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Flood risk and flood management in Zarabad and Konarak Districts 2024 (Makoran), Balochestan, Iran

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Abstract

Flooding is the most devastating natural hazard in Iran and the recent flooding has demonstrated its severeness. Floods are common throughout the country. However, their characteristics differ from region to region. Flooding behavior of the major basins and flood management at the national level are investigated in this article. Monsoon rainfalls are the main source of floods in the River Rapch Zarabad Basin, while Mediterranean Waves and Cyclones, which are generated over the Arabian Sea, induce flooding in the Makoran Coastal Area Rapch and Kahir Basin. Fluvial floods in the Zarabad Basin have caused major economic losses. Iran government has spent vast resources on relief operations and flood works since the country came into existence. A number of provincial and federal acts, ordinances, accords, and treaties shape the national flood policy. Institutional setup for flood hazard and crisis management has evolved over the years. Nevertheless, data show no major reduction in the flood-to-damage ratio. The inter-linkage of structural and non-structural measures and their combined efficiency must be analyzed and optimized for more effective flood management. 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.

Keywords: Disaster; Flood; Integrated flood; Risk management; Risk assessment; Vulnerability Floods

1. Introduction

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 “[1]”. 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. 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 “[9]” and “[35]”. In a modern

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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. 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 “[10]” and “[35]”.

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. 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 port of Konarak, Zarabad,Kahir and Chahbahar. A location plan is shown in Figure 1.

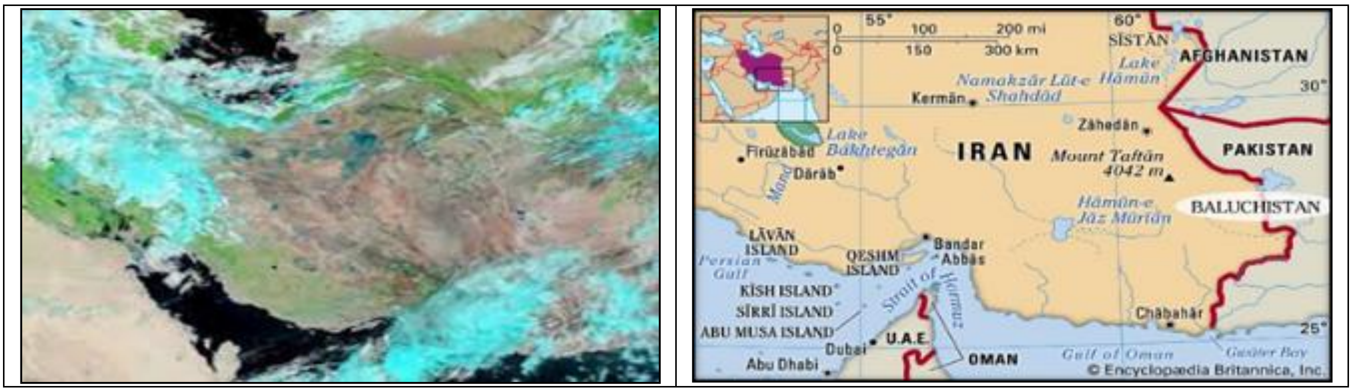

Figure 1 The area of study Rivers Rapch, Kahir and Kajoo in Makoran Region, Iran

2. Material and Methodology

This study reviews the existing literature on the flood, flood management, and socioeconomic cost in Iran focusing on riverine and extreme floods (2024). The theoretical framework of the study is shown in Figure 1. Therefore, Figure 1 Flood hazard map indicates the most vulnerable districts of Iran with a major river system map developed after.

This review follows a process 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. VOS Viewer software was used for social network analysis and hierarchical clustering analysis, which finally presents the research changes of urban flooding in a quantitative and dynamic way. Research hotspots in different stages are compared, future trends are predicted according to keywords, and future research directions are explored. Cite Space is an information visualization software that can analyze the characteristics of the literature in various research fields. It includes analysis related to keywords, authors, cited studies, countries, research institutions and journals. It provides visual forms of keyword clustering, cooperative networks, co-cited networks, literature sources, regional distribution and so on.

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 port of Chahbahar. Therefore, flash flood disasters occurred in Zarabad, Kahir, Gasrgand and Dashtyari districts on cities on 11/2/ 2024 which is illustrated in figure (2).

Figure 2 Illustrates human effects on riverine flood risk disasters River Rapch , Kahir and Kajoo Overtopped levee during the flash flood in 11th February 2024

2.1. Climate change and flows in the Rapch, Kahir and Kajoo Rivers Basin

Climate change is also expected to affect the South Asian monsoon. The IPCC in its Third Assessment Report has reported that there will be increase in South Asian monsoon by 8-24%, which will bring additional water causing floods and damages to the infrastructure. This requires that Iran should start preparing itself for possible future changes in climate change and its impact on Iran. Better water management would probably be the best strategy to cope with the projected climate changes and their impact on Iran's agricultural economy and environment "[3]" and "[11]".

Iran is highly dependent on its water resources originating in the mountains of the upper Zagoros for sustaining its irrigated agriculture. Hence any variation in the available water resources through climate changes or other human interventions will lead to serious challenges of food security and livelihood of millions of poor. There are evidences that due to rise in temperatures, there will be excessive glacier melt of Zagoros and Damavand Glaciers and flows of rivers at Karhka will be excessive by about 50%, and thereafter there will be great reduction in flows and they will be reduced to about 40% of the year 2010 value by the end of century. The increase in flow during the second decade of the century will be 6.4 BCM annually and after that there will be a steady decline of 27 BCM in Zagoros in the next 50 years (Figure 2) "[16]" and "[25]".

2.2. Natural and Physical Environment of Makoran

In Makoran, the flood study could be said with location of Rapch, Kahir, Sarbaz and Kajoo rivers the upstream parts of the rivers flow through heavily mountainous and hilly regions while the remainder of rivers flows through broad, flat valleys. The upland, villages landscapes are dominated by a mix of forests, which forests comprised of Nannorrhops (Mazari palm trees) and tamarixes etc. Also the upstream half of the rivers below Pishin and Zirdan flood control dams are dominated by coarse gravels, with areas of fines and larger sands also present to a lesser degrees. The downstream half of both rivers below the dams are predominately small to medium sized sand or cobbles.

Therefore, interspersed with areas of fine sediment and larger sands and boulders, the coarse gravels are also present in those particular areas. Furthermore, the historic water quality problems stemmed from drainage and rainfall runoff, which also caused low dissolved oxygen, elevated water temperatures and high turbidity. Low summer flows have also caused some problems in the river but these are primarily a natural function arising from the small drainage size. Although, there are many reaches existed, so the majority of reaches are located of the side of the rivers. However urban development along these rivers in Makoran is important feature, providing crucial life history for flood control and also for such as rearing and holding habitat for fish, and over wintering habitat for migrating waterfowl. The existing fill and spill for flood control dams operations result in seasonal fluctuations surface elevations "[17]".

2.3. Analyses Rainfall Data Which Flash Flood occurred

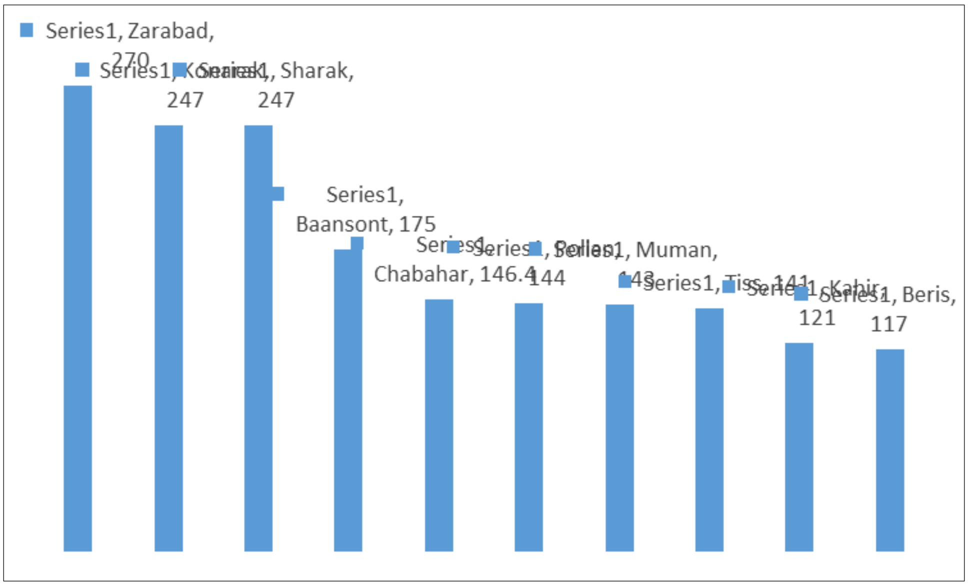

Figure 3 Heavy Rainfall with Flash Flood occurred on 11/2/2024 in the Zarabad, Konarak, Kahir in Makoran Region, Iran

The rainfall data that has been obtained gives a realistic description of the flash flood occurred on 11/2/2024 within 24 hours rainfall in Zarabad 270 mm, Konarak 247 mm, Kahir 121 mm, Sharak 246 mm, Baansont 175 mm, Chabahar 146.4 mm, Pollan 144 mm, Muman 143 mm, and Tiss 141 mm, Beris 117 mm then arid climate in Balochistan, and clearly illustrates the times of the year when rainfall is more or less likely " [2]".

Increasingly focusing in case of rainfall in the Balochistan (Makoran) region it is important during this rainfall flash flood is occurred. The rainfall data that has been determined gives a realistic description and definition of the arid climate in Balochistan and clearly illustrates the times of the year when ever rainfall is more or less likely occurred during certain periods of year. However in this way it is concluded that the lognormal distribution may be used to analyse annual data, because that the Gumbel extreme value distribution is preferable for monthly data from the wet months (Marriott M.J. & Zainudini M.A., 2006). So the dry months are not amenable to this type of analysis eventually for the arid region of Sistan and Balochistan (Makoran) when and where heavy rainfall can be happened; due to the high temperature and humid and cold fronted breeze with the inter-tropical convergence area when penetrates to the coastal surface thus sever and such as heavy precipitation occurred in that particular region of the Balochistan which is analyse and shown in figure 3 "[2]".

2.4. Impact on agriculture and livestock

The impact of the flood on the agriculture sector can be divided into the following six categories: 1) Livestock evacuation in an urgent situation; 2) Avoidance of spring field exposure, allowing livestock to be sheltered or moved to certain other floodfree places; 3) Harm to crop and grass productivity in worst affected areas with massive loss of pasture 4) Driven production loss and affected the performance of cultivation and agricultural land; 5) Destroyed irrigation structures and facilities at the farm ; 6) Loss of advantageous soil invertebrates, in particular earthworms, elevated risk of animal disease, including infection of liver fluke. As agriculture remains the largest sector of Iran's economy, employing 43 percent of the population, its yearly contribution to the GDP period "[15]" and "[24]".

Climate change typically has minor effects on the world food supply, but the consequences of climate change are widely distributed unevenly. Low-income economies, such as those in South Asia and Africa, experienced most of the casualties. By taking the data from 1999 to 2015 and by using the Feasible General Least Square (FGLS) model studied the climate changes impact on Iran major crop yields "[20]" and "[26]".

2.5. Impact on human health

Floods pose an enormous challenge to the healthcare system and its efficacy. For example, it can damage access to drinkable water by infiltrating the aquifers, thus increasing the transmission of waterborne diseases. The health concerns are classified as direct and indirect "[5]". Where direct effects arise from deep water and flooding penetration, including death, debris injury, environmental pollution, and hypothermia. Indirect effects include threats related to the water disruption to the natural and physical environment, including communicable diseases, obesity, famine-related diseases, and displaced population-related diseases. The number of people affected by the different diseases by the 2010's flood "[21]" .

The floods' health effects could also be categorized as instantaneous medium and long-term. Flooding can also develop a high number of breeding grounds for insect and infection-borne diseases such as malaria. There have been various reports of increased risk throughout Asia, Africa, and Middle East in historically tropical countries. Public medical professionals and relief workers also warn after natural disasters that the dead bodies of affected people can trigger disease outbreaks such as cholera. The anxiety induced by such statements enables societies, local governments, and institutions to dispose of affected people quickly without identification. This leads to psychological stress for family members alive and causes legal issues including land, insurance claims, and inherited wealth.

Evaluated the impact of floods on public health by taking the data of massive floods for the period of 11th February 2024 in the region of Makoran in the south of Iran "[30]".

They found that floods are linked with an earache, psychological distress, and gastroenteritis. Psychological damage may illustrate some of the additional physical illnesses recorded by affected people, and likely even by children. Strategies to encourage the adaptation of the community to disasters, where flood management has deteriorated will provide logistical assistance for flood victims and adequate therapeutic help. However, in Iran, studies conducted on the causes and spread of diarrhea at the expense of flooding. It highlighted the important demographic, economic, and social aspects from the preview of amenities provided by the system "[5]", "[21]" and "[30]".

2.6. Flood warning system in Iran

According, Flood Forecasting and Warning System (FFWS) main aim is to inform the public and other stakeholders of an imminent flood as early and effectively as possible. In Iran, the mechanism of flood warning and control undertakes three phases: 1) The PMD tracks the monsoon weather pattern, which produces either from the South in the Arabian Sea or from the East in the Bay of India in the first stage. Their movements are monitored for flood warning "[4]".

The upper catchments lying in Iran or over the border, and estimates are generated one to 2 days in advance for expected rains and the severity of such rains. In the case of rains, the volume of rainfall is estimated and evaluated above the rim stations for their possible run-off relationship) after that is the stage of flood creation that starts with the generation of runoff from the rim stations and flows down into the Rapch, Jagin and Kahir Rivers and its tributary. Projected rainfall and flow data and real upstream flows are the hydro-meteorological portions of the flood "[14]".

Prediction ultimately, the hydrological part of the forecasting network is to track and control the route of the flood wave below the rim station of the rivers at the downstream locations. This is handled by Water Management Dept., of Iran and controlled in respective provinces by the irrigation departments.

The early warning system of Iran is efficient to some extent; however, the flood warning system only aims to provide information, rather protective measures. In our opinion, as we have also mentioned in the study, such acts can only help lessen the losses to be incurred "[14]" and "[23]".

2.7. Flood management in Iran

The flood prevention strategy is a relatively complicated problem in Iran. In each of the four provinces, the complexity of the issue differs because of their specific physiographic, climatic, geographical, and socioeconomic circumstances (Chaudhri, 1991). Early severe flooding happened in 1960, 1969, and 1987. However, no systematic flood control program was implemented at the national level, owing to scarce funding and administrative structures. Protection and control of flooding remained the exclusive responsibility of regional governments until 1999. That improved after 2004 destroying floods that took 47 lives and caused damage of 160 billion Iran Reyals "[9]" , "[10]" and "[35]".

2.8. Evolution of flood management system in Iran

In 1998 Iran faced severe floods which led to the establishment of the Federal Flood Commission (FFC) in 1999. The commission worked under the Ministry of Water and Power and was established to implement nationwide flood management, particularly concerning the Rapch and Kahir River Basin. The main functions of the FFC include developing national flood management measures; approving flood management plans drawn up by local governments and federal entities; examining flood damage to facilities in the public sector, and analysis of repair and rehabilitation plans; flood forecasting, and alert program enhancement measures; providing guidelines on standards for the management of flood protection reservoirs. "[35]" .

The first National Flood Protection Plan (NFPP-I) was developed after the creation of the FFC, with a spending timeline to be introduced throughout the 1998–2005 decade. A Federal Coordination Cell (now reshaped as FID Cell) was formed in 2008 to organize the Provincial Irrigation Departments ' operations, especially in the drainage region. In 2004 Dam Protection Council was set up to examine established dams via DSO WAMDA and proposals for new dams etc. "[35]".

In Iran, flood control initiatives consist primarily of flood-protection embankments, spurs, studs, and sophisticated flood-prediction strategies "[10]".

2.9. Structural and non-structural measures for flood protection

Flood management and protection problems are closely related to land use and water management issues. These include inadequate water management at field and system level, insufficient pollution control, increased casualties and damages during floods and during flooding operation, maintenance and operational problems, negative environmental impacts and long term problems due to subsidence and impacts of climate change. In order to find solution of these problems, it is important to analyze who are the main actors in the field and what may be their roles and responsibilities. The standard measures for flood protection are usually divided by structural and non-structural measures. "[2]" , "[3]" and "[17]".

2.9.1. Structural measures

Structural measures are related to physical provisions to reduce the risk of flooding. These include dams, dikes, storm surge barriers etc. Existence of enough storage to mitigate the impact of super floods is of paramount importance for flood protection. These storages should be built both on-channel and off-channel to attenuate flood peaks. In historic 2010 floods, the Zirdan reservoir the peak discharge from 735,000 cusecs at inflow to 504,000 cusecs at the outflow. Similarly, Pishin reservoir on the Sarbaz River reduced peak flow of 244,000 cusecs at inflow to 125,000 cusecs at the outflow. These two reservoirs played a critical role in lowering the flood peaks at Makoran and Chabahar Barrages downstream which otherwise could have played havoc with the Balochestan strategic irrigation infrastructure "[17]".

The present reservoir capacity of Balochestan (live storage) corresponds to 9% of the IRS average annual flow and is far lower than world average of 40% and many water stressed Province of the region [35]. In the past few years, government is emphasizing more and more on the construction of small dams to provide irrigation facilities to the small scale irrigation schemes. The small dams may address the poverty issues in selected villages but would not help in eradicating poverty in large areas. The envisaged small dams will have a storage capacity of about 1850 cubic meters '[35]".

the requirements of small scale irrigation and meet domestic water requirements. But in no way can they be considered as true replacement for large dams. For instance, to store water equivalent to Kahir dam we would need to construct 15 small dams, and that too will be exclusive of power generation. Therefore, where it is necessary to build small dams, the importance of large dams should not be ignored as they are imperative for sustained national economic growth "[10]" and "[35]".

2.9.2. Non-structural measures

These measures are related to flood forecasting, flood warning, flood mapping, emergency evacuation plans and land use zoning etc. In Balochestan, Iran, flood forecasting and flood warning systems are very week. The devastating floods of 2010 and 2011 are the good examples of our weak capabilities in this field which results in large scale damages of human life, livestock and properties. Therefore flood warning and forecasting systems all over the country need extension and improvement. Installation of modern tools such as weather radars and software and increasing capacity of individuals to interpret the data received from these radars needs immediate attention. Weather radars have proved to be efficient and effective in measuring real time precipitation in many countries especially in Japan, France. These radars can significantly improve the accuracy of meteorological forecasting which can help in better planning and preparedness for floods "[14]".

Non-structural measures such as restoration of wetlands for flood retentions and room for rivers should be given serious consideration. Hydrological responses to rainfall are strongly linked with the local characterization of soil such as water storage capacity, infiltration rates and preceding rainfall conditions. The type and density of vegetation are also equally important to understand the catchment response to rainfall. Human alteration to catchments and unplanned urban development also play a significant role in flood hazards. Therefore these need to be checked carefully. Loss of vegetation and changing pervious natural surfaces to less pervious or impervious artificial surfaces leads to an increased storm water runoffs and can result in san increased incidences of flash floods "[4]".

Balochestan also needs to enhance its capacity towards disaster management, preparedness and emergency relief efforts. In 2010 and 2011 floods more than 1 million were affected. Many of these damages could have been saved if we were better prepared to face these floods and our emergency relief services were adequate. Considering the reality that climate changes might bring more frequent floods in future, we need to develop separate contingency plans for the most vulnerable areas. For this purpose, mapping of flood zones and identification of most vulnerable areas would be the first step. This work should be given priority and then necessary protective measures should be taken in these areas "[14]".

Lack of coordination between inter-departments at the provincial and federal level has been one of the major bottlenecks in successful and effective implementation of various water management and flood protection strategies. In Makoran, Balochestan, water resources are managed by different organizations therefore appropriate institutional arrangements should be made for proper coordination of different ministries and line agencies involved in the management of water resources. The roles and responsibilities of these organizations should be clearly defined to avoid overlapping and to ensure effective management of water resources at all levels "[23]".

3. Results

Floods are a frequently occurring phenomenon due to heavy monsoon rains in Iran. The size and magnitude of the floods that Iran has confronted in the last few years would have been a problem for any nation. Recent severe floods have shown that there is a lack of adequate cooperation between flood control agencies, due in part to shortcomings in current technological capacities, such as warning signals, preparedness initiatives, disaster response, and systemic flood prevention measures. This is important to further develop flood monitoring and alert systems to reduce the damages of potential floods. Although Iran's flood warning and detection systems have shown their effectiveness, the forecasting ability of the network is still weak. At the same time the institutions, NDMA and PDMA, operate at national and provincial levels, dispersing the rehabilitation responsibilities to local bureaucracy rather than establishing a grassroots-level structure with reference to small cities and villages. It also makes rehabilitation procedures weak and ineffective in most areas. Nonetheless, a cohesive response by the Iran community and the combined efforts of all the international and domestic agencies concerned remained crucial. Only providing damage reimbursements to flood victims is not the remedy; we need to get rid of this problem. Iran's water management also needs to develop more reservoirs—lakes, and dams as a way to combat floods. The government should generate and incorporate robust public awareness initiatives to educate the public on flood risks and flood preparedness. In conclusion, to achieve effective flood control, a risk-based proactive strategy is needed "[18]" and "[19]".

In August 2010, Iran suffered one of the most severe floods in its history. Floods are the most frequently occurring and damaging natural hazards in the country. Of all population who are affected by natural hazards, 90% are subjected to flooding. In the recent flooding, almost 80 persons died and financial damages were in the range of six of billions US dollars. According to available official statistics, about 200 people lost their lives and economical losses amounted to approximately $7 billion 2010 flooding. These estimates are carried out at the local administration level and uncertainty in these values is unknown. Although no major flood had occurred since 1995, the devastating flooding in 2010 demonstrated the continuous presence of flood risks. The nature of flooding varies according to geography. Fluvial floods in the Makoran plain prove most devastating as the terrain is flat, densely populated, and economically developed, "[22]", "[28]" and "[32]". Hill torrents (flash flooding) are the second most destructive type of flood. Hill torrents threaten large areas of the country (Fig. 2) and claim human lives most frequently. Floods due to cyclones and intensive localized rain are dominant at other locations. Exceptionally high floods have also occurred due to the breaching of some of the small dams, e.g. the Kahir dam in Kahir, which breached on February 11, 2024, washing away more than 13 people "[19]" and "[6]".

Recommendations

Flood management in Iran is a task that requires both vast resources and comprehensive understanding of the flood problem. The nature of floods varies drastically throughout the country due to contrasting physiographic, climatic, hydrologic, demographic, and socio-economic factors. The present approach for flood management

incorporates both structural and non-structural measures, yet their inter-linkage and combined efficiency still need to be optimized. The efficiency of any proposed measure should be evaluated for its integration into existing measures to achieve efficient and economically viable solutions. Change in flow regime due to low flows in eastern rivers after the Makoran Water Treaty and enhanced flood protection measures have attracted economic activities and settlements in floodplains. Flood management arrangements are concentrated around the Rapch and Kahir rivers because of the frequent and devastating nature of flooding. Those floodplains that have not faced flooding over a considerable time are under extremely high risk. Vulnerability on such locations has increased due to a false sense of safety "[6]" and "[7]".

4. Conclusions

Flooding has always been an issue in the Rapch and Kahir basin. Monsoon rainfalls are the main source of floods in the basin. High flows are experienced in summer due to the increased rate of rain water and monsoon rains. The nature of flooding varies according to geography. Fluvial floods in the Makoran plain prove most devastating, as the terrain is flat, densely populated and economically developed. Hill torrents (flash floods) are the second most destructive type of flood.

Projected climate changes are expected to increased variability of monsoon and winter rains which can increase the inter-annual and intra-annual variability of river flows resulting in serious floods in future. In order to be prepared for this situation, Balochestan needs to work on both structural and non-structural measures for flood protection. Iran must increase its storage capacity to mitigate the effects of super floods. The role of two major reservoirs Pishin, Zirdan and Kahir in reducing peaks of floods during 2024 has been enormous. Construction of small dams can help in small scale irrigation schemes but would not be able to play their effective role in hydropower generation and flood management.

In addition to these structural measures, we need to give equal emphasize on non-structural measures. we need to enhance our flood forecasting and flood warning capacity which is currently very weak. Restoration of existing wetlands, proper planning of urban development, improving preparedness and relief services and increasing coordination between different provincial and federal departments involved in water management and flood protection are few steps that can significantly improve our capacity to protect and manage floods in the country.

Compliance with ethical standards

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