and 8. The duration of observations at these stations varies from 53 to 70 years. Daily runoff data from the beginning of observations up to and including 2015 were processed. The change of climatic characteristics was assessed using the data of 9 meteorological posts and hydrological stations located in the basin of the Tisza River within Ukraine.
In the early stages of the study, QGIS was used to create a database. Maps of the geological structure, terrain, spatial distribution of climatic characteristics (precipitation, temperature, snow cover) were vectorized to assess the impact of natural factors on the minimum runoff formation (Pochaievets et al., 2018).
Data Analysis block. Calculations of the intra-annual runoff distribution, estimates of the homogeneity and variability of the minimum runoff, and its long-term fluctuations were also performed using GIS tools. The result was:
- map of zoning of the territory with two districts according to the intra-annual distribution of runoff - eastern and western (link);
- maps of isolines of the spatial distribution of coefficient of variation for summer-autumn and winter periods of minimum runoff.

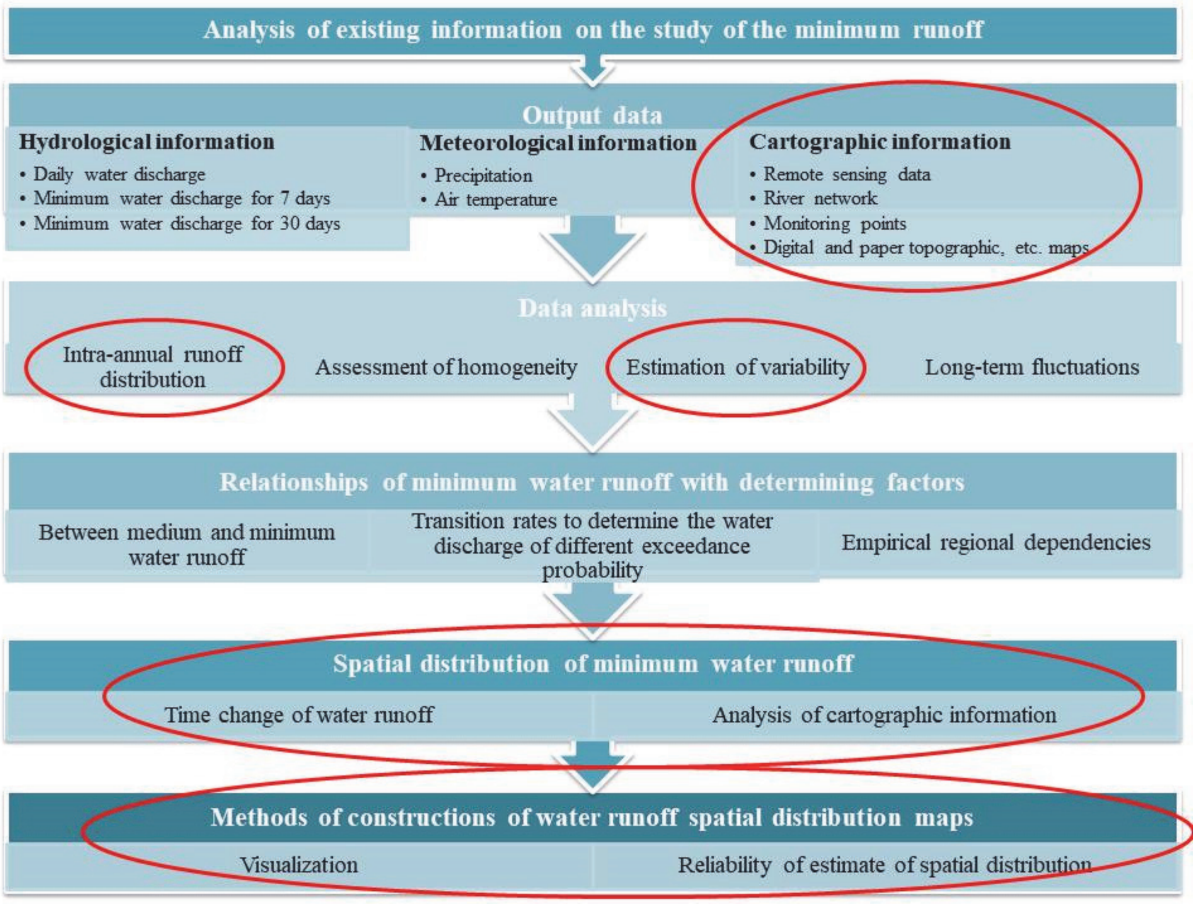

Figure 1 *Algorithm for estimating the minimum water runoff of mountain rivers*

Block "Spatial distribution of minimum water runoff ". The estimation of the time changed the minimum water flow for updating existing maps of the distribution of a minimum water flow for 30 days and held on an analysis of existing regulations and existing cartographic materials to determine the minimum water flow (Pochaievets et al., 2019; Obodovskyi et al., 2019).

Block «Methods of construction of water runoff spatial distribution maps».

- A method for constructing maps of the minimum water runoff module for mountain rivers has been developed;
- 4 maps of the isolines of modules of minimum water runoff for mountain rivers of 80% of estimated security are constructed:
  - 2 maps of the isolines of modules of minimum water runoff for 30 days (summer-autumn and winter period);
  - 2 maps of the isolines of modules of minimum water runoff for 7 days (summer-autumn and winter period);
- the reliability of the estimate of maps of spatial distribution.

Examples. Consider a typical scheme for constructing maps of isolines of runoff characteristics on the example of mountain rivers. Such maps include maps of the spatial distribution of the coefficient of variation and maps of the isolines of the module of minimum water flow. The open-source product QGIS and SAGA were used to obtain the results. It is also important to note that all source data were taken from open sources or calculated independently (Obodovslyi et al., 2019, 2020; Samoilenko et al., 2018; Lukianets et al., 2021; Korniienko et al., 2020).

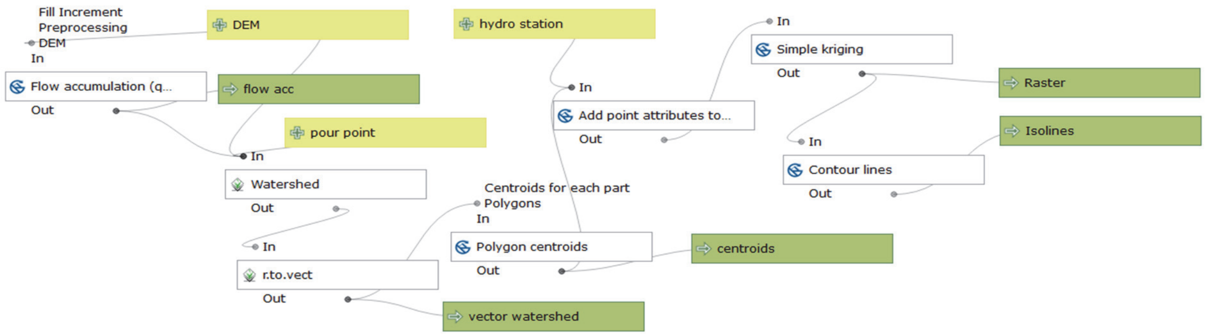

Figure 2 *Agorithm for constructing a map of modules of minimum water runoff in QGIS*

According to the algorithm (Figure 2), with the use of source information (Block Output data) was used terrain information (DEM) and the vector point layer of the hydrological station. At this stage, it is planned to allocate the boundaries of river basins and watersheds in the alignment of hydrological stations. As a result, the data bank is filled with new vector layers. Using the SAGA Terrain Analyzes module, intermediate layers were obtained, such as flow direction layer, flow accumulation, pour point, stream network (river network), basins, and raster watershed.

The convenience of this algorithm is that it is possible to create a catchment area for each element of the hydrographic network and individual hydrological posts. It is necessary to determine the centres of gravity of catchments or centroids of catchments (Polygon centroids) to construct maps of hydrological characteristics. The previously created vector file of catchment basins (Vector watershed) is used as input data. For each centroid of the catchment, their coordinates are automatically determined. For the polygon centres, the calculated data of the minimum modulus of water runoff for 7 to 30 days with 80% exceedance probability in the form of an attribute table and the value of the coefficient of variation were entered for each operating hydrological station. A preliminary analysis was performed, and their values were calculated to present these modules of water runoff in their spatial distribution. The next step is to choose the method of interpolation. It is necessary to consider all available methods of interpolation to choose the one that best describes the distribution of water runoff across the territory. The Simple Kriging method was used. The result is a new raster surface (Raster) with the runoff module data at each point. Next, with the contour lines module's help, isolines are removed with a given step in the form of a vector layer (isolines).

Conclusions. According to the algorithm for estimating the minimum water runoff of mountain rivers, calculations of the Tisza basin's minimum runoff within Ukraine using GIS were performed. As a result, methodological approaches to constructing the spatial distribution of hydrological characteristics of mountain rivers have been developed. The use of GIS made it possible to estimate the spatial distribution of the module of minimum water runoff for 7 and 30 days and their coefficients of variation.

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