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Importance of using space information and GIS technologies in the process of selecting analogue terrains in hydrological research

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Abstract

The research is devoted to the wider application of GIS technologies in hydrological studies, especially in the assessment of water resources of rivers. Runoff formation is a very complex process that occurs under the influence of multiple factors. Studies show that the more flow-forming factors that are considered in the assessment process, the more accurate and reliable the results are. The practice of studying water resources based on the analogy of observed and unobserved river basins is a widespread approach in hydrology. Previously, analogies created on the basis of one or several predictors did not allow to obtain reliable results in the selection of analogue terrains. Modern scientific innovations have enabled more detailed analysis and modeling of runoff-forming processes. With our proposed method, analog geospaces are selected based on the similarity of most components through space information, and assessment is performed using GIS and other multifunctional technologies. Another advantage of the assessment with the new method is the ability to easily restore climate and runoff data for unobserved and extreme regions. Thus, on the basis of basins with hydrometeorological data, it is possible to estimate the water resources of any other unstudied rivers with high accuracy without time-space restrictions. Comparison of the actual and calculated by the proposed method of runoff for most of the river basins of Azerbaijan shows that the error between them was up to 10% in 92 cases out of 100.

1. Introduction

It is impossible to imagine modern scientific research without the use of space imagery and geospatial data. Previously, scientific-experimental researches were mainly carried out by terrestrial visual methods by organizing field expeditions, but now 80-90% of them are performed on the basis of space information. The Earth sciences section is the most widespread field of multi-functional operations performed through geospatial data and GIS technologies. Geoinformation data are also widely used in the field of hydrology, especially in the recovery of hydrometeorological data and the estimation of water resources (Abanish, et al. 2021; Gokhan Cuceloglu, et al. 2017).

2. Method

Our main goal in the submission is to investigate the role of space images and geoinformation during the restoration of hydrometeorological quantities and the assessment of water resources in unobserved areas. For this purpose, a number of traditional and modern methods have been used. Even during the application of traditional methods, the study processing was carried out completely with modern GIS-technologies (Mahmudov and Teymurov 2022). The scientific research process is based on 3 important sources: primary reliable data, modern scientific approach methods and high-precision computing technologies. To obtain accurate results, first of all, it is important to have

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reliable research materials. During the study, information about most of the factors influencing water resources is collected without physical contact of the territory. LULC data (Land use & Land cover) are obtained on the basis of fragments of multispectral (hyperspectral) satellite images. Various difference indices (NDIs) are used to determine the landscape and soil cover, vegetation density, humidity and aridity of the area. The most important of these are indices for vegetation (NDVI), water (NDWI), build-up (NDBI), urban (UI), erosion and bare soil (NDBaI), salinization (NDSI), drought (NDDI) and humidity (NDMI) (Teymurov, 2023).

The heigh, slope, aspect indicators of the relief are determined by the digital elevation model (DEM); and using the Hydrology, Surface and Density program in ArcGIS, the morphometric features of rivers and the range of horizontal and vertical fragmentation of the surface are found. İn procces restoring climate data from traditional methods, the methods of Graphical Relationships, Interpolation and Analogy were used; and modern methods, preference was given to Counter-approach and NDI methods.

3. Results

It is known that all the components that make up natural complexes are closely related and interact with each other. These effects occur in a regular manner, and changes observed in any component are reflected in other components as well. Among the natural components, relief, heat and humidity level have a leading effect. During the study, most of the factors that play a role in the flow-formation and the change in the volume of water resources are taken into account. These factors are divided into 3 groups:

1) **Inputs that make up the surface cover of the territory**. These include LULC (land use & land cover) and HSG (Hydrological soil groups). LULC–is the sum of natural and anthropogenic landscapes characterizing the general appearance of the surface cover of the territory. HSG–is an indicator reflecting the surface runoff and infiltration capacity of soils. According to the granulometric composition, 4 HSG are separated (A, B, C, D). From group A to group D, there is a tendency to weaken infiltration and increase flow. 2) **Morphometric quantities**. These include the relief of the area (height, slope degree, exposure of slopes), river basins area, horizontal and vertical fragmentation of the surface, river network density, etc. includes. 3) **Climate and humidity factors**. These include factors such as air temperature, atmospheric precipitation, actual and potential evaporation, humidity coefficient, maximum water retention of soils, actual soil moisture, hydrological losses, initial abstraction. Flow factors can be combined in 2 groups in terms of obtaining information about them: 1. Geospatial data components that can be obtained through space information. This includes most flow factors. 2. Components restored on the basis of a database of similar locations. It includes climate indicators.

The most widely used methods when studying the water resources of the ungauged areas were the Counter-approach and Analogue terrains selection.

Analogue terrains–are areas with similar physical and geographical conditions between river basins with measurement data and no observations. The functional mechanism of terrains analogy is designed to search unknown elements in areas without data by using the relationship between components (especially in quantitative terms) based on the database of long-term observation areas. The results of long-term observations and artificially created experimental river basins showed that the greater the number of runoff-forming components included in the calculations, the closer the relationship between the components. This thesis showed itself in the higher correlation in the estimation of flow quantities. So, the more similar the physical-geographic conditions in which the flow is formed, if the analogy is made with the maximum number of factors affecting, the flow quantities are closer to each other.

The Counter-approach technology is based on the fact that if most of the flow factors are known, the unknown parameters are recovered from the database of available factors. In other words, when using Counter-approach technology, the research process is performed from the end to the beginning. A suitable place and time to be compared is selected, and the influence of factors is checked individually or by joining them in a complex manner.

At present, it is possible to achieve maximum (sometimes 100%) similarities between river basins through satellite images and modern GIS technologies. Similar terrains are distinguished not only by the complex factors themselves, but also by their different quantitative and gradational limits. As a result, inter terrain analogy sometimes appears in millions of variants during the processing carried out in ArcGIS various calculation, comparison and probabilistic software. Figure 1 shows analogue terrains in the forested areas of the Karabakh region, distinguished by the combination of the forest with other flow-forming factors.

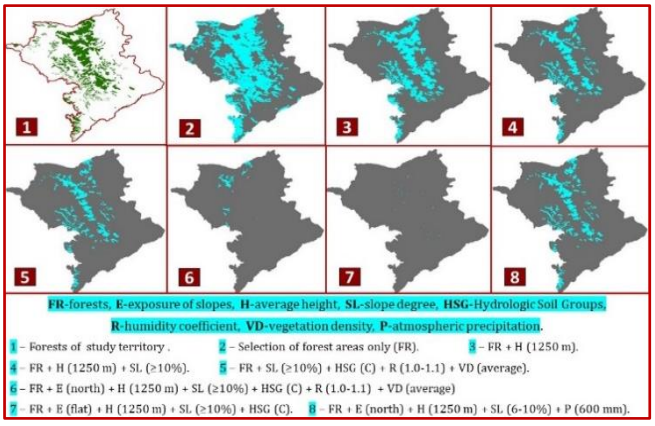

Figure 1. Selection of analogue terrains with the joint participation of various factors

As the intraspecies diversity of components and their quantities change, the number of similar spaces (polygons) decreases. Using ArcGIS program, the number

of similar polygons in the Karabakh region, separated only with the participation of forests, was 388506. Each time a new predictor was added to the processing, the number of analogue terrains changed as follows: average elevation – 142141, slope – 71536, humidity coefficient and vegetation density – 12268, exposure (north) – 1728, flat surfaces – 26. As it can be seen, the geospaces that are similar for most predictors in terms of physical-geographical conditions only within the study area are a minority. Therefore, when selecting similar terrains, no distinction is made for the location of the river basin with measurement data. Thus, the principle of similarity of the same river basin located in the same physical-geographic provinces, different rivers in the same province, rivers located in different provinces and even in other countries can be referred to.

4. Discussion

Currently, the world's fresh water resources are rapidly decreasing. Assessment of water resources is very important in terms of water supply of the economy and population, protection of the existing ecosystem, territorial planning and solving other problems. Through our proposed new method (CWBM), the entire research process is performed without space-time limitations based on satellite images of the area and GIS technologies. CWBM is an innovative and operative-interactive method. The results obtained with it are distinguished by their sensitivity and adequacy to any changes, being of high accuracy. The advantages of the new method make it urgent to promote it and expand the use of its application possibilities.

5. Conclusion

The following scientific innovations were applied for the first time during the assessment of flow-forming factors and water resources: 1. Simultaneous application of new different scientific approaches in the processing process, such as Counter-approach technology and Analogue terrains selection. 2. Participation of complex flow-forming factors in the selection of analogue areas. 3. Adding new predictors such as vegetation density, aspect (exposure of slopes), horizontal fragmentation of the surface, humidity level of territory to the process of selecting similar places. 4. Assessment the impact of each of the flow-forming factors on water resources both separately and together. 5. Separate calculation of the natural and anthropogenic impact on the change in the volume of water resources, etc.

Acknowledgement

Currently, the integration of scientists and fields of science representing different countries, especially the goals of expanding the application of GIS technologies in this process, is one of the most urgent problems of world science. Such international projects serve the exchange of scientific ideas between different countries and the development of science as a whole. We express our gratitude to the initiators of the project and all their hardworking staff for ensuring our participation in this important event.

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