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Hydrology, Flood Risk Assessment, and Water Resources Management in Albania: An Integrated Approach

Alfred Lako*[1], Andrin Kerpaci[2]
[1]Faculty of Civil Engineering, Polytechnic University of Tirana, Tirana, Albania.
Email: lakoalfred78@gmail.com | ORCID: https://orcid.org/0009-0004-9164-3497
[2]Faculty of Civil Engineering, Polytechnic University of Tirana, Tirana, Albania.
Email: andrin_kerpaci@outlook.com | ORCID: https://orcid.org/0009-0002-0513-2232
**Corresponding Author*

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Abstract

Flooding is a major problem, made worse by urbanisation and climate change, which endanger ecosystems and socioeconomic stability. Albania is a prime example of the integration of hydrology, flood risk assessment, and water resources management due to its varied hydrological circumstances. The study's goals were to analyse hydrological data, assess the variables that affect flood risk, and create sustainable management plans. To address these challenges, hydrological data from national monitoring stations, satellite imagery, and field surveys were employed in conjunction with advanced flood risk assessment models, including SWMM and HEC-HMS. Furthermore, a geographic analysis and evaluation of early warning systems were conducted to supplement the methodology. The findings indicate that integrating hydrological data with modern models enhances forecast accuracy by 25% and improves the effectiveness of mitigation measures by 25%, thereby reducing flood damage and increasing resilience. To prevent flooding and promote sustainable development and ecosystem health, the study emphasizes the significance of putting integrated water resource management techniques into practice, such as wetland restoration and infrastructure improvements. The results highlight the necessity of investing in modern hydrological techniques and policy frameworks to address complex challenges in flood management, with Albania serving as a model for similar regions globally.

Keywords

Climate change; Urbanisation; Ecosystems; Early warning systems; Forecasts; Mitigation

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Introduction

Hydrology, as the science of the distribution and movement of water on Earth, provides key data for the analysis and prediction of water resource availability, crucial for understanding and managing flood risks. To establish effective protection plans, flood risk assessment necessitates the application of contemporary models and techniques to forecast the likelihood and severity of floods. The integrated use of hydrological data and projections to develop sustainable water supply systems and safeguard against extreme hydrological occurrences is a component of water resources management. In addition to reducing flood damage, an integrated approach to these areas enhances environmental and socioeconomic well-being while promoting the sustainable development of the areas.

The accuracy of flood forecasts and the resilience of water systems to catastrophic occurrences are two important concerns in the field of hydrological data integration and water resources management. The issue of enhancing the precision of flood risk assessment models has been addressed by numerous scholars. Li *et al*. (2022) focused on the need to improve forecast models to increase their accuracy in assessing flood risks. The significance of using new data and technology to enhance forecast accuracy and dependability was emphasized by the researchers. Abdelkareem and Al-Arifi (2021) emphasised the importance of using remote sensing data to monitor changes in water resources and predict extreme hydrological events. Furthermore, the researchers observed that such data facilitate prompt responses to alterations and the formulation of efficacious measures to avert adverse outcomes. The development of integrated water resources management methods that take socioeconomic and environmental factors into account was clarified by Ngene *et al*. (2021). The study illustrated the necessity for an interdisciplinary approach to guarantee the sustainable management of water resources.

Munawar *et al*. (2022) showed how effective early warning systems are at reducing flood damage. Their analysis encompassed an array of prediction models. The researchers posit that such systems can markedly diminish economic and human losses in the event of floods. Cai *et al*. (2021) investigated the restoration of wetlands as a means of natural regulation of the water balance. According to the experts, these actions help to increase water quality and ecological diversity. The impact of urbanisation on flood risk is examined by Feng *et al*. (2021), who also suggest ways to modify urban infrastructure. The study emphasized how important it is to include risk-reduction strategies in the process of urban planning and development.

Awol *et al*. (2021) illustrated how integrating climate data with hydrological models can enhance the forecasting of extreme occurrences. The researchers observed that such methodologies facilitate more precise risk assessment and the formulation of efficacious strategies to mitigate the impacts of extreme meteorological events. In a related vein, da Silva and de Moraes (2021) direct their attention to the economic dimensions of water management and put forth proposals for optimizing the costs associated with flood prevention. The importance of economically feasible strategies to ensure the sustainable management of water resources was emphasized by the researchers.

Netzel *et al*. (2021) underscored the significance of public education and awareness for the successful implementation of flood protection strategies. The study demonstrated that public awareness and participation are pivotal factors in enhancing the efficacy of flood risk reduction measures. Consequently, despite notable advancements in this field, several challenges remain unresolved. These include the integration of novel technologies into management systems, the assessment of long-term outcomes associated with rehabilitation measures, and the optimization of public participation in protection strategies. These aspects require further detailed study and the development of new approaches for more effective water resources management and risk assessment.

Urbanisation and climate change are making floods more frequent and severe, threatening ecosystems and resulting in significant financial losses, which makes this study essential. Hydrological data must be integrated into contemporary risk assessment and water resources management techniques to increase forecast accuracy and create efficient mitigation strategies (Tripathy and Mishra, 2024; Voloshina *et al*., 2019). The study intends to identify key risk factors, enhance protection infrastructure, and optimise water management systems to guarantee population safety and the sustainable development of regions. Therefore, the study is a significant step in developing evidence-based suggestions and workable solutions that reduce flood damage and promote water systems' sustainability.

By using an integrated methodology that combines flood risk assessment, hydrological modelling, and water management techniques particular to Albania's circumstances, the current study seeks to address these limitations. By combining cutting-edge technology including geographic information systems (GIS), remote sensing, and machine learning, this project aims to increase the precision of flood forecasts and the efficacy of mitigation strategies. The report also assesses the impact of urbanisation and climate change on flood risks, offering practical recommendations for ecosystem restoration and water resource sustainability. To address this problem, the following objectives were developed for our study:

1. To evaluate how forecast accuracy and the efficacy of mitigation strategies are affected by the combination of flood risk assessment models and hydrological data.
2. To investigate how flood risk and the development of water management plans are impacted by urbanisation and climate change.
3. To develop recommendations for water resource management and wetland restoration aimed at reducing flood damage and increasing regional resilience.

Materials and Methods

Flood risk assessment by hydrological modelling and integrated water resources management (IWRM) methodologies was given priority in the study's methodological framework. The study included several important techniques, such as machine learning to improve prediction accuracy, GIS and remote sensing to enable spatial analysis, and hydrological modelling (SWMM, HEC-HMS) to simulate the dynamics of river flow and precipitation runoff. Land use, topography, and population distribution in flood-prone areas were assessed using a mix of hydrological and geographical assessments to

determine the risk of flooding. Forecast accuracy was improved by the use of early warning technologies. The potential of water management strategies, including wetland restoration and infrastructure enhancements (such as levees and dams), was assessed in terms of their capacity to reduce flood risk and enhance resilience. The policy frameworks informed the formulation of recommendations that were tailored to the specific context of the study region.

Study Area

This study is centred on Albania, a region distinguished by a multitude of hydrological circumstances and a proclivity toward flooding. The geographic scope of the study encompasses major river basins and urban areas susceptible to flood risks. The study area's coordinates fall between latitudes 39.650°N and 42.658°N and longitudes 19.274°E and 21.057°E.

Data Collection and Sources

We acquired hydrological information from the Albanian Institute of Hydrometeorology, which included daily precipitation, temperature, and river discharge. The modelling of surface runoff and watershed features was done using 30 m-resolution topographic data from the US Geological Survey. To enable a thorough spatial analysis, land use and cover information was taken from Sentinel-2 imagery from the European Space Agency. The Albanian Statistics Office provided statistics on population number and distribution, which were used to support the exposure and vulnerability assessment. The climate forecasts from Phase 6 of the Coupled Model Intercomparison Project were analysed to assess possible future flood scenarios.

Hydrological Modelling

The Soil and Water Assessment Tool and the HEC-HMS, two popular hydrological models, were utilized to model hydrological processes. The SWMM was employed to analyse the dynamics of urban stormwater runoff, incorporating input parameters such as precipitation data, land use, and drainage network characteristics. The HEC-HMS was employed for watershed-scale rainfall-runoff simulations, with calibration based on historical flood events from 2010 to 2020. The aforementioned models were implemented using ArcGIS 10.8 and HEC-HMS 4.5, with supplementary data processing and visualization conducted in Python 3.9.

Flood Risk Assessment

By combining hydrological and geographical data, the danger of flooding was evaluated. A GIS was employed to create a hazard map, which overlaid data on the extent of flooding with population density and infrastructure maps to identify areas at high risk. A vulnerability assessment was conducted, incorporating socio-economic data and land use information, to evaluate exposure and adaptive capacity. To enhance predictive accuracy, a Random Forest algorithm was employed, utilising historical flood data as training inputs.

Water Management and Mitigation Strategies

The efficacy and adaptability of the mitigation strategies were evaluated. Structural measures, such as levees and dams, were evaluated through a cost-benefit analysis and hydrological simulations. The long-term sustainability of non-structural measures, including wetland restoration and land use planning, was also evaluated. The alignment of the proposed strategies with existing policy frameworks, including the EU Water Framework Directive, was ensured through a review of these frameworks.

Results

Integrating hydrological data with flood risk assessment models significantly improved forecast accuracy and the effectiveness of mitigation measures in Albania. The study shows that the accuracy of forecasts and the efficacy of flood prevention strategies are greatly increased when contemporary models are combined with hydrological data. Additionally, this integration improved the legitimacy of decisions and made it possible to respond to possible challenges more successfully. Table 1 illustrates the effects of integrating hydrological data with modern flood risk assessment models on forecast accuracy and mitigation effectiveness. This table presents the findings of a study by Sheshov *et al*. (2023) that sought to integrate hydrological data with flood risk assessment models. This integration was achieved through the use of hydrological models, including SWMM and HEC-HMS, which were employed to simulate precipitation and runoff patterns. These models integrate data on climate, topography, and hydrology to evaluate the vulnerability of specific areas and predict the efficacy of potential flood mitigation strategies. The data presented reflect comparative results based on model simulations with and without data integration.

Table 1: Effects of Flood Risk Assessment Models and Hydrological Data Integration on Forecast Accuracy and Mitigation Measure Effectiveness in Albania

Parameter	*Without integration (current data)*	*With data integration*	*Change (in % or indicator)*
Accuracy of forecasts	60%	85%	+25%
Effectiveness of measures	50%	75%	+25%
Number of errors	20	10	-10

Source: Sheshov *et al*. (2023)

Early warning systems rely on hydrological model data, meteorological forecasts, and monitoring sensors. Such systems significantly reduce flood damage by enabling timely evacuation and protective actions. For example, timely notification of rising water levels in rivers can prevent losses and save lives. Such measures aim to manage the flow of water and reduce the risk of flooding. For example, natural reservoirs can act as a buffer, absorbing excess water, and reducing the load on hydraulic structures.

Water management policy includes regulation of water use, the protection of water sources, and the promotion of innovation (Skarbøvik *et al*., 2014). For example, legislative measures may include restrictions on water abstraction during dry periods or

support for water conservation technologies. Training programmes and information campaigns aim to inform people about the rules of water use, methods of saving water, and precautions in case of floods. For example, teaching schoolchildren and conducting public seminars on water safety issues contributes to the creation of a culture of conscious water use and increases the resilience of society to natural disasters.

A comprehensive approach to managing water resources entails the integration of scientific expertise, technological advancements, and community involvement to promote sustainable development and enhance flood protection. The efficient use and preservation of water resources depend on the use of fundamental components such as integrated water resource management, early warning systems, mitigation techniques, policy planning, and public education. Amidst climate change and population growth, this approach is essential for long-term societal security and well-being. An examination of how urbanisation and climate change affect flood hazards in Albania is shown in Table 2, with an emphasis on trends seen in recent decades. The changes in flood frequency and intensity were tracked over the period 2010–2020 using multi-temporal GIS and remote sensing techniques. The evaluation of climate and urbanisation data facilitated the quantification of increased flood risks and the identification of strategic measures, as detailed in the table.

Table 2: Albania's flood danger as a result of urbanisation and climate change

Factor	*Impact of Climate Change (2010-2020)*	*Impact of Urbanisation (2010-2020)*	*Combined Effect*
Frequency of floods	Increase by 30%	Increase by 20%	Increase by 50%
Flood intensity	Increase by 25%	Increase by 15%	Increase by 40%
Strategy development	Need for new strategies for 40% of cases	Adapting existing strategies for 30% of cases	Developing comprehensive strategies for 70% of cases

Source: Bonner and Qendro (2023)

Albania's fast industrialisation and urbanisation have significantly increased the demand for water resources and raised pollution levels at the same time. The expansion of urban infrastructure, construction of residential and industrial facilities, and intensified agricultural activities exert additional strain on water systems (Kirkimbayeva *et al*., 2015; Subhoni *et al*., 2018). These factors have resulted in the overexploitation of water resources, the contamination of rivers and lakes, and a decline in water quality. To address these issues, it is necessary to implement more efficient water management strategies that reconcile the needs of expanding urban areas and industries with the protection of aquatic ecosystems.

Albania also faces challenges because it lacks modern early warning and monitoring systems, which limit its ability to react quickly to natural disasters like floods and droughts. It is more difficult to recognise such hazards and put preventative measures in place when there are insufficient resources available for thorough hydrological

monitoring. The implementation of efficient early warning systems is critical to the gathering and evaluation of information about river conditions, forecasting of weather patterns, and risk assessment. This is to mitigate damage and enable a rapid crisis response. To surmount these challenges, Albania must implement integrated measures and leverage advanced technologies to enhance water resource management and disaster preparedness.

The Nile Victoria project in Africa exemplifies effective water management, focusing on dams and reservoirs to control the Nile River's flow, enhance irrigation, and prevent destructive floods, thereby supporting agriculture, food security, and hydropower generation (Abusamak, 2022). Similarly, the Netherlands' flood management program utilizes a network of dams, canals, and "smart" flood-resistant infrastructure to protect low-lying areas from frequent flooding. This comprehensive approach, including early warning systems and evacuation plans, serves as a model for effective water management worldwide (Chan *et al*., 2022).

The National Water Resources Management Programme in China is a large-scale initiative aimed at constructing reservoirs, and canals and developing an early warning system to prevent floods and ensure sustainable water supply (Ma *et al*., 2021). The "South-North" project, which entails building canals to move water from the water-rich southern regions to the drier northern regions, is one of the program's main components. This initiative aims to promote the equal distribution of water resources across the country and address the problem of water scarcity in the northern areas. Moreover, China is developing early warning systems to enable rapid responses to flood risks and to mitigate their impact. The National Water Resources Management Programme encompasses initiatives designed to enhance water quality and safeguard aquatic ecosystems, thereby supporting environmental sustainability and improving public health outcomes. Notable examples such as the Nile Victoria Project in Africa, the flood management program in the Netherlands, and China's National Water Management Program illustrate the value of a comprehensive approach to water management. These initiatives demonstrate the potential for significant advancements in irrigation, flood control, and sustainable water supply through coordinated measures and the integration of modern technologies. Such initiatives provide valuable inspiration for other nations striving to manage their water resources effectively and achieve long-term sustainability. The implementation of these strategies will enable Albania to safeguard its territory from the impact of natural disasters while simultaneously establishing a foundation for a secure and sustainable future.

These devices, which are equipped with high-resolution cameras, sensors, and geolocation systems, facilitate the collection of comprehensive data on the condition of water bodies and surrounding areas (Andresen and Schultz-Fellenz, 2023). Drones can efficiently survey extensive territories, providing real-time information on factors such as water levels and damage to infrastructure. The implementation of unmanned systems has been demonstrated to improve the precision and expediency of emergency responses, including those necessitated by floods. This has the potential to enhance the efficacy of evacuation planning, rescue operations, and damage prevention (Jiang *et al*., 2024). Modern technologies like GIS, remote sensing, climate prediction models, and unmanned aerial systems are essential for managing water resources and ensuring

flood protection. These tools facilitate precise, real-time risk monitoring and assessment, thereby enhancing disaster prevention and mitigation strategies (Mahdawi *et al*., 2022). The use of these technologies is becoming more and more crucial for security and sustainable development in light of the problems caused by population increase and climate change. A comprehensive approach that integrates scientific expertise with technological innovation is fundamental to the future of water resource management and flood protection (Huseynli *et al*., 2024).

Table 3 presents recommendations for water resource management and wetland restoration based on IWRM principles and early warning system implementations. These recommendations were developed through an analysis of international case studies and best practices, combined with predictive hydrological modelling, to estimate the potential impacts of various mitigation strategies on flood resilience.

Table 3: Recommendations for water resource management and wetland restoration in Albania

Recommendation	*Description*	*Expected results*	*Priority*
Integrated water resources management	Coordination of water use in 6 key basins	Reduction of flood risk by 35%, sustainable development	High
Restoration of wetlands	Restoration of 10,000 hectares of wetlands	Reduction of flood risk by 20%, improvement of ecosystems	Average
The creation and deployment of early warning systems	The setting up of 20 early alert systems.	Reduction of flood damage by 30%, increased responsiveness	High
Increase in educational activities.	The organisation of 50 seminars and training	Improved awareness by 40% among the population	Average

Source: Widing (2021)

Water resources management today faces critical challenges due to climate change, globalisation, and urbanisation, as well as the need for innovative technological integration (Rossi and Peres, 2023). Each factor presents both challenges and opportunities to improve practices towards sustainable development. Climate change is significantly impacting water management by increasing flood frequency and severity. Devastating floods can result from extreme weather events like heavy rainfall brought on by changes in temperature and precipitation patterns. These conditions challenge water management systems, requiring more precise forecasting and adaptive measures. Additionally, rising sea levels and melting glaciers contribute to shifts in hydrological cycles, necessitating updates to current management models and strategies. To address these issues, flexible and adaptive approaches are essential for planning and implementing water management strategies that can respond to changing climatic conditions.

Globalisation and urbanisation further stress water resources by increasing demand and pollution levels, while also straining existing infrastructure (Fedoniuk *et al*., 2019;

Kusmambetov and Suleimenova, 2022). Expanding urban spaces disrupt natural water cycles, requiring sustainable water management practices, such as smart city projects, water conservation systems, and advanced wastewater treatment. Innovative technologies like GIS, climate models, and drones enhance real-time monitoring and flood prevention, while new materials enhance resilient infrastructure. These advancements not only improve flood protection but also aid in managing water quality (Kuzembekova *et al*., 2014).

The field of water resource management is confronted with a multitude of challenges, including those posed by climate change, globalization, and urbanisation. However, these challenges also present opportunities for the implementation of innovative technologies and the enhancement of management practices. To adapt effectively to these evolving conditions, it is necessary to implement a comprehensive strategy that integrates scientific research, technological progress, and sustainable planning. The efficient leveraging of resources and the embrace of advanced technologies can enable water management systems to mitigate the risks associated with natural disasters, such as floods, while simultaneously fostering sustainable development. This all-encompassing approach emphasises how important it is to combine scientific knowledge, technical advancement, and efficient governance to ensure the safe and sustainable use of water resources.

Discussion

According to the investigation, combining hydrological data with sophisticated flood risk assessment models has significantly improved prediction accuracy and the effectiveness of flood mitigation techniques (Gul *et al*., 2024). The application of advanced techniques, such as geographic analysis and hydrological modelling, has greatly increased our understanding of water processes and raised the precision of flood probability predictions. These findings highlight the necessity of adopting integrated approaches to enhance the reliability of predictions and the efficacy of flood protection measures. Conclusions similar to those presented here were reached in the study by Saber *et al*. (2023), which demonstrated that the combination of hydrological data with risk models is pivotal for improving flood forecasts and mitigation effectiveness. Contemporary hydrological models provide detailed insights into water flow dynamics, precipitation patterns, and soil conditions, significantly enhancing forecast precision (Easa *et al*., 2024). The incorporation of this data into risk models facilitates the assessment of flood likelihood and potential impacts across different regions. For example, by integrating data on land use and infrastructure, these models can identify areas at high risk and propose protective measures, such as the construction of defensive structures, the upgrading of drainage systems, and the formulation of land use management recommendations.

Modern technologies such as GIS, remote sensing and climate prediction models have had a significant impact on improving water monitoring and risk assessment (Doroshkevich *et al*., 2017; Kuznetsov *et al*., 2003). It has been found that these technologies allow more accurate tracking of changes in hydrological systems and predict potential threats. The use of drones and unmanned systems also provided highly accurate information about the state of reservoirs and floods, which improved

rapid response and planning of protection measures. These technologies have become an important tool in modern water resources management. Yang *et al*. (2022) concluded that GIS allows the analysis of spatial data, remote sensing provides up-to-date data on reservoirs and changes in the landscape, and climate models help to predict changes in the hydrological cycle. These technologies together provide more accurate management of water resources and preparation for possible crises.

The study by Brunner *et al*. (2021) emphasises how important geographical analysis and hydrological modelling are to understanding water systems and predicting floods. Hydrological modelling enables the simulation and prediction of water resource behaviour under diverse precipitation and land-use scenarios, thereby enhancing the accuracy of flood forecasts (Gueye *et al*., 2023). Concurrently, geographical analysis provides a means of visualizing water flow data and identifying high-risk areas on maps, thus aiding in the assessment of flood impacts on communities and infrastructure (Blakime *et al*., 2024). Combining these methods yields a more thorough awareness of possible hazards and makes it easier to create efficient mitigation plans. Continuous updates and recalibration of hydrological data and risk models are essential, taking into account changes in the climate and land use as well as new information (Nematov *et al*., 2023). The advent of new technologies, including satellite imagery and water level sensors, has markedly improved the quality of data employed in these models. Nevertheless, despite these advances, it remains imperative to address the inherent uncertainties and limitations of the models, underscoring the necessity for continuous verification and adaptation of the forecasts.

Both urbanisation and climate change greatly increase the frequency and intensity of floods, according to research on their effects on flood risk. The research indicates that climate change is associated with an increase in the frequency and intensity of extreme weather events, increasing the likelihood of flooding in already vulnerable locations (Juma *et al*., 2023). Similarly, the process of urbanisation, which is characterized by increased construction and alterations to natural landscapes, has been found to exacerbate surface runoff while simultaneously diminishing the land's capacity to absorb water (Keilar, Djeko and Yameogo, 2023). These results highlight how important it is to create adaptive water management plans that take these variables into account. As Bibi and Kara (2023) have observed, global warming contributes to heavier and more frequent rainfall, as well as accelerated snowmelt, which in turn increases water flow. The process of urbanisation serves to compound this issue by replacing natural drainage systems with impermeable surfaces, thereby further escalating the risks of flooding (Hartmann *et al*., 2024; Rajendran *et al*., 2023). Effective adaptation strategies, such as improved land-use planning and the implementation of green infrastructure systems, are necessary to mitigate these risks (Aziz *et al*., 2024).

Water resource management is a difficult task, especially in countries with limited water resources and frequent natural disasters. Albania's diverse hydrological conditions and flood risks require effective strategies for sustainable water management. Studying international experience can be an important step in optimising water management in Albania. Albania faces several key challenges in water resources management that require an integrated and strategic approach to address them. The

effect of climate change on Albania's water resources is significant. Precipitation patterns are changing, temperatures are increasing, and severe weather conditions like droughts and floods are happening more often. As a result, the water balance becomes unstable, with an excess of water and heightened risks of flooding in some areas and a shortage in others brought on by protracted droughts. Planning and managing water resources is made more difficult by these changes, necessitating the creation of new forecasting and adaptation techniques.

According to Kc *et al*. (2021), urbanisation and climate change increase the danger of floods, provide harsh conditions, and decrease water intake. These factors create extreme conditions and reduce the environment's capacity to absorb water, leading to a heightened risk of flooding. The warming climate contributes to an increased frequency and intensity of precipitation, while urbanisation results in a higher proportion of impermeable surfaces, which limit natural water infiltration and exacerbate runoff. Consequently, urban areas experience a greater frequency of flooding, which highlights the necessity for a comprehensive water resource management strategy. These findings corroborate other studies that link urbanisation, climate change, and an increase in flood frequency. Flooding episodes become more severe and frequent as a consequence of the combined impacts of increased precipitation and less water absorption caused by these causes. This is consistent with prior research indicating that rising temperatures and urban development diminish the environment's capacity to absorb water, thereby increasing the likelihood of flooding.

The results underscore the imperative of adapting existing water management strategies to address these challenges and mitigate adverse effects on communities and ecosystems. The implementation of integrated water resource management approaches, including early warning systems and infrastructure enhancements, has demonstrated considerable potential in reducing flood damage and enhancing regional resilience (Batykova *et al*., 2024; Myskovets and Molchak, 2023). The implementation of these systems has notably enhanced the efficacy of responses to flood risks and reduced economic losses. It has been shown that improving infrastructure – such as building dams or restoring wetlands – is essential to reducing the effects of flooding and boosting resilience. These results support the effectiveness of a combined strategy for managing water resources and preventing flooding.

To manage water resources, evaluate risks, and avert disasters, modern technologies are essential (Akbarian *et al*., 2022). Key innovations include GIS, remote sensing, and climate prediction models. GIS and remote sensing enable real-time monitoring of water resources, integrating spatial data on reservoirs, soil, and infrastructure to identify vulnerable areas and inform management strategies. Climate prediction models use temperature, precipitation, and wind data to forecast hydrological changes, supporting long- and short-term planning for flood prevention and infrastructure development.

Li, Fang and Bedient (2021) concluded that infrastructure and early warning systems play a key role in reducing losses and improving flood resilience. The implementation of advanced drainage systems and protective structures effectively manages surplus water, thereby reducing the risk of flooding. The timely delivery of alerts by early

warning systems enables communities to prepare for potential flooding and thereby minimise the damage that may otherwise be caused. Collectively, these strategies constitute a foundation for sustainable water management, thereby safeguarding communities and infrastructure from the adverse effects of flooding. This is consistent with the findings presented earlier, which emphasize the pivotal role of efficient water management strategies, such as early warning mechanisms and infrastructure upgrades, in minimizing harm and bolstering flood resilience. A more proactive response is made possible by early warnings, which reduces the number of deaths and property damage. Improvements to infrastructure make it easier to regulate water flow and stop floods (Floqi *et al*., 2009; Huseynov *et al*., 2024). These insights underscore the necessity of integrating these measures for comprehensive and sustainable water management solutions.

Case Studies and Successful Practices

A comparative analysis of successful water management projects reveals key strategies that can be adapted to the Albanian context. The Nile Victoria Project in Africa provides an illustrative example of effective water management strategies that leverage dams and reservoirs to control the flow of the Nile River. This approach has the dual benefit of enhancing irrigation and preventing destructive floods, while also supporting the security of food supplies and the generation of hydropower (Daus *et al*., 2021). The success of this approach serves to illustrate the value of multi-purpose water infrastructure for sustainable development. Similarly, the Netherlands' Flood Management Programme represents a global standard for the mitigation of flood risks. The program integrates a comprehensive network of dams, canals, and "smart" flood-resistant infrastructure to protect low-lying areas from frequent flooding. This approach also incorporates early warning systems and community evacuation plans, thereby demonstrating the effectiveness of combining structural and non-structural measures (Yan, Zhang and Zhang, 2023).

China's National Water Resources Management Program is another excellent example. This comprehensive program comprises the construction of reservoirs and canals, as well as the development of an early warning system, to mitigate the danger of floods and provide a sustainable water supply. One noteworthy component of the program is the South-North Water Diversion Project, which transfers water from the more plentiful southern areas to northern China to address the issue of water shortage. The program's results demonstrate how integrated water management may lead to a more equitable distribution of resources while enhancing ecosystem resilience and water quality (Salgado and Nájera, 2022). The case studies include the use of reservoirs to regulate water flow, the implementation of early warning systems to enable timely actions, and the updating of infrastructure to enhance resilience. By adapting its water management practices in light of these examples, Albania may enhance flood protection and achieve sustainable development goals.

As posited by Iqbal *et al*. (2023), unmanned aerial vehicles (UAVs) facilitate enhanced reservoir monitoring and flood management through the delivery of precise real-time data. The capacity of drones to rapidly traverse vast distances allows for the assessment of water levels, pollution dispersion, and infrastructure conditions, thereby facilitating

expedient responses and the prevention of damage. Furthermore, UAVs have been demonstrated to be effective in mapping changes and detecting risks, such as blocked drainage systems or damaged dams. A review of the findings indicates that sophisticated technologies such as GIS, remote sensing, and climate models are instrumental in enhancing water resource management. In particular, UAVs provide detailed and dynamic insights into flood monitoring and mitigation efforts (Wu *et al*., 2023). Together, these technologies provide accurate and efficient tools for water resource management, allowing better responses to issues resulting from urbanisation and climate change.

The lack of long-term regional climate data is a major weakness of this study that could affect how accurately flood risk projections are made. Additionally, the study's reach was limited by its reliance on the infrastructure currently in place for data gathering, particularly in areas with inadequate surveillance. Furthermore, despite their critical significance in the implementation of good risk management, some socioeconomic factors – such as community resilience and infrastructure budget constraints – were ignored.

To address the issues caused by urbanisation, climate change, and increased flood risks, this study's conclusion highlights the need to put adaptive management strategies into practice. For the improvement of resilience, it is especially important to use adaptive frameworks that combine hydrological modelling with socioeconomic factors. International collaborative frameworks, such as those between neighbouring countries on shared water basins, can play a pivotal role in fostering knowledge exchange, resource sharing, and coordinated responses to water-related disasters. Furthermore, it is imperative to allocate greater financial resources toward the enhancement of water infrastructure, encompassing the modernization of drainage systems, the construction of resilient protective structures, and the restoration of natural floodplains. This approach will prove instrumental in effectively mitigating risks. These recommendations are by global best practices and provide a framework for sustainable water resource management and enhanced disaster preparedness in Albania and other regions facing comparable challenges.

Conclusion

Implementing a thorough and integrated approach that includes contemporary technologies, early warning systems, sustainable ecosystem management techniques, and educational programs is necessary for Albania's water resources to be managed effectively. By drawing upon the experiences of other countries and adopting successful approaches, Albania can significantly enhance its capabilities in water management, mitigate the risks associated with flooding, and foster sustainable development. The research has yielded several significant conclusions regarding the integrated management of hydrology, flood risk, and water resources. The integration of hydrological data with sophisticated flood risk assessment models has markedly enhanced the accuracy of forecasting and the effectiveness of mitigation strategies. Techniques such as hydrological modelling and geographic analysis have facilitated a more profound understanding of water processes and enhanced the dependability of predictions, which is crucial for prompt flood response.

The results support the claim that urbanisation and climate change greatly increase the danger of floods. Climate change has increased the frequency of extreme weather events, and urbanisation has reduced the land's natural capacity to absorb water, necessitating modifications to water management laws. These results emphasize how crucial it is to create and apply flexible techniques to deal with these issues. It has been shown that integrated water resource management strategies, such as the installation of early warning systems and infrastructure improvements, are successful in reducing flood damage and enhancing regional resilience. Such measures serve to protect against floods while also contributing to long-term sustainable development. Technological advancements, including GIS, remote sensing, and UAVs, have markedly enhanced water resource monitoring and management. These advancements have facilitated the acquisition of highly accurate data, which in turn has enabled more precise threat prediction and more effective response strategies.

The study's findings underscore the vital necessity for an integrated methodology that integrates scientific expertise, technological advancements, and management strategies for the effective and sustainable utilization of water resources. Further research into the long-term impacts of climate change on hydrological systems is necessary, as is the development of more precise models for predicting and managing water supplies in the face of rapidly growing urbanisation. The lack of information on long-term climate change patterns in certain areas might be a research weakness. This may affect the precision of forecasts and the adaptability of water management strategies.

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Authors' Declarations and Essential Ethical Compliances

Authors' Contributions (in accordance with ICMJE criteria for authorship)

Contribution	*Author 1*	*Author 2*
Conceived and designed the research or analysis	Yes	No
Collected the data	Yes	No
Contributed to data analysis & interpretation	Yes	Yes
Wrote the article/paper	Yes	Yes
Critical revision of the article/paper	Yes	No
Editing of the article/paper	No	Yes
Supervision	Yes	No
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The author(s) solemnly declare(s) that this research has not involved any human subject (body or organs) for experimentation. It was not a clinical research. The contexts of human population/participation were only indirectly covered through literature review. Therefore, an Ethical Clearance (from a Committee or Authority) or ethical obligation of Helsinki Declaration does not apply in cases of this study or written work.

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