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A Review on the Flood Managing: from flood control to flood resilience in Makoran, Sooran and Saravan districts, Sistan and Balochestan, Iran

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ABSTRACT: *Floods are among the most destructive natural disasters, presenting significant challenges due to their unpredictability and complex behavior. This study develops a robust flood prediction framework for the River Neheng and Mashkid Rivers, Iran, by integrating traditional statistical methods with advanced machine learning models. Climate change and socioeconomic developments are increasing the frequency and severity of floods. In recent decades, climate change is exacerbating meteorological disasters around the world, causing more serious urban flood disaster losses. Many solutions in related research have been proposed to enhance urban adaptation to climate change, including urban flooding simulations, risk reduction and urban flood-resistance capacity. Flood management is widely recognized as an effective way to reduce the adverse consequences, and a more resilient and sustainable flood management approach has been the goal in recent studies [1]. This study used a detailed bibliometric analysis of keywords, terms and timelines in the research field of the flood research. It provides new insight into the flood research trends, by examining the research frontiers from 2018 to 2021. We conclude that the trend of flood research has experienced a transition from flood control to flood resilience. The review shows that flood research has moved from traditional flood management, which provides mitigation strategies, to flood risk management, which provides an adaptation approach—adjusting mitigation measures, to flood resilience management, which provides a more resilient and sustainable plan to cope with flood disasters. This study proposes a model-based methodology to estimate design precipitation for long durations during the winter and spring seasons through its application to the drainage areas. For basins with large reservoir storage, design precipitation and floods need to be estimated based on long-duration processes rather than focusing only on flood peaks or single storm durations.I also present a detailed overview of the field of flood research, and review the definition of risk, risk analysis methods, flood management, flood risk management, flood resilience, and corresponding implementation strategies.*

KEYWORDS: *Disaster, Flood, Makoran, Flood Control, Integrated flood, Resilience indicators, Management strategies, Risk management.*

INTRODUCTION

A flood is a natural event that could arise for various reasons, including weather changes and other hydro-meteorological events, such as heavy rainfall, monsoons, typhoons, and even significant landslides entering rivers, reservoirs, or dams. Floods affect agriculture, infrastructure, and cause loss of human lives, and negatively impact a country's economy. In Iran, floods are frequent natural disasters that occur almost every year during the monsoon seasons [3].

The study was conducted at Sooran and Saravan districts rivers in Makoran. Thus location up on which this study concentrates is bounded by the southern Iran and Western Pakistan, approximately, by the line of latitude 25˚ to the South and the line of longitude 60˚ to the west. The area consists of an inland chain of steeply sloping bare rock (mountains) which drain onto a coastal alluvial plain. The analysis is based on a multi-sites analysis approach, since the five rivers locations are not considered sufficiently similar to be pooled together [17]. The Study Area might be classified as "Tropical Triple season Moderate Climate Zone", which is characterized by single rainfall season from July-September and its moderating influence in temperature. The river flow and rainfall temperature pattern of the area based on the record of data obtained from the Iranian Meteorological and water resources organization department. Iran continues to suffer from natural hazards that threaten to affect the lives and livelihood of its citizens. Due to its unique geo-climatic conditions, Iran is one of the most disaster prone countries in the world and undergoes natural disasters including floods, earthquakes and drought [14]. A location plan is shown in Figure 1.

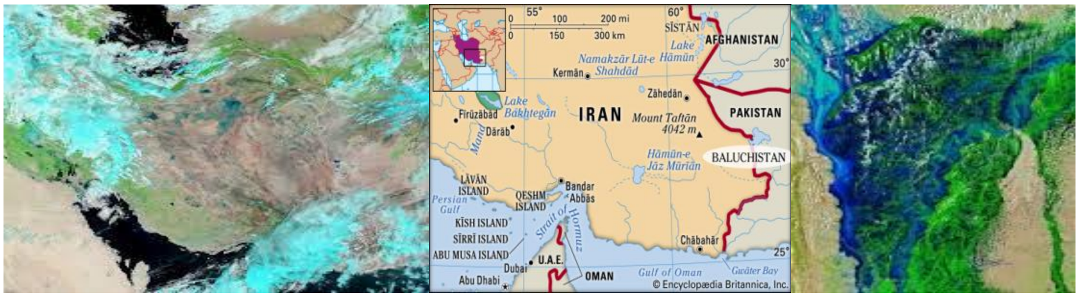


Figure 1: The area of study in Sooran, Sarvan and Districts in Makoran Region, Sistan and Balochestan, Iran

MATERIAL AND METHODOLOGY

This study proposes a model-based methodology to estimate design precipitation for long durations during the winter and spring seasons through its application to the drainage areas. For basins with large reservoir storage, design precipitation and floods need to be estimated based on long-duration processes rather than focusing only on flood peaks or single storm durations [5].

I also present a detailed overview of the field of flood research, and review the definition of risk, risk analysis methods, flood management, flood risk management, flood resilience, and corresponding implementation strategies.

This study reviews the existing literature on the flood, flood management, and socioeconomic cost in Iran focusing on riverine and extreme floods (2021). The theoretical framework of the study is shown in Figure 1. Figure 1 Flood hazard map indicates the most vulnerable districts of Iran with a major river system map developed [13].

This review follows a process figure (Figure 1) for a scientometric and systematic analysis of the literature that relates to urban flood resilience. In order to clarify the current research status and development trends of urban flood resilience, Cite Space software was used for keyword frequency statistics and high-frequency keyword screening analysis [14].

Increasingly, then the area of the study is near the border of Iran and Pakistan, extending south from Afghanistan to the Gulf of Oman. A location plan is shown in Figure 1. Data for in this paper has been obtained from the Water Resources Department of the Islamic Republic of Iran Meteorological Organisation (IRIMO), and relates to the Province of Sistan and Balochistan. It is noted that there is also a neighbouring Province of Balochistan to the west in Pakistan. The climate of the region varies from subtropical arid and semi-arid to temperate sub-humid in the plains of Sistan and Balochistan. The rainfall data studied in this paper comes from the southern part of the region, including the Makoran [22]. Therefore, flash flood disasters occurred in Sooran , Saravan districts on cities on 20/2/ 2021 which is illustrated in figure (2).

Figure 2. Shown human effects on riverine flood risk disasters Sooran , Saravan, Overtopped levee during the flash flood in 20th February 2021

SUSTAINABLE DEVELOPMENT, HUMAN SECURITY AND THE ENVIRONMENT

Therefore, human security, which encompasses the physical security of individuals and communities, but also economic security, food security, health security, environmental security and political security, is embedded in the concept of sustainable development. Environmental security implies a healthy environment as opposed to environmental threats, when resources are mismanaged and/or degraded [9]. The relationship between human security and the environment is most pronounced in areas where human dependence on access to natural resources is greatest. When these resources are threatened because of environmental changes, human security is also threatened [20]. As a result, people are forced to move from rural areas to marginal lands or urban settlements, starting another cycle of unsustainable development and insecurity. From the flood management perspective, environmental degradation has the potential to threaten human security in many different ways. First, it can increase the magnitude and frequency of flood hazards. Second, by affecting other components of human security such as economic and food security (e.g. land degradation affecting agricultural productivity) and health security (e.g. polluted water), it increases the vulnerability of those exposed to such hazards. Adequate consideration of environmental impacts in flood management activities is therefore important within the context of both sustainable development and human security [3].

THE ENVIRONMENT AND ECOSYSTEMS

Thus, the environment could be defined as “the surroundings in which an entity operates. This includes air, water, land, natural resources, flora, fauna, humans and their interrelation”. The climate, the physical setting and the resulting river flow regimes, set within various ecosystems, with human activities superimposed, determine the environment of a flood plain. Human activities have profound impacts on the various ecosystems within the environment. An ecosystem is a dynamic system of plant, animal and microorganism communities and their nonliving environment, interacting as a functional unit. Ecosystems, such as forests, wetlands and lakes comprise all the organisms present in the area along with their physical, or a biotic, environment and their mutual interactions [9]. An ecosystem has a structure or organization, given by the different interacting living and non-living components. The higher the number of system elements, comprising an ecosystem and their mutual interactions, the more effectively any disturbances within the ecosystem can be balanced out. Hence ecosystems are resilient (able to return to their original state after a perturbation), but at the same time difficult to recreate if destroyed [10]. Ecological processes keep the planet fit for life by providing food, air to breathe, medicines and much of what we call “quality of life”. The immense biological, chemical and physical diversity of the earth forms the essential building blocks of ecosystems [25]. The key issue in sustainable development in general, and water resources development in particular, therefore, is to secure the capacity of the systems to absorb continuous change without losing their capacity to provide a continuous supply of ecological goods and services. It is extremely important, therefore, to understand and to protect complex ecosystems such as forests, wetlands and river ecosystems; not only their structures but also their functioning. On a management level, development strategies which consider the need to protect ecosystem [14].

Thus, on a management level, development strategies, which consider the need to protect ecosystem functioning, are termed “ecosystem approaches”. Within such an approach, one particular resource, activity or set of environmental goods and services cannot be considered separately from others. Thus, “the ecosystem approach is a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way. Ecosystem approaches are applicable at all scales, from the local to the global. Flood plains present the best option for livelihoods, particularly in developing countries where poverty alleviation and Environmental Aspects of Integrated Flood Management [16].

ECOSYSTEM SERVICES AND THE NATURAL ENVIRONMENT

Throughout history, people have benefited immensely from sound ecosystems, but they have also worked to protect themselves from a range of far from benign natural environmental conditions. However, the term “natural” has come to imply “clean and safe” to many people, particularly in developed countries [10]. The natural environment can be divided into two types, pristine or wild – not altered by human activities, or modified to human requirements to allow improved quality of life and economic well-being. In order to understand environmental sustainability, the extent to which the environment can be maintained in its pristine wild form has to be addressed from the human security perspective. This will enable ecosystem services to be obtained without a cost and deal with the issue in a balanced manner [4]. Therefore, when discussing ecosystem services, the term “natural” implies “nurtured” and not nature in its wild form. Some of the health services provided by ecosystems are good examples of the ambiguity presented through the classic dichotomy between “natural” and “nurtured”. From a human security perspective, some of the natural hazards in the wild, pristine environment can be:

• Heat, cold, rain, wind and related natural disasters.

• Infections caused by insects and parasites that spread from person to person or animal to person through air, food or water; • Dust, damp, wood smoke, pollen and other airborne hazards; and, • Injuries from falls, fires and animal attacks.

DISCUSSION

6.1. Overview of Catchment Flooding

However, to illustrate the areas of the catchment generally susceptible to flooding, the maximum flood depths associated with the most back-loaded observed profile leading to the most severe flooding are plotted in Figure for Saravan Dyke [22]. In both catchments, substantial inundated areas are observable around the track of the main watercourse. In Sooran beck, the most notable areas are: in the centre of the catchment, to the east of Saravan district (Figure -1); and around the industrial estate in the southern reaches of the catchment (Figure- 2). In Sooran Dyke, prominent inundated areas include locations to the south of Makoran, where the watercourse intersects a main road (Figure-2), and the area of wetlands in the lower catchment reaches (Figure -1). We are primarily interested in urban areas, and in both catchments, flooding of streets and gardens are simulated by the model [13].

6.2. Changes to Catchment Flooding

The following key differences in catchment flooding are observed:

- Back-loaded profiles result in more of the catchment experiencing flooding at some point during the simulation than front-loaded profiles.
- The majority of the cells which are flooded with the back-loaded profile scenario, but not with the front-loaded profile scenario, are within the least severe depth and hazard classes, but in the higher velocity categories.
- Back-loaded profiles do not tend to cause new areas to flood, but incrementally increase flood extent in existing affected areas.
- Saravan ack-loaded profiles reach their maximum flood extent later, and this extent is larger than for front-loaded profiles [7].

These results are explored in more detail in the sections below.

6.3. Total Flood Extent

Therefore, results demonstrate that rainfall events with the same total rainfall depth, but distributed differently over time, can result in different flood extents. With the idealized profiles, the most back-loaded profile causes the most extensive flooding in both catchments, with ~15% greater flooded area than the most front-loaded profile. Similarly, for the observed profiles, the most back-loaded profile results in the most extensive flooding in both catchments (Figure, with ~25% greater flooded area than the front-loaded profile with the least extensive flooding. For the idealised profiles, as the timing of the peak is shifted towards the end of the profile there is a consistent trend towards more extensive flooding. However, for the observed profiles, the trend is noisier [27]. For instance, there are front-loaded profiles, with greater flooded areas than back-loaded profiles. This can be attributed to the concurrent variation in peak intensity found in the observed profiles. The front-loaded profile has a much higher peak intensity than the back-loaded profile and this also influences the flooding generated. Given these findings, in subsequent comparisons, I focus on (the most front-loaded) and (the most back-loaded) for the idealized profiles [5]. For the observed profiles, I compare (the second most front-loaded, but which results in the least flooding due to its low peak) and (the most back-loaded). We also note that the centre observed profiles result in a smaller flooded area than the FEH profile, likely because of the observed profiles' lower peak magnitudes (see Figure 2) [19].

RESULTS

Increasingly, Rainfall-driven urban surface water flooding is one of the most common natural disasters that lead to traffic disruption, economic loss, and even casualties. Assessing its hazards is critical not only for flood management but also for urban and territorial planning [11].

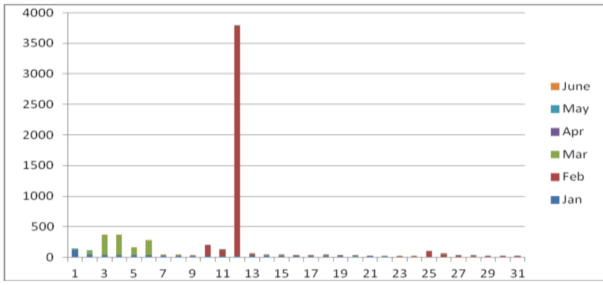
Both discharge data from stream gauge stations and from post-flood analysis were available in the study. Discharge data from stream gauge stations were available for two cases, whereas data from post-flood analysis were used in the remaining four cases. Post-event analysis methods include a range of procedures for indirect estimation of peak discharges, generally encompassing the following steps: identification of the flow process (which was categorized into the following classes:1- liquid flow 2- hyper concentrated flow 3- debris flow), high water marks identification, post-flood river geometry survey, and application of appropriate hydraulic methods for peak flood computation [23]. With regard to the classification of the flow process, only liquid flows were considered in this study. Together with peak discharge values, post flood analysis methods were used also to derive time of the raising flow, flood peak time, and rate of recession. Timing estimates were obtained based on eye witness's interviews and accounts. A standardized method for post-event analysis was used throughout the study. Estimates of flood peak for the earlier events were reviewed considering the original field notes, photographs, reports, and documentation, and conducting field visits to the flood locations [27]. Discharge data from stream gauges were obtained based on extrapolation of rating curves from smaller observed flows. The rating curves were checked to evaluate the degree of extrapolation required and to assess the quality of the final estimates [26].

Although great care was devoted to the various steps of discharge estimations, we should note that all the peak flood data should be regarded as affected by considerable uncertainty. An accuracy of 15–20 min has been reported for the timing estimates obtained by means of eyewitnesses interviews. The large percentage of discharge data obtained from post-event analysis underlines the importance of indirect discharge estimates in setting up catalogues of flash floods [24]. This is particularly the case for events which impact small catchment areas. Categorizes catchment areas according to the method used to derive the peak flood data (stream gauge versus post-event analysis). Discharge data from gauging stations generally concern catchments which are significantly larger than those for which estimates are obtained from post-event analysis. This is not an unexpected finding: larger scale flash floods events have higher probability to be recorded by stream flow measuring stations [28].

Whereas events with smaller spatial extent generally impact ungauged basins. An implication of this finding is that systematic survey of flash floods is particularly important in the region where these events are climatologically characterized by smaller spatial extent, such as in the sub-continental areas. Without systematic post-event analysis, it may be unlikely to develop reliable flash flood catalogues in these areas.

Focusing the river Neheng for the purposes of water flow and gauged at two gauging station called Tump and Miran gauging stations though the catchment for Makoran station is 750 km2 and the catchment area for the Gasrgand hydrometric station is 460km2 however, the river network is a complex inter relationship of a historically. A conceptual approach that allowed some degree of perception of the hydrological processes to be expressed in mathematical form. The establishment and development of distributed monthly maximum flow analysis that account for the spatial variability of hydrological processes is appropriate to achieve river discharge in Balochistan, thus the different monthly maximum discharge m^3/s are illustrated in Figures (3, 4, 5 and 6), which indicated various rate of flow for Saravan River during wet months [26].

In the light of the storms and flood monthly maximum the calibration of river Saravan basically illustrated during month of December 2021 has been tested by computer the peak discharge was 755 m3/s ,whereas during month of December 2014 was tested 3459 m^3/s, for the February 2021 was tested 3751 m^3/s, for the March peak discharge has been tested by excel was 854 m^3/s where as for the same river on the month of April suddenly rate of flow dropped to 6 m3/s even though for other months during summer rate of flow for Nehang river is completely drought or nil discharge accordingly to the dry months when there is no rainfall in the all-region, this is the link between rainfall and storm characteristics and its effect on monthly maximum discharge have been dealt with in the past also the storms characteristics mainly considered were the storm pattern, might be speed and direction of rainstorm moving in the downstream direction produces a higher peak flow than storms moving upstream which can be concluded that storms moving at the same speed as the stream velocity have more impact on peak discharge than rapidly moving storms [11].



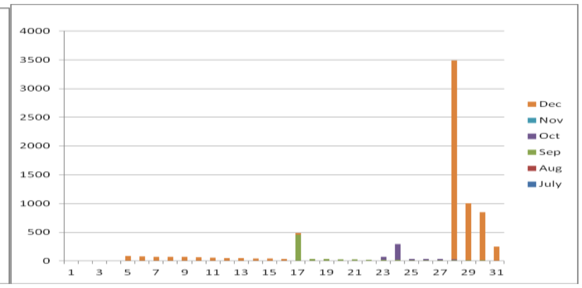


Figure (3 and 4): River Mashkid and Nehang (Saravan, Sooran) monthly Maximum rate flow During flash flood from Jan. to June 2021

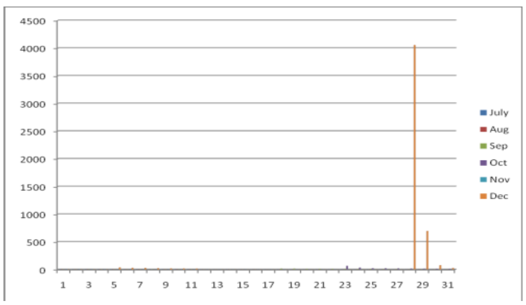


Figure-5. Monthly Maximum Rate of flow River Saravan Flash Flood Jan to June Flash Flood During 2023 2023

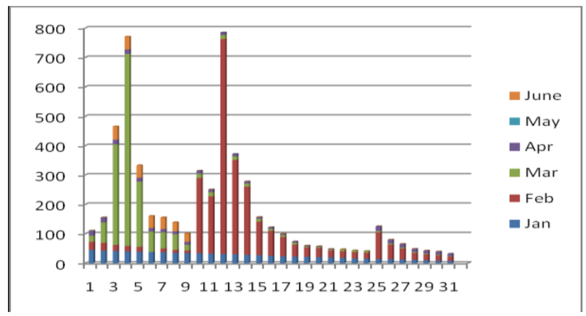


Figure-6. Monthly Maximum Discharge During During flash flood from Jan. to June.

FLOOD MANAGEMENT

Therefore, risk management has been established as a well defined procedure for handling risks due to natural, environmental or man made hazards, of which floods are representative. Risk management has been discussed in many previous papers giving different meanings to the term a result of the fact that risk management actually takes place on three different levels of actions: the operational level, which is associated with operating an existing system, a project planning level, which is used when a new, or a revision of an existing project is planned, and a project design level, which is embedded into the second level and describes the process of reaching an optimal solution for the project. The first two levels will be briefly described in the paper. It will be emphasized that the transition from the first to the second level is a dynamic process [16]. As the value system of a nation changes, and as the natural boundary conditions are modified by human actions or global changes, an existing system will be found not meeting the demands of the present society, and actions on the second level are initiated. The decisions for change depend on the changes in options available for handling a flood situation, as well as on the changes in risk perception and attitudes towards risk. On the third level, the actual cost of a design are evaluated and compared with the benefits obtained from the planned project. In particular, on this level the residual risk is considered, i.e. the risk which remains even after a project is completed and fully operational [4].

FLOOD RISK MANAGEMENT

Flood risk management as a process has been discussed extensively, without regard to the actors involved in the process. It is more useful to interpret risk management as a process which involves three different sets of actions, depending on the operators involved. The first is the set of actions which are needed to operate an existing system. It consists of four parts, as will be described briefly in the second chapter [15]. When the system is no longer adequate, to meet the needs of people for example, because of changes in land use, increases in population, or climate change then the next set of actions starts: the planning for a new or revised system,

which is adapted to the changed conditions. The planning process leads to a decision for the new system. Embedded in this set is the third one, the process of obtaining an optimum design for and constructing a project. Many hydraulic engineers consider only the third level as part of their activity. To them, the solution to flood problems is a logical chain starting with flood studies by hydrological methods, such as extreme value analysis, selection of a design discharge, deciding on a structural system for containing the design discharge, and implementing what has been decided on—in other words, the solution to flood problems is considered a classical engineering task like many others, such as designing a highway or a sewage disposal system [31].
In a way, this is still true for the tasks of some hydraulic engineers, namely those that are called to do the designing and building of a flood protection system, once it has been decided that such a system is to be built. In a modern framework of design, this task can also be very demanding, as it is required to do such a engineering job in a most efficient way and including a thorough assessment of the safety of the engineered system against failure [32]. On a higher level, however, the engineering approach must be seen as embedded in the decision process of planning for flood risk management. Not only engineers are involved in this process, but also many social groupings of a society, from political decision makers to people that are directly exposed to floods. The sequence of the three sets of actions is a result of the fact that the task of flood risk management is never done. Each generation will have to reconsider its options, and sets its own priorities according to the prevailing value system of the society. This aspect is developed in detail in the second part of the paper. It leads to the planning process as response to changes in society and environment, as described in the third part of the paper. Engineering aspects (the third set of actions) are only touched upon, with reference to earlier contributions to the subject [15, 31].

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CONCLUSION
This study presents a flood inundation model based on the deep learning of incorporated, Blocks, and Random Cutout to solve the underestimation problem and improve the prediction performance. The proposed model can rapidly assess urban surface floods, providing informed decisions for flood management. The experimental results using the Exeter case study showed the potential of the model in providing accurate flood assessments. This report provides new insight into flood research trends, by examining current research frontiers, and clearly shows a timeline for flood research. It will help stakeholders understand the advantages of the different strategies of traditional flood management, flood risk management, and flood resilience. The next step for stakeholders is facing uncertain climates, diverting human-induced disasters, and building more resilient communities, cities, and watersheds. This study suggests flood adaptation and mitigation measures along with the integration of the dual strategies of flood risk management and flood resilience, to effectively reduce water-related adversities [33]
In this paper, the significance of dam operation and its impact on flooding was evaluated. Stakeholder communication and roles and responsibilities were translated as parameters into computational models and simulated at various levels. Flood simulations were undertaken in four case study catchments under various rainfall patterns and return periods. This allowed the relative importance of Initial Reservoir Volume, Release Duration, and the maximum gate opening to be assessed while considering dam purpose, operational degrees of freedom, rainfall, and tributaries. The results found Release Duration had stronger correlations with maximum dam outflow in dams that could release large flows. Dams with large storages had stronger correlations between

the initial volume and reduced downstream flows. By understanding their relative importance, this study highlights the capabilities of these factors and helps build a case for improving dam management. This approach may address the increasing complexity of dam operations and ultimately reduce flood risk for communities [30]. This integrated methodology provides a detailed and robust assessment of future discharge dynamics and flood risk in the region. The findings offer critical insights for water resource management, climate adaptation planning, and the development of proactive flood mitigation strategies. They serve as a valuable resource for policymakers, engineers, and environmental planners working to reduce flood vulnerability in the Saravan River basin [29].

REFERENCES

*[1] Abidalla, W. A. A. 2013. "Flood Frequency Analysis for Greater–ZAB River." Journal of University of Babylon **21**, no. 4: 1254–1262.*

*[2] Ahmad, I., A. Abbas, M. Aslam, and I. Ahmad. 2015. "Total Annual Rainfall Frequency Analysis in Pakistan Using Methods of L-Moments and TL-Moments." Science International (Lahore) **27**: 2331.*

[3] Arshad, R., and S. Shafi. 2010. Pakistan Floods 2010: Preliminary Damage and Needs Assessment. Asian Development Bank and World Bank.

*[4] Asif, M., M. M. Kuglitsch, I. Pelivan, and R. Albano. 2025. "Review and Intercomparison of Machine Learning Applications for Short-Term Flood Forecasting." Water Resources Management **39**: 1–21.*

*[5] Bhakar, S., M. Iqbal, M. Devanda, N. Chhajed, and A. K. Bansal. 2008. "Probablity Analysis of Rainfall at Kota." Indian Journal of Agricultural Research **42**, no. 3: 201–206.*

*[6] Deraman, W. H. A. W., N. J. Abd Mutalib, and N. Z. Mukhtar. 2017. "Determination of Return Period for Flood Frequency Analysis Using Normal and Related Distributions." Journal of Physics Conference Series **890**: 012162.*

[7] Abadi, M., P. Barham, J. Chen, et al. 2016. " Tensor Flow: A System for Large-Scale Machine Learning." In Proceedings of the 12th USENIX Conference on Operating Systems Design and Implementation, 265–283. USENIX Association.

*[8] Abdulkareem, J. H., B. Pradhan, W. N. A. Sulaiman, and N. R. Jamil. 2018. "Review of Studies on Hydrological Modelling in Malaysia." Modeling Earth Systems and Environment **4**, no. 4: 1577–1605.*

*[9] Ahmed, N., and J. Lee. 2021. " Predicting Urban Flooding Susceptibility of Public Transit Systems Using Machine Learning Approaches: A Case Study of the Largest City in Canada." In Proceedings of the 4th ACM SIGSPATIAL International Workshop on Advances in Resilient and Intelligent Cities, 32–41. Association for Computing Machinery. **https://doi.org/10.1145/348438**.*

*[10] Ajit, A., K. Acharya, and A. Samanta. 2020. " A Review of Convolutional Neural Networks." In 2020 International Conference on Emerging Trends in Information Technology and Engineering (ic-ETITE), 1–5. IEEE. **https://doi.org/10.1109/ic-E3.2020.049**.*

[11] Marriott, M. J. and M. A. Zainudini. 2006. A review of rainfall data from the Iranian province of Sistan and Balochistan. Proceedings of the Advances in Computing and Technology Conference, London. ISBN-0-9550008-1-5, pp.113- 118

*[12] Bulti, D. T., and B. G. Abebe. 2020. "A Review of Flood Modeling Methods for Urban Pluvial Flood Application." Modeling Earth Systems and Environment **6**, no. 3: 1293–1302. **https://doi.org/10.1007/s40808-020-008***

*[13] Environment Agency. 2019a. "Flood Risk Maps 2019." **https://www.gov.uk/government/publications/flood-risk-maps-2019**.*

*[14] Environment Agency. 2019b. "What Is the Risk of Flooding From Surface Water Map?" **https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/842485/What-is-the-Risk-of-Flooding-from-Surface-Water-Map.pdf**.*

*[15] Environment Agency. 2022. "Exeter Flood Defence Scheme." **https://www.gov.uk/government/publications/exeter-flood-defence-scheme/exeter-flood-defence-scheme**.*

*[16] Fu, G., Y. Jin, S. Sun, Z. Yuan, and D. Butler. 2022. "The Role of Deep Learning in Urban Water Management: A Critical Review." Water Research **223**: 118973. **https://doi.org/10.1016/j.watres.2022.118973**.*

*[16] Fu, G., S. Sun, L. Hoang, Z. Yuan, and D. Butler. 2023. "Artificial Intelligence Underpins Urban Water Infrastructure of the Future: A Holistic Perspective." Cambridge Prisms: Water **1**: 1–35. **https://doi.org/10.1017/wat.2023.15***

*[17] Ehiorobo, J., and N. Uso. 2015. "Flood Frequency Analysis in the Lower River Niger Basin at Onitsha Bridge Head." Journal of Engineering Research **19**: 33–44.*

*[18] Hamidi, A. R., J. Wang, S. Guo, and Z. Zeng. 2020. "Flood Vulnerability Assessment Using MOVE Framework: A Case Study of the Northern Part of District Peshawar, Pakistan." Natural Hazards **101**: 385–408.*

*[19] Kordrostami, S., M. A. Alim, F. Karim, and A. Rahman. 2020. "Regional Flood Frequency Analysis Using an Artificial Neural Network Model." Geosciences **10**, no. 4: 127.*

*[20] Li, L., and K. S. Jun. 2022. "A Hybrid Approach to Improve Flood Forecasting by Combining a Hydrodynamic Flow Model and Artificial Neural Networks." Water (Basel) **14**, no. 9: 1393. **Google Scholar***

*[21] Madhushanka, G., M. Jayasinghe, and R. Rajapakse. 2025. "Multiple-Day-Ahead Flood Prediction in the South Asian Tropical Zone Using Deep Learning." Journal of Hydrologic Engineering **30**, no. 1: 04024054.*

[22] *Mangukiya, N. K., D. J. Mehta, and R. Jariwala. 2022. "Flood Frequency Analysis and Inundation Mapping for Lower Narmada Basin, India." Water Practice & Technology **17**, no. 2: 612–622.*

[23] *Mujiburrehman, K. 2013. "Frequency Analysis of Flood Flow at Garudeshwar Station in Narmada River, Gujarat, India." Universal Journal of Environmental Research and Technology **3**, no. 6: 677.*

[24] *Mukherjee, M. K. 2013. "Flood Frequency Analysis of River Subernarekha, India, Using Gumbel's Extreme Value Distribution." International Journal of Computational Engineering Research **3**, no. 7: 12–19.**Google Scholar***

[25] *Qamer, F. M., S. Abbas, B. Ahmad, et al. 2023. "A Framework for Multi-Sensor Satellite Data to Evaluate Crop Production Losses: The Case Study of 2022 Pakistan Floods." Scientific Reports **13**, no. 1: 4240.**Google Scholar***

[26] *Samantaray, S., A. Sahoo, Z. M. Yaseen, and M. S. al-Suwaiyan. 2025. "River Discharge Prediction Based Multivariate Climatological Variables Using Hybridized Long Short-Term Memory With Nature Inspired Algorithm." Journal of Hydrology **649**: 132453.*

[27] *Sathe, B., M. Khir, and R. Sankhua. 2012. "Rainfall Analysis and Design Flood Estimation for Upper Krishna River Basin Catchment in India." International Journal of Science & Engg. Reasearch **3**, no. 8: 1–20.**Google Scholar***

[28] *Ullah, B., M. Fawad, A. U. Khan, et al. 2023. "Futuristic Streamflow Prediction Based on CMIP6 Scenarios Using Machine Learning Models." Water Resources Management **37**, no. 15: 6089–6106.**Google Scholar***

[29] *Wang, S., B. Peng, O. Xu, Y. Zhang, and J. Wang. 2025. "Mountain Flood Forecasting in Small Watershed Based on Loop Multi-Step Machine Learning Regression Model." Scientific Reports **15**, no. 1: 12413.*

[30] *Waqas, M., S. N. Jan, B. Ullah, A. U. Khan, and B. Niaz Khan. 2025. "Prediction of Particulate Matter PM2. 5 Level in the Air of Islamabad, Pakistan by Using Machine Learning and Deep Learning Approaches." Journal of Air Pollution and Health **10**: 37–60.*

[31] *United Nations Office for Disaster Risk Reduction. UNSDR Terminology on Disaster Risk Reduction; United Nations Office for Disaster Risk Reduction (UNDRR): Geneva, Switzerland, 2009. [Google Scholar]*

[32] *Yu, Q., C. Liu, R. Li, et al. 2025. "Research on a Hybrid Model for Flood Probability Prediction Based on Time Convolutional Network and Particle Swarm Optimization Algorithm." Scientific Reports **15**, no. 1: 6870.*

[33] *Zakaullah, U., M. M. Saeed, I. Ahmad, and G. Nabi. 2012. "Flood Frequency Analysis of Homogeneous Regions of Jhelum River Basin." International Journal of Water Resources and Environmental Engineering **4**: 144–149.*