GIS technologies for assessing hydroecological state of rivers in the Aral sea basin

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Abstract. This article analyzes the results of a study on the difficulties and possibilities of using information technology to support the adoption of novel approaches in hydroecology and hydropower. Additionally, it examines the advancement of geographic information systems (GIS) for hydroecological and hydro-technical monitoring and their utilization as educational tools for students. Researching the utilization of information systems to develop environmentally friendly approaches for managing hydraulic infrastructure. The paper centred on the present subject of developing GIS systems for hydro-ecological monitoring, which are valuable tools for improving the information systems of the Aral Sea basin. Furthermore, it assists in optimizing models to create ecologically sustainable approaches for utilizing hydrotechnical constructions. Utilizing the amalgamation of findings from many scientific studies inside a single GIS database may be both feasible and advantageous, serving as a versatile instrument for modeling. An illustration of this methodology may be seen as a unified system where the amalgamation yields outcomes: the water-salt balancing system across all rivers in Uzbekistan. The digital mapping system and schemes are used to build ecologically sustainable methods for operating hydraulic and hydroelectric plants in Uzbekistan. The Aral Sea basin monitoring system (ASBMS) is a computerized system that uses ArcView to monitor the hydroecological quality of surface waters in the Aral Sea basin. Keywords: ecological situation, hydroecology, hydroecological maps, GIS technology, Aral Sea basin.

1 Introduction

The ecological situation in the Aral Sea basin has deteriorated due to agricultural operations' influence on the natural environment. The creation of a system of sustainable agriculture and environmental protection measures should be based on an evaluation of the changes that occur as a result of these impacts. Environmental assessment involves identifying the current and potential alterations in the status of the natural environment that impact both agricultural production and the living conditions of the people.

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Agriculture has a substantial and diverse impact on the environment. There are numerous techniques for computing and assessing different facets of this influence and its level of risk. However, there is only one universally applicable way. The intricate nature of these natural systems, which are impacted by a wide range of natural and human-induced elements, which, in turn, are interconnected and interdependent, accounts for the utilization of several criteria and methodologies in evaluating environmental hazards. Nevertheless, irrespective of the characteristics and types of these linkages, they collectively constitute a collection of distinct environmental circumstances that can be identified, categorized, and prioritized.

2 Material and research methods

Hence, we selected the ArcView GIS system for our work due to its exceptional adaptability in forecasting the condition of water bodies and groundwater in relation to both human-induced and natural influences, utilizing mathematical models or, as commonly acknowledged, Computer Information Technology.

Furthermore, it is essential that the outcomes of mathematical modelling can seamlessly integrate into decision support mechanisms by being readily transferable to the GIS. On the other hand, the modelling system needs to identify and import the necessary GIS data, such as pollutant levels, riverbed morphology, ground elevations, and hydrogeological data, in order to perform calculations. Mathematical models for water bodies must be created by experts in hydrology, hydrogeology, and hydraulic engineering, while professionals in the field should handle professional GIS technology. By successfully integrating a robust mathematical model with a high-quality GIS, it becomes feasible to optimize the impact of the modelling outcomes and broaden the effective range of the GIS.

As an illustration, the advancement of computer technologies in the software products created by the Danish Hydraulic Institute (DHI) occurred through a continuous strategic collaboration with ESRI. Consequently, all DHI software products are connected to ArcView GIS and ARC/INFO, and specific GIS applications have been created by combining ArcView characteristics with DHI mathematical models. Currently, there are several advanced technologies available in the computer information industry that can be utilized in engineering and management practices. They are implemented in the software products below - this is MIKE BASIN - a software tool for planning the management of water resources in river basins (for users of ArcView GIS). MIKE SHE is a 3D computer simulation system for the earth phase of the hydrological cycle - precipitation, surface runoff, snowmelt, evaporation, seepage, hydrogeological processes, transport of pollutants and impurities, the impact of groundwater pumping, etc. MOUSE – Sewerage modeling system – surface runoff, hydrodynamics, sediments, pollution and impurities transfer, water quality, etc. MOUSE GIS – a special GIS application for the MOUSE system, created on the basis of ArcView and intended for visualization of modeling results. MIKE 11 - river modeling - surface runoff, hydrodynamics, hydraulic structures, flooding, dam failures, transport of impurities and pollution, sediment movement (washout and deposition), water quality, eutrophication, heavy metals. MIKE 11 GIS - dedicated modeling system interface [1].

Geographic Information System (GIS) provides a unique opportunity to gain a fresh perspective on the world that surrounds us. GIS, or Geographic Information System, is a contemporary computer system used for mapping and analyzing tangible objects and events occurring on Earth without relying on generalizations or imagery. This technology integrates conventional database functions, such as querying and statistical analysis, with the enhanced visualization and geographical analysis advantages offered by maps. GIS stands out from other information systems due to its distinct capabilities, which offer exclusive opportunities for analyzing and predicting various phenomena and events in the world. It allows for understanding and emphasizing the main factors and causes, as well as their potential
consequences while aiding in the planning of strategic decisions and assessing the immediate outcomes of actions taken. The practices of cartography and geospatial analysis have a long history. GIS technology offers a contemporary and efficient way to assess and solve problems that affect humanity as a whole, as well as specific organizations or groups of people. It gives convenience and speed in problem-solving. It streamlines the process of analyzing and predicting. Before the advent of GIS, only a select few have the skill of extrapolating and thoroughly examining geographical data to arrive at well-informed conclusions using contemporary methods and technologies.

Utilizing GIS technologies, specifically the ArcView GIS software, enables you to carry out diverse scientific tasks while developing ecological maps effectively. This allows you to visually and comprehensively present, investigate, and analyze the geographically collected data in a user-friendly and visually appealing manner. Hence, the word GIS, which stands for geographic information system, provides a comprehensive description of the fundamental nature of this software. The map is widely recognized as the most comprehensive and visually effective tool for analyzing spatial relationships. GIS enables the visualization of ecological changes over time through cartographic images. Thus, when addressing our issues, ArcView GIS promptly offers a pre-existing array of capabilities that may be readily utilized to generate several diverse maps.

Further details can be acquired from ESRI (USA) via the Internet. ArcView allows users to retrieve data stored in shapefile format (specifically, the ArcView format) and utilize data in several other formats. ArcView can be utilized to generate personalized geographic data. Using GIS technology, you can access and see an already-created ArcView project.

• Choose geographical characteristics portrayed on the map
• Enlarge the view of the specific area you are interested in
• Identify and label the objects represented on the map
• Gain entry to the database. Generate a map that includes a title, legend, and scale bar.

Adding tabular data to a pre-existing map is a straightforward task, but its impact is significant. Hydroecological issues often require prompt and appropriate interventions, and the efficiency of these interventions is strongly linked to the efficiency of processing and delivering information. This is where GIS comes in. It enables the creation of complex thematic electronic maps and enhances information assistance for making ecologically critical decisions at all levels of government administration. So, the next time you're working on a map, remember that adding tabular data is not just a task, it's a crucial step towards effective decision-making.

3 Results and their discussion

Our work is centred around a set of intricate digital hydro-ecological maps of the Aral Sea basin. These maps are accompanied by a database that holds detailed information about the hydro-ecological condition, specifically regarding hydrochemical pollution. Additionally, we have developed tools to calculate and visualize comprehensive indicators using diverse spatial data. The ecological monitoring map of the Aral Sea basin includes hydrochemical data from 2010 to 2015. This data is displayed in two formats: diagrams and tables. By clicking on the observation point with a computer mouse, users can get the corresponding results. Figure 1 displays an illustrative digital map representing the initial stage of hydroecological monitoring for the rivers within the Aral Sea basin.
Fig. 1. An example of using GIS technologies to assess the hydroecological state of the rivers of the Aral Sea basin (numbers of gauging stations are indicated on the diagram)

Maps of hydroecological monitoring on a paper basis at a scale of 1:1000000 and a database of attributive information on the hydrochemical state of the Aral Sea basin were used as primary documents.

In the compiled map, almost all methods were used, depending on the task of the study and the available data.

Hydroecological zoning is a method that analyzes the geographic and alchemical aspects of a basin to assess its natural and reclamation conditions. This method considers both natural and human-induced elements [2-3].

In order to develop a methodology for hydro-ecological monitoring, we started by analyzing the following indicators:
- Exceeding the maximum permissible concentration (MPC) of mineralization and main ions.
- Exceeding the MPC of all considered substances.
- The amount of annual collector-drainage runoff from irrigation areas that flow into the Amudarya River.
- The level of river water pollution was evaluated using the NIIIIVP method at TIIAME.
- Areas were identified based on the primary factor causing pollution, such as collector-drainage, industrial, or domestic water.

When developing a hydroecological monitoring methodology, we considered the influence of collector-drainage flows and industrial wastewater. Utilizing mathematical cartography modelling and a computer data bank significantly streamlines the zoning procedure. Hydrochemical indicators are validated by observing changes over time. Maps are created using long-term data averages, considering hydrological phases such as low water and high water.

4 Conclusion

The use of GIS technology and optimization models can efficiently solve the following problems in developing ecologically appropriate operating modes for hydraulic structures and hydropower facilities: The aim is to determine the laws and properties governing the progression of hydrological and hydrochemical processes in the Amu Darya and Syr Darya River basins and to evaluate their influence on hydraulic structures. Furthermore, the objective is to ascertain the significance of hydro-ecological monitoring in evaluating water
quality, which involves a complete assessment of the combined impacts of human activities and physical-geographical elements on the formation of water quality. Develop a hydro-ecological classification system that takes into account several factors, such as socio-demographic, economic, hydrochemical, and other variables that impact the hydro-ecological state. Furthermore, provides a collection of innovative hydroecological mapping methodologies utilizing GIS technology. Develop precise mathematical models for hydraulic and hydrological systems to precisely assess the possibility of improving the operating efficiency of hydraulic infrastructure. Develop a decision support system utilizing it. Producing practical recommendations for addressing various scientific and practical problems related to environmental goals and assessing natural resources.

The majority of the approaches listed below were employed in developing the methodology for hydro-ecological monitoring:

Cartographic diagrams employ a technique that involves the placement of different types of diagrams at specific sites or areas. These diagrams represent the overall concentration of specific chemical components in water within various river basins and specific monitoring stations. They can be categorized as linear, areal, or structural diagrams.

- The qualitative background method involves dividing the mapped area into homogeneous areas.
- The isoline method is used when there is a continuous field with smooth changes in the properties of the mapped component.
- Another method that can be used is the off-scale signs method, which is used to depict pollution sources, population morbidity, and other similar factors.

References