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Methods for Assessing Flood-Prone Areas

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ABSTRACT

Assessing flood risk is essential for disaster prevention and land-use planning. This study examines techniques employed in developed countries to identify areas susceptible to flooding. The evaluation emphasizes hydraulic and hydrological modeling methods, the combination of Geographic Information Systems (GIS) with remote sensing data, and the impact of climate change on flood hazard evaluations. The integration of GIS, hydrodynamic modeling, and remote sensing enhances the precision of risk assessments and fosters sustainable management practices.

Key words: *flood hazard, GIS, hydrodynamic modeling, risk assessment.*

Introduction. Flooding ranks among the most common natural disasters, leading to significant human, economic, and environmental damage each year. The World Meteorological Organization (2023) reports that floods represent nearly 40% of all natural calamities globally. The rise in both the frequency and severity of flood occurrences is closely associated with climate change, rapid urban sprawl, and deforestation, which disrupt natural runoff and drainage systems. As a result, accurately identifying and evaluating areas susceptible to flooding has become a crucial aspect of contemporary hydrological research and disaster risk management.

In recent decades, there has been considerable advancement in modeling and mapping flood hazards. Countries with developed economies, including the United States, the United Kingdom, Germany, the Netherlands, Japan, and Australia, have adopted sophisticated hydrodynamic models, Geographic Information Systems (GIS), and remote sensing technologies to evaluate and anticipate flood risks [1]. These technologies enable researchers and policymakers to simulate various flood scenarios, assess water depths during inundation, and devise strategies for preventive infrastructure.

Conversely, many developing regions still depend on simplified empirical methods and limited hydrometric data for flood risk assessments. Integrating advanced modeling techniques into national flood management systems continues to pose a significant challenge. This study seeks to summarize and compare globally recognized methods for assessing flood-prone areas, with a focus on their relevance to the circumstances in Azerbaijan and comparable hydrographic environments. This research enhances the understanding of effective flood risk assessment methods and offers perspectives on tailoring global experiences to meet local requirements.

Methods and Data. The evaluation of areas vulnerable to flooding utilizes a combination of hydrological and hydraulic modeling, remote sensing, and Geographic Information Systems (GIS). This research involved a review and comparison of international methodologies employed in various developed nations. The analysis was bolstered by secondary data collected from scientific publications, institutional reports, and publicly available hydrological databases [2].

Hydrological Modeling. Hydrological models replicate rainfall–runoff dynamics to forecast the volume and timing of surface water flows. Among the most commonly used models, HEC-HMS (Hydrologic Modeling System) created by the U.S. Army Corps of Engineers is a key model in the United States. In Australia, the ARR (Australian Rainfall and Runoff) guidelines establish standardized approaches for calculating design floods based on regional precipitation information [3]. These models depend on meteorological inputs, characteristics of the catchment area, and soil infiltration variables.

Hydraulic Modeling. Hydraulic models illustrate the physical dynamics of water movement in rivers and floodplains. The one-dimensional (1D) and two-dimensional (2D) Saint-Venant equations serve as the mathematical basis for such models:

$$\frac{\partial Q}{\partial x}+\frac{\partial A}{\partial t}=0,\quad \frac{\partial Q}{\partial t}+\frac{\partial}{\partial x}\left(\frac{Q^2}{A}+gAh\right)=gA\left(S_0-S_f\right)$$

where Q – discharge, A – flow area, t – time, x – distance, h – water depth, S_0 – bed slope, and S_f – friction slope.

Widely used software includes HEC-RAS (USA), MIKE FLOOD (Germany), INFOWORKS ICM (United Kingdom), and SOBEK (Netherlands). These tools allow simulation of flood propagation, inundation mapping, and evaluation of protective structures.

GIS and Remote Sensing Integration. The combination of GIS and remote sensing technologies enhances spatial accuracy in flood risk assessment. LiDAR (Light Detection and Ranging) and satellite-based Digital Elevation Models (DEM) are frequently used to derive topography and surface characteristics. By overlaying hydrological results with land-use and population density data, researchers can determine the potential exposure and vulnerability of flood-prone areas [4, 5].

Data Sources and Limitations. Hydrological and meteorological data were referenced from global databases such as NOAA, NASA, and the European Space Agency (ESA). The comparative analysis focused on the methodological frameworks rather than specific field observations. Lack of data and model parameter uncertainty remain major limitations, especially in developing regions such as the South Caucasus.

Comparative Analysis of International Approaches. Different countries have developed distinctive frameworks for evaluating and managing flood-prone regions based on their climatic, topographic, and institutional conditions. Table 1 summarizes the main approaches and tools applied in selected developed countries.

Table 1. Comparative overview of flood risk assessment methods in developed countries.

Country	Main Tools/Models	Core Features
USA	HEC-RAS, HEC-HMS, FEMA Flood Maps	Integration of hydrological and hydraulic models; standardized national flood mapping; real-time data assimilation.
United Kingdom	INFOWORKS ICM, ISIS, Flood Map for Planning	Advanced 2D modeling; focus on urban flooding and climate change impact.
Germany	MIKE FLOOD, Hydro_AS-2D	Compliance with EU Floods Directive; probabilistic hazard mapping.
Netherlands	SOBEK, Delft-FEWS	Coupled river–coastal flood modeling; integration of remote sensing and sensor networks.
Japan	2D/3D hydrodynamic models, radar data	Emphasis on short-term flood forecasting; integration of rainfall radar and real-time telemetry.
Australia	TUFLOW, XP-RAFTS, ARR Guidelines	Designed for flash floods; regionalized rainfall–runoff estimation.

A review of international practices shows that both the United States and the Netherlands operate highly advanced flood management systems, where real-time hydrological monitoring is closely linked with hydraulic modeling and public risk communication. In the United Kingdom, flood hazard assessment is strongly integrated into land-use and spatial planning through the frameworks established by the Environment Agency. In Germany, the mapping and classification of flood risks are conducted under legally binding procedures consistent with the European Floods Directive (2007/60/EC). Japan, in turn, places particular emphasis on the use of modern technologies to strengthen its early warning and forecasting capacities. Meanwhile, Australia's approach is shaped by its predominantly arid climate, focusing on methods tailored to the modeling of short-duration flash floods in smaller catchments.

Overall, these countries share several common principles:

1. The use of 2D/3D numerical models for hydraulic simulation.
2. GIS-based flood hazard mapping for planning and emergency response.
3. The inclusion of climate change scenarios and probabilistic analysis in flood forecasts.
4. Public access to flood maps and open data portals to enhance community resilience.

These practices form a methodological foundation for countries aiming to improve their flood risk assessment frameworks. The adaptability of these methods depends on data availability, computational resources, and institutional coordination.

Discussion. The comparative analysis of international methodologies demonstrates that the efficiency of flood risk assessment strongly depends on the integration of data, modeling precision, and institutional coordination. Developed countries apply a combination of hydrological, hydraulic, and geospatial tools that enable dynamic flood forecasting and high-resolution hazard mapping. These systems not only improve prediction accuracy but also give a chance to prepare and make awareness for public beforehand.

Studies have shown that two- and three-dimensional hydrodynamic models such as HEC-RAS, SOBEK, and MIKE FLOOD are key tools for providing realistic simulations of flow processes in the design of dams, reservoirs, and early warning systems. However, the reliability of these model results is directly related to the availability of detailed topographic data (e.g., LiDAR-based DEMs) and continuous hydrometric observations. The application of GIS technologies allows for a clear description of hazard zones, the degree of population exposure to risk, and the level of vulnerability of important infrastructure elements, which supports scientifically based land use decisions [6, 7, 8].

However, existing systems also have certain limitations. In many cases, the hydrological observation data required for model calibration are insufficient, or the lack of long-term observation series reduces the accuracy of the results. Also, the application of modeling parameters obtained for one basin to another creates additional uncertainties. Climate change also complicates this process, as traditional models cannot always adequately reflect changing rainfall intensity and frequency patterns.

Countries with limited hydrological and topographic data should use a hybrid approach. This means using statistical and remote-sensing methods along with physically based hydrodynamic modeling to fill in gaps in the data. Adapting international tools like HEC-RAS and MIKE FLOOD to work in certain areas, with the help of national GIS databases, could make it much easier to figure out how likely floods are to happen in those areas. Working with research institutions and platforms that let people share data would also make the overall flood management framework stronger [9, 10].

Conclusion. A comparative review of global approaches to flood-prone area assessment highlights the successful practices adopted in several advanced countries, including the United States, the United Kingdom, Germany, the Netherlands, Japan, and Australia. Findings suggest that integrating hydrological and hydraulic models with GIS and remote sensing tools greatly improves both the precision and reliability of flood hazard mapping. The use of two- and three-dimensional hydrodynamic modeling enables more realistic simulations of water movement, while the incorporation of LiDAR and satellite-derived data ensures an accurate representation of surface topography.

The comparative analysis highlights that the most successful systems are those supported by comprehensive data management, real-time monitoring, and institutional cooperation. For Azerbaijan, especially for the areas along the Kura River, implementing hybrid methods that incorporate international modeling tools (like HEC-RAS and MIKE FLOOD) along with local GIS data can improve flood risk assessment capabilities. Utilizing these approaches will aid in sustainable spatial planning, infrastructure protection, and disaster risk mitigation at the national level.

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წყალდიდობისადმი მიდრეკილი ტერიტორიების შეფასების მეთოდები

ჰ. ჰუსეინოვი, ვ. ალიევი

რეზიუმე

წყალდიდობის რისკის შეფასება გადამწყვეტი მნიშვნელობისაა კატასტროფების პრევენციისა და მიწათსარგებლობის დაგეგმარებისთვის. ეს კვლევა იკვლევს განვითარებულ ქვეყნებში წყალდიდობისადმი მიდრეკილი ტერიტორიების იდენტიფიცირებისთვის გამოყენებულ მეთოდებს. შეფასება ფოკუსირებულია ჰიდრავლიკურ და ჰიდროლოგიურ მოდელირების მეთოდებზე, გეოგრაფიული საინფორმაციო სისტემების (GIS) დისტანციური ზონდირების მონაცემებთან კომბინაციაზე და კლიმატის ცვლილების გავლენას წყალდიდობის საფრთხის შეფასებაზე. GIS-ის, ჰიდროდინამიკური მოდელირებისა და დისტანციური ზონდირების ინტეგრაცია აუმჯობესებს რისკის შეფასების სიზუსტეს და ხელს უწყობს მდგრადი მართვის მეთოდების დანერგვას.

საკვანძო სიტყვები: წყალდიდობის საშიშროება, GIS, ჰიდროდინამიკური მოდელირება, რისკის შეფასება.

Методы оценки территорий, подверженных наводнениям

Х. Гусейнов, В. Алиев

Резюме

Оценка риска наводнений имеет решающее значение для предотвращения стихийных бедствий и планирования землепользования. В данном исследовании рассматриваются методы, используемые в развитых странах для выявления территорий, подверженных наводнениям. Особое внимание в оценке уделяется методам гидравлического и гидрологического моделирования, сочетанию географических информационных систем (ГИС) с данными дистанционного зондирования и влиянию изменения климата на оценку опасности наводнений. Интеграция ГИС, гидродинамического моделирования и дистанционного зондирования повышает точность оценки риска и способствует внедрению методов устойчивого управления.

Ключевые слова: опасность наводнений, ГИС, гидродинамическое моделирование, оценка риска.