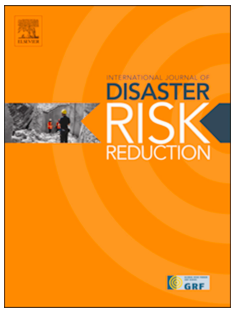
# Accepted Manuscript




Applying systems thinking to flood disaster management for a sustainable development

Junaid Rehman, Osama Sohaib, Mohammad Asif, Biswajeet Pradhan

PII: S2212-4209(18)30980-4

DOI: https://doi.org/10.1016/j.ijdrr.2019.101101

Article Number: 101101

Reference: IJDRR 101101

To appear in: *International Journal of Disaster Risk Reduction*

Received Date: 22 August 2018

Revised Date: 11 February 2019

Accepted Date: 20 February 2019

Please cite this article as: J. Rehman, O. Sohaib, M. Asif, B. Pradhan, Applying systems thinking to flood disaster management for a sustainable development, *International Journal of Disaster Risk Reduction* (2019), doi: https://doi.org/10.1016/j.ijdrr.2019.101101.

# Applying Systems Thinking to Flood Disaster Management for a Sustainable Development

**Junaid Rehman[1], Osama Sohaib[1, 2], Mohammad Asif[3], and Biswajeet Pradhan[1, 2*]**

[1]School of Information, Systems and Modelling
[2]Centre for Advanced Modelling and Geospatial Information Systems (CAMGIS), Faculty of Engineering and IT, University of Technology Sydney, Australia; Junaid.Rehman@student.uts.edu.au, Osama.Sohaib@uts.edu.au, Biswajeet.Pradhan @uts.edu.au
[3] Department of Computer Science, National Textile University, Faisalabad Pakistan; asif@ntu.edu.pk

*****Biswajeet24@gmail.com or Biswajeet.Pradhan@uts.edu.au (Corresponding author)

**Abstract:** The rapid urbanization and environmental imbalance have significantly challenged Pakistan's organizational capacity to respond and initiate relief efforts and hence increasing its vulnerability to flood disaster situations. This study considers systems thinking approaches such as, Causal Loop Diagram (CLD) and Driver-Pressures-States-Impacts-Responses (DPSIR) framework to identify key stakeholders to disaster risk reduction and analyze various social, technical, institutional, cultural, infrastructural and environmental factors that contribute to flooding in Pakistan. Based on the information collected through expert interviews with key government officials and analyzing the existing literature and research reports on floods and disaster management, policy recommendations for long-term flood disaster response strategies have been made. The comprehensive set of recommendations towards effective flood management and mitigation would help build resilience from floods by raising community awareness and enhancing institutional capacities at federal, provincial and district government levels in the countries like Pakistan and other developing nations facing catastrophic flood situations.

**Keywords:** Disaster risk reduction; disaster management; risk management; system thinking; Pakistan

## 1. Introduction

Natural calamities such as earthquakes, floods, droughts, bushfires, soil erosion, storms, epidemic diseases, landslides and cyclones occur more frequently due to the climatic variation in a region [1]. Floods are one of the serious socio-natural disaster [2] affecting the socio-economic living. Asian continent is prone to natural disasters [3] wherein the countries like Bangladesh, India, China and Pakistan have confronted catastrophic flooding situations during the last decade [4]. Flooding in Pakistan has been a recurring phenomenon that has caused heavy losses to infrastructure, agriculture and human life [5].

Pakistan is a developing country, with inadequate flood preparedness and risk management mechanism. This was evident from the floods of 2010 that revealed a gap governing availability of comprehensive policy framework on flood disaster risk reduction and lack of coordination between key stakeholders such as disaster management institutions and governments at federal, provincial and local levels [6]. Disaster Risk Reduction (DRR) is not merely the state responsibility but it has to do with all the parts of government, civil society, media and public and private sector organizations. Hence, in order to be prepared for natural disasters, effective disaster management strategy needs to be adopted backed by proper monitoring and Early Warning System (EWS).

Floods, being a problem of systemic nature, the application of mere technical problem-solving approaches are not sufficient towards addressing the problem. Structural measures for managing flood disasters are costly for developing countries hence the solutions must be socio-economically viable and environmentally feasible. Therefore, effective integrated flood management strategy is needed through the involvement of all the relevant stakeholders and sectors. The strategy must take into account collective efforts at communal and institutional level which can be made more effective through empowerment, capacity enhancement and improved coordination among these stakeholders.

Therefore, the purpose of this study is to give policy recommendation about flood disaster management in Pakistan by investigating the system thinking methods (such as Causal Loop Diagram (CLD), and Driver-Pressures-States-Impacts-Responses (DPSIR) framework) described in the literature [29, 32] for flood risk management. Interviews with key government officials were

conducted as a primary data collection, also reviewing and analyzing the existing research and report on floods and disaster management as a secondary source of information. The overall findings discuss flood risk management strategies and recommendations for coping flood problems in Pakistan.

This paper is comprised of five sections. The section 2 presents some background information on flood disasters in Pakistan. Section 3 highlights on research data and methodology. Section 4 discusses analysis and results. Section 5 presents the recommendations for flood disaster risk reduction. Finally, the last section provides concluding remarks on this work. The application of systems thinking approach towards investigating the phenomenon of flooding in Pakistan and suggesting concrete recommendations & preparedness mechanism for various tiers of government and other stakeholders would add new perspectives and contribute to research literature in the context of developing economies.

## 2. Background and Literature Review

### 2.1. Flood Disasters

Flood disasters involving occurrence of natural events triggered by geomorphological conditions and subsequently requiring human interventions, are amongst the issues of thickly-populated urban dwelling that significantly add to the miseries of marginalized and vulnerable communities in the developing nations. Communities in these countries face many problems overwhelming the institutional capacity to respond [32].

For flood risk assessments, researchers have described floods in four different forms such as urban, flash, coastal and riverine floods [7, 8]. However, most of the previous research (e.g., [7, 9]) identify riverine floods as the frequently-occurring flood disasters having high impact on urban communities in developing countries [10]. According to Powell et al. [45], risk identification and assessment is usually undertaken in four stages in flood risk management: “(1) hazard identification and assessment; (2) exposure assessment; (3) vulnerability assessment; and (4) risk assessment”. Previous research and policy reports have described the methods and strategies of flood risk for assessment (such as [11, 12, 13, 14]).

Zhang [15] discussed that the flood disaster risk represents a probabilistic occurrence of floods of varying intensity and losses associated. In view of reducing flood-related vulnerabilities, Montz [16] emphasized on a need to improve hydrological systems and at the same time address social, political and economic factors that add to these vulnerabilities. The ever-increasing flood problems are mostly triggered by the issues like ecological disturbance and rapid urban development. Effects of global socio-economic and environmental changes, when combined with inadequate institutional support can result in increased risk and threat to the quality of life of many people [17].

## 2.2 Flood Disasters in Pakistan

During the last decade, the consequences of natural disasters in Pakistan such as floods, earthquakes, heat-wave, land-sliding, storms and epidemics have been catastrophic which collectively affected more than 50 million people with 80,708 fatalities and estimated US$25.5 Billion loss to the economy. Among these, the notably devastating were the floods of 2010 & 2011 that rendered an estimated loss of US$ 9.5B & 2.5B respectively.

Owing to its hydro-meteorological conditions, Pakistan is prone to floods [18]. Besides, excessive rainfall in the monsoon season is yet another contributing factor towards flood situations in Pakistan. The flooding of 2010 was mainly caused by the heavy rainfall and glacier meltdown in Pakistan [18, 19, 20]. In the year 2010, disastrous flood were caused by the heavy monsoon rainfall and glacier meltdown in Pakistan [18, 19, 20]. Rivers in Pakistan are not perennial, approx. 80 percent of the water is expected during the monsoon season [6].

Pakistan has established disaster management structure and signed the then applicable Hyogo Framework for Action-HFA (2005-2015) [21] to ensure its commitment to improving its disaster management system to exhibit its preparedness and better reconstruction mechanism. The country has reported strong national commitment to HFA priority actions. Nonetheless, the gap between commitment and ground reality was evident from the floods of 2010. According to 2011 Oxfam International report [22], the floods of 2010 were among the worst humanitarian crises in the history of Pakistan. As an estimate, it affected around 20 Million people with 1985 lost their lives and 3,000

injured. More or less 1.6 Million houses were destroyed with loss of jobs in excess of 5 Million. In addition, one Million families turned homeless and more than one million people had to starve due to food crisis during the disaster. The floods also rendered heavy damages to crops, irrigation system infrastructure. Despite the efforts of relief volunteers, the response to the crisis was poorly prioritized and managed.

A considerable part of the country is still not under the coverage by early warning system and infrastructure for flood protection such as protection walls, watercourses and river embankments. Delivering an effective, timely, adequate and dynamic humanitarian response to mitigate potential impacts of floods have been hindered by the persistent social neglect of inequalities, inadequate government preparedness of disasters, inadequate system of disaster management and absence of relief measures in case of emergency [6].

The National Disaster Management Authority (NDMA) of Pakistan serves as a coordinating & monitoring body for disaster management [36]. NDMA has offices in all the provinces of Pakistan and works in coordination with provincial government authorities for enhancing flood preparedness and taking measures towards mitigating flood disasters and post-flood reconstruction efforts. Recently, the government of Pakistan has taken important steps in the development of a framework for disaster management institutions [6]. Nonetheless, a lot more still needs to be done. The policy implementation of a vibrant disaster management system especially at the level of communities is crucial in order to minimize risk and enable people to help themselves when faced with the crisis. Figure 1 [36, 37] illustrates the Integrated Context Analysis (ICA) performed in Pakistan in 2017 of flood events recorded between 1950 and 2015.

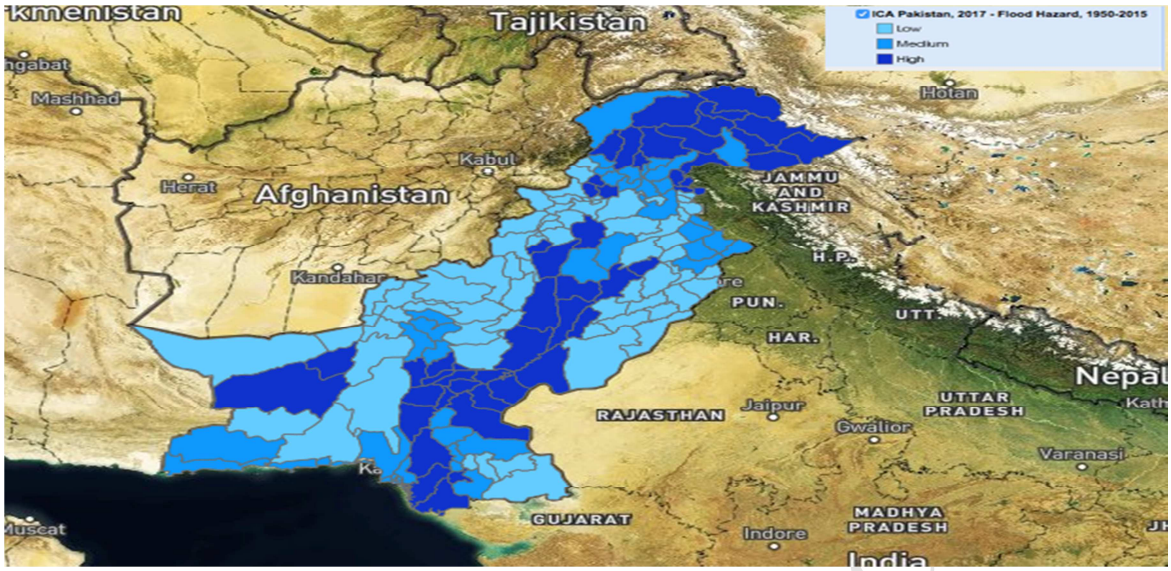



**Figure 1: Flood hazards in Pakistan [37]**

2.3 Qualitative System Dynamics (QSD) Modelling approach

Flood disaster risk reduction and management is a complex process comprising of expertise in a multi-stakeholder environment and combining various data sources & information [45]. Qualitative System Dynamics (QSD) is a structured approach for qualitative analysis, which is suitable for conceptual analysis in multi-stakeholder environments, such as disaster risk management. QSD is a widely used technique derived from the mainstream of systems dynamics that employs visual Influence diagrams to provide understandings of the behaviour and evolution of complex systems [46]. The foundation of QSD in the risk analysis elicitation is based on casual maps and the Soft System Methodology (SSM) [45]. For example, identifying the organizational multi-stakeholder though the use of SSM [47], and risk identification and assessment from multi-stakeholder participation through the use of underlying maps [48].

For the purposes of risk reduction in floods disaster, the abilities of QSD to denote specific system dynamics and facilitate the qualitative expression in multi-stakeholder environments are of particular importance. Moreover, system approaches such as system dynamics as an approach is also a well-established method in the risk analysis literature [45]. In particular, the use of influence diagrams, also called causal loop diagrams, is quite evident [46, 49] and hence constitutes a major

part of our research methodology which is further complemented by the qualitative enquiry (interviews) in order to deeply understand the flooding problem in the context of Pakistan.

## 3. Data and Methodology

Following the modelling approach in section 2.3, formulation of an effective strategy necessitates critical assessment of the current situation. An effective strategy must include an assessment of the current situation. When it comes to strategic planning process, it is critical to consider the environmental context of the problem. This requires identification of organizations and actors involved as an important aspect of institutional analysis. For effective river-basin development and integrated flood management, it is essential to carefully identify DRR stakeholders in the context of Pakistan coupled with the roles & obligations they have in the flood risk management [32]. As per World Meteorological Organization [28], R&D institutes; government organizations, departments, and ministries; flood-prone communities; NGOs and voluntary organizations are the important stakeholders in integrated flood management.

For the purpose of this study, data were collected from multitude of primary and secondary sources. Interviews with key government officials served as primary data for this research. A total of five interviews were conducted from flood-related government departments in Punjab and Khyber Pakhtunkhwa (KPK) provinces of Pakistan. All interviews were conducted from September 2017 to December 2017.

Participant (P1) is from Irrigation department, P2 is responsible in the Meteorology department, P3 works in the Punjab Emergency Service Rescue, P4 works in World Health Organization (WHO) regional office in KPK , and P5 is serving at National Health Emergency Preparedness and Response Network, Punjab. All participants have more than ten years of work experience.

Secondary data were obtained by review and analysis of the existing literature on disaster management and flood risk reduction. Besides, Government documents, and the reports issued by United Nations and NGOs were also reviewed to investigate the causes of and responses to the flood disasters. Systems thinking approach is applied to highlight the complete picture of floods and forms the basis of the fact that system components can be understood by observing their relationship with

each other and with other systems. It uses diagrams for analyzing socio-technical problems of complex nature by describing how various sub-systems of a complex system interact and how changing one factor can influence other elements. In order to understand and address the flood problems in the context of Pakistan, this study adopts similar approach as applied by Akmalah and Grigg [32] for addressing flooding phenomena in Jakarta, Indonesia.

## 4. Results

### *4.1 Flood Risk Assessment and Management in Pakistan*

Ge et al. [23] explained that method for assessing disaster-related risks have witnessed a transformation from qualitative to quantitative analysis that carefully combines social, economic, environmental, institutional and technical factors. Being a comprehensive method involving multi-factored indexing, the flood risk-assessment index was developed in several ways by employing different techniques [24]. Liu et al. [25] and Lu et al. [43] both proposed that flood disaster emerges from natural floods faced by the human society and its creation is based on three conditions such as flood-causing factors, flood-prone environment and flood-bearing entities. In line with the flood risk assessment indexing done by Lu et al. [43], the same approach has been utilized to develop risk assessment index in the context of Pakistan.

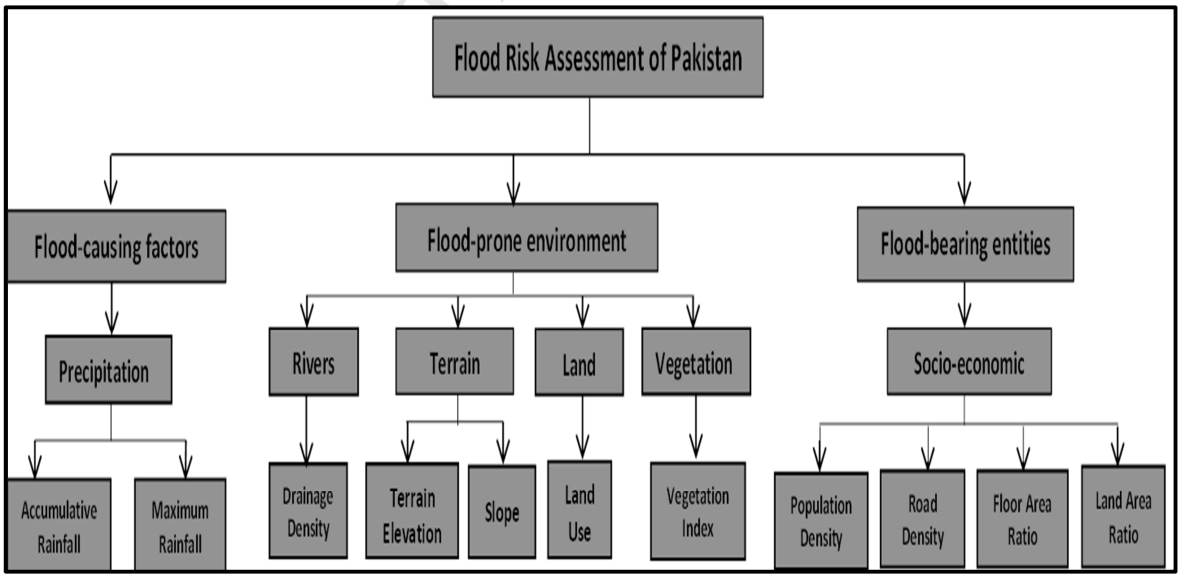



**Figure 2: Risk Assessment Index of Floods in Pakistan [24, 25, 43]**

As can be seen in the above diagram on risk assessment index of floods in Pakistan, the factors such as land, river, vegetation, terrain, precipitation along with other socio-economic conditions have been incorporated. In Pakistan-specific flooding context, the factors like 'increase in ground water level, extreme monsoon rainfalls and land denudation' can be considered as *Flood-causing Factors*, whereas 'rivers, lands, vegetation' can be categorized under *Flood-prone Environment*, and finally the 'flood-affected communities and public infrastructure' can be mapped under *Flood-bearing Entities*. As a whole, the flood risk assessment index, mapping the environmental, topographical and socio-economic factors, helps in understanding the flood risks phenomena in Pakistan and subsequently assists in developing specific set of recommendations for diverse stakeholders to DRR. To this end, all interview participants (P1 to P5) agreed to the above key factors in the context of Pakistan.

Andjelkovic [26] emphasized that effective floods management involves a variety of measures that reduce the vulnerable of human life and infrastructure to floods. These flood management activities mainly include policy planning, forecasting, informing, reporting, warning, educating and raising public awareness as a whole. According to the P1:

> "Information such as public awareness, arrangements for evacuation and rescuing, post-flood debriefing, warning to flood-affected communities should be included in preparedness plans of the flood disaster. The plan should be publically displayed and made widely available to the community and be subject to regular review in coordination with the local community."

According to the guidelines on participatory planning and management for flood mitigation as preparedness [27], strategic planning in flood management requires thorough awareness and understanding of the risks. The timely preparation and circulation of the awareness plans and programs serve as the key factors towards effective risk reduction and management. To build resilience and for efficient mobilization of resources, community awareness is crucial [27]. Nonetheless, due to varying socio-economic conditions and education levels, the community perception of floods risk and their consequences may vary. The public motivation and awareness are quite important in vulnerability reduction [27, 33-34]. According to the P2:

> "Public education is an important mean for encouraging flood preparedness and mitigation programs. These programs emphasize on solutions changing society attitude to make people more vulnerable. The knowledge of flood risk management and level of awareness particularly in rural communities of Pakistan is still low."

According to the World Meteorological Organisation [28], stakeholders reflecting social, economic, environmental needs must play a role in planning and implementation of sustainable flood management strategies. The lack of or week institutional capacities are among the most common barriers to the effective implementation of these strategies. Therefore, in order to develop a mechanism to enhance monitoring, outreach and adjustment capabilities, the institutions must redefine the scope of work and responsibilities and re-allocate resources to achieve priority objectives. Partnerships offer more viable solutions to devise integrated flood mitigation strategies by bringing together leadership and expertise of government, business, academia, R&D institutions, non-profit groups and community organizations to reduce the flood disasters and enable post-flood recovery easier.

As stated by P4:

> "It is the local community that can provide immediate support during the sudden strike of the flood disaster. However, community participation and involvement in Pakistan is still low and in early stages as in many developing countries. Therefore, facilitating community mobilization, building cohesion, encouraging involvement in the decision-making process and recognizing the specific needs of individuals and social groups are some important roles that must be undertaken by disaster management institutions of Pakistan."

### *4.2. Applications of Systems Thinking*

#### 4.2.1. Casual Loop Diagrams for 'Causes' and 'Effects' of Flooding in Pakistan

Based on the responses from all Interviewers (P1 to P5), Figure 3 and 4 below represent descriptive Causal Loop Diagrams (CLDs) that have been developed by identifying the issues and

factors that contribute to flooding [32]. Figure 3 shows some physical causes of flooding which arise due to heavy rains that lead to saturation of grounds, increasing surface water flooding, which leads to failure of the drainage system and subsequently the surface water flooding.

According to the P5:

"Heavy rainfall in the monsoon season is the main reason of flooding in Pakistan, however, flood control and lack of adequate drainage system are also the causes."

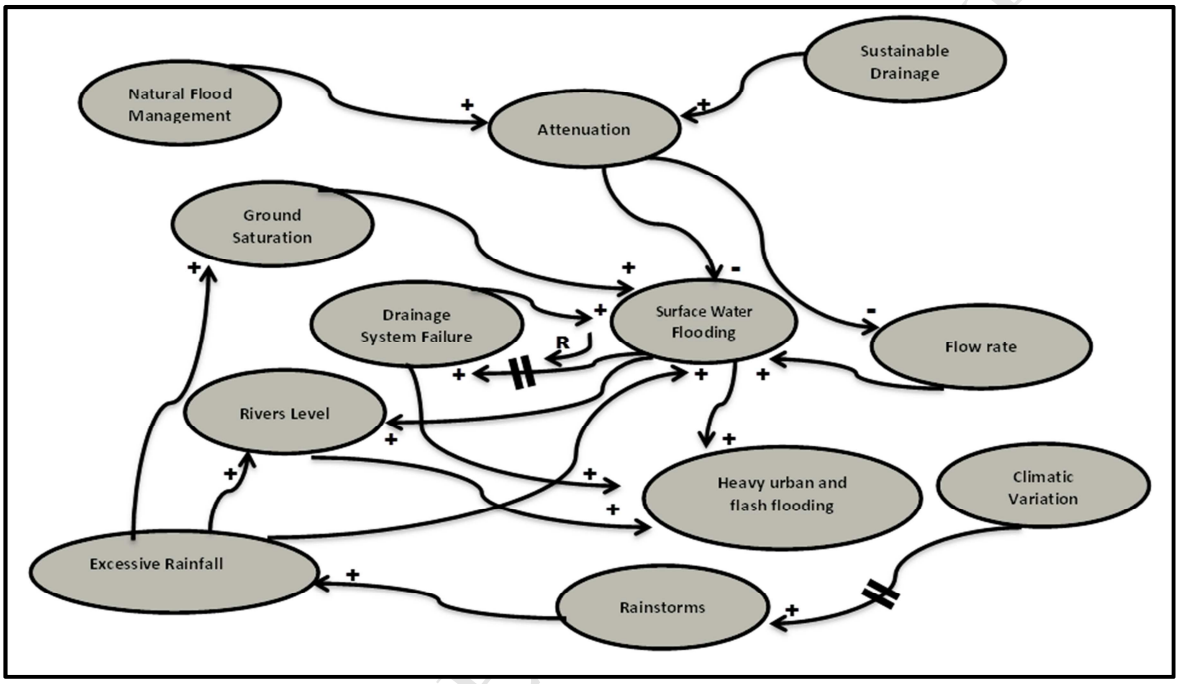



**Figure 3: General CLD for Physical Causes of Floods [32]**

Figure 4 shows some effects of flooding and what available infrastructure, preparedness mechanism and strategies are in place for coping flood disasters.

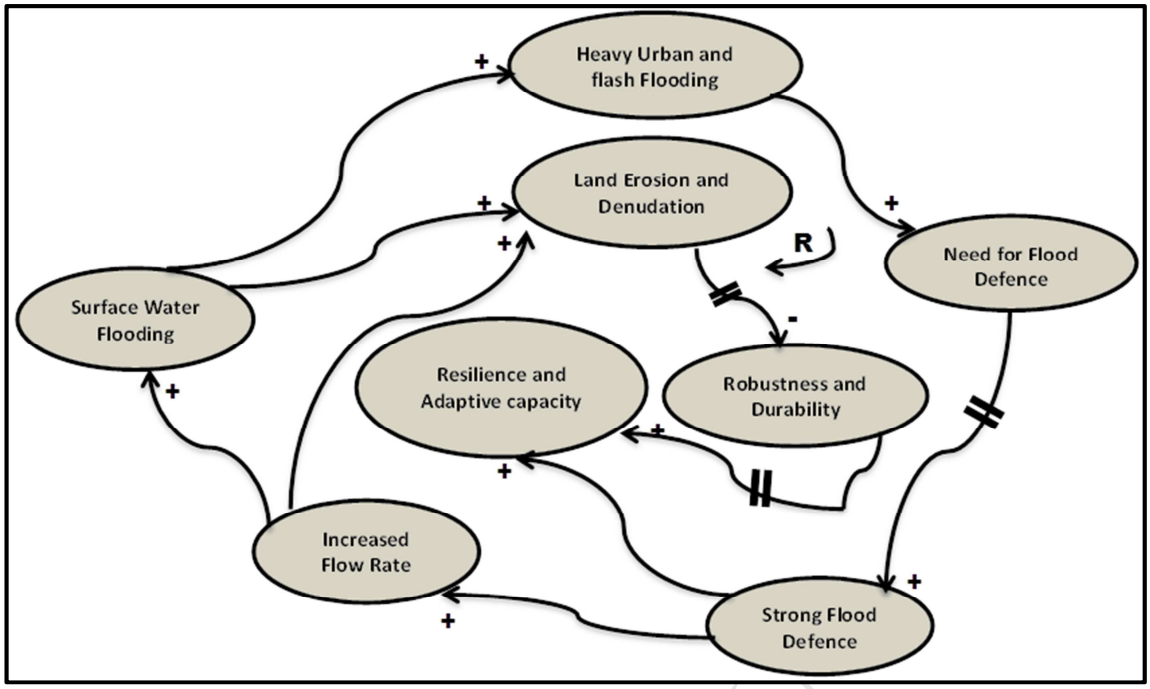



**Figure 4: General CLD for Effects of Floods [32]**

4.2.2. DPSIR Framework

Developed by European Environmental Agency (EAA) [29], the Driver-Pressures-States-Impacts-Responses (DPSIR) framework, serves as a causal framework to establish a relationship between various elements of environment and society [30]. When it comes to flood-related disasters, DPSIR framework serves as an efficient way to determine the effectiveness of flood risk preparedness and reduction measures that have been put in place. The proposed CLD considers various socio-economic, institutional, technical, financial, natural, environmental and geomorphological factors in the wake of given constraints, assumptions and limitations [31, 32]. When applying DPSIR framework [32], the first step involves gathering information on various elements of DPSIR, followed by the assumption of the relationships that potentially exist between the elements of DPSIR chain.

The findings of the interviews pave the way towards the application of DPSIR framework to analyze flooding problems in the context of Pakistan. DPSIR application involves initially setting the problem context followed by its illustration using a process flow diagram (Figure 5) that represents a nexus between various elements (subsystems) of the system. This process is further aided by the identification of factors contributing towards flood problems in Pakistan (Figure 6). Finally, by

considering various driving forces and the elements of DPSIR framework, a comprehensive Causal Loop Diagram representing flood problems in Pakistan is presented (Figure 7).

According to P3:

"The driving forces such as urbanization add to pressures such as deforestation, which adds to the state of increasing flood catastrophes. Impacts such as property loss then cause responses such as flood mitigation strategy."

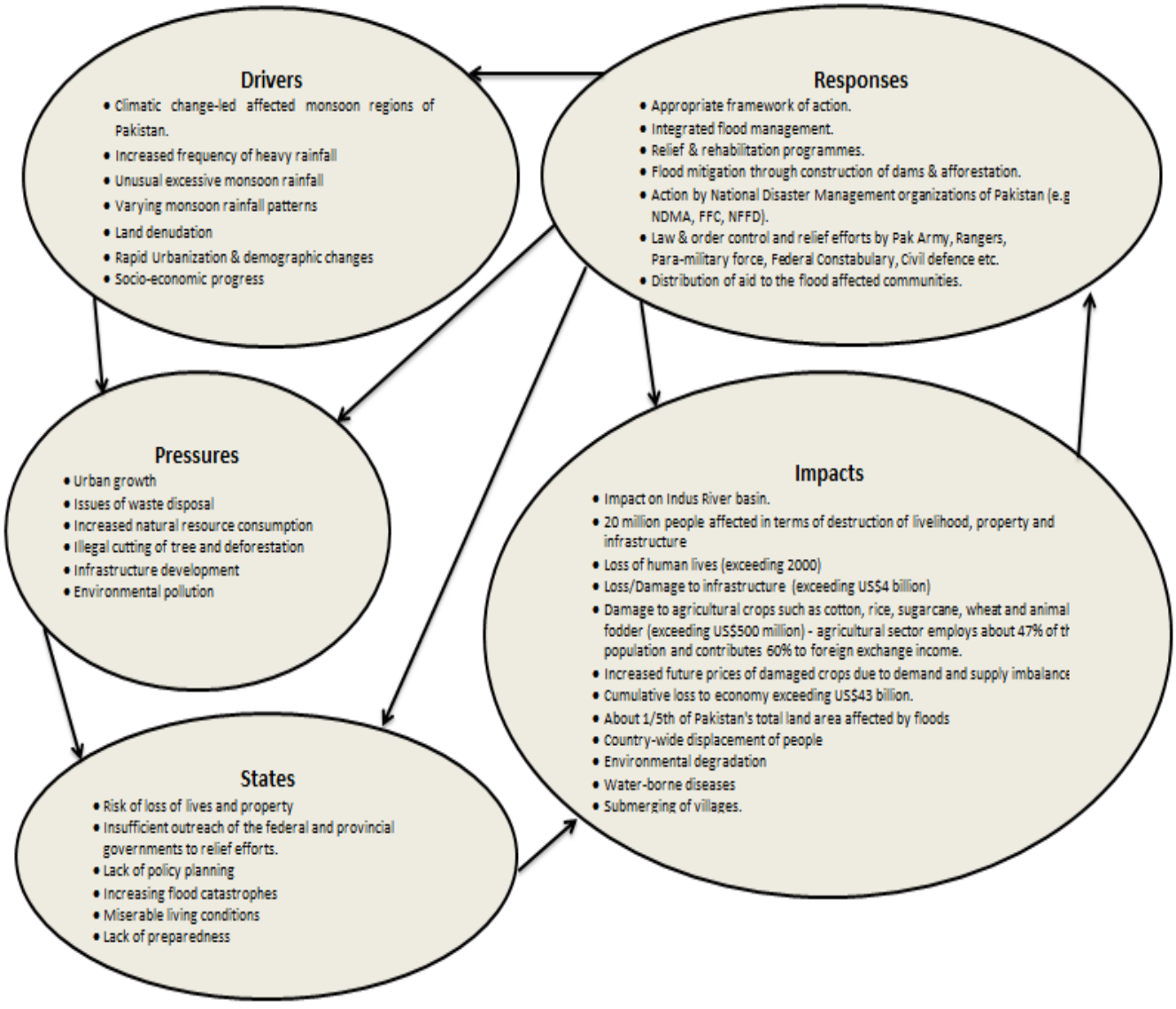



**Figure 5: Application of DPSIR Framework for Investigating Flood Problem in Pakistan [32]**

Participants P1 and P3 mentioned:

"Various stakeholders such as disaster management authorities, government departments, public communities, media, civil society, NGOs can play their role in mobilizing

communities, raising awareness and subsequently building resilience and preparedness through a coordinated effort and collective wisdom."

In addition, P2 explicitly stated:

"The Causal Loop Diagram (CLD) helps understand the relationships that exist between the general public, media, NGOs and government authorities and the way they can interact and cooperate with each other to assesses floods reduction through an application of available technological, social, institutional and environmental policies, services and systems."

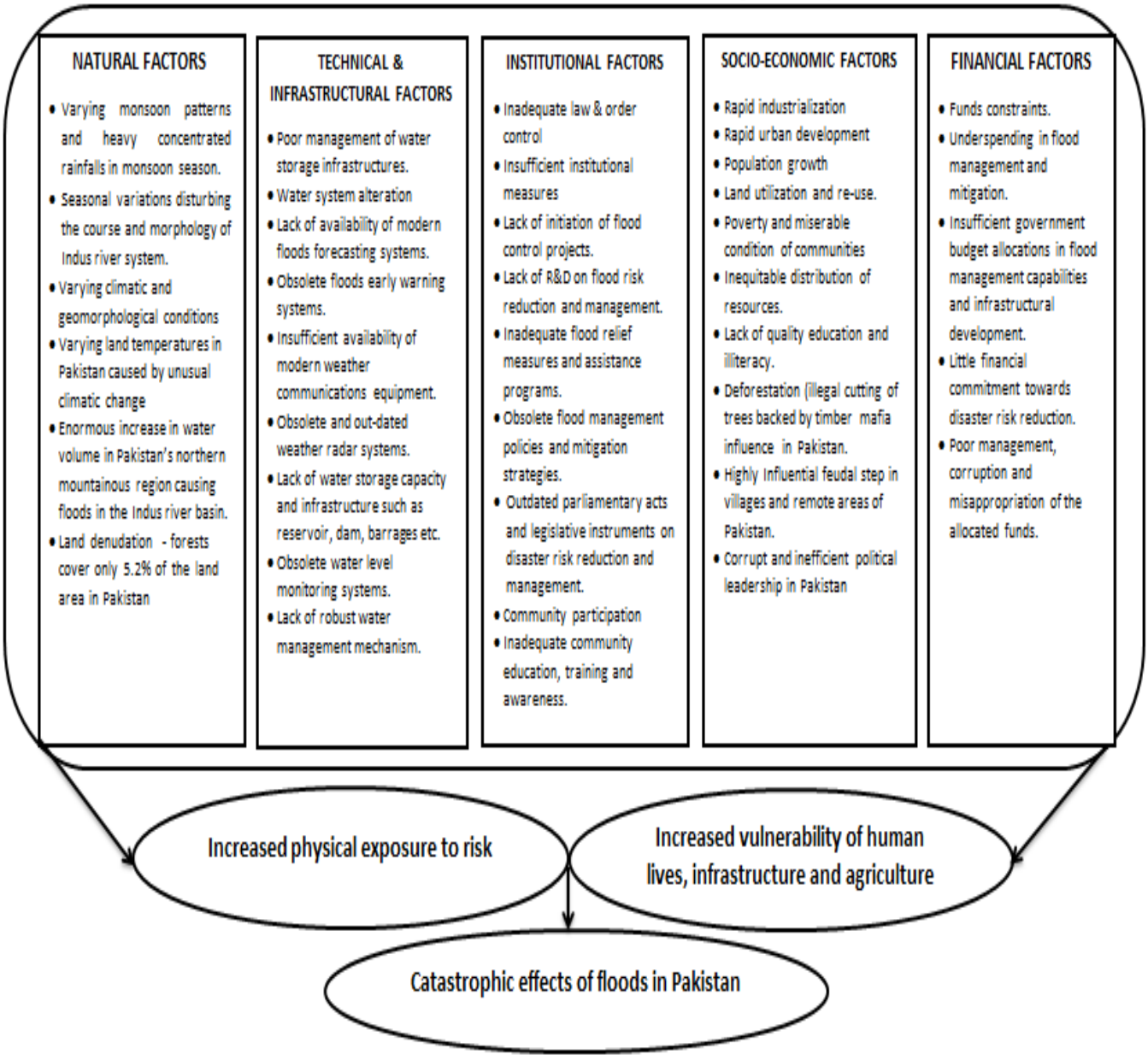



**Figure 6: Factors Contributing Flood Problems in Pakistan [32] [38] [39] [40] [41]**


**Figure 7: Comprehensive Causal Loop Diagram (CLD) for Flood Problems in Pakistan [32]**

According to P5:

"The floods in Pakistan necessitated a pressing need to revisit the causal drivers of vulnerability that turned natural calamity into human disasters and hindered smooth recovery. These factors will keep on weakening the efforts aimed at improving country's resilience to future disaster unless addressed through nationally coordinated plans and pro-poor reconstruction policies."

All participants (P1-P5) discussed the positive and negative effects of flood problem in Pakistan, which is aligned with Akmalah and Grigg [32]. Figure 6 illustrates the various factors associated with flood problems.

Building local capacity and substantially funding community-based disaster risk management were some initiatives to be undertaken as part of government of Pakistan's commitment made under Hyogo Framework for Action (HFA) [21]. Moreover, Pakistan also committed to the Sendai Framework on DRR, which offered an important context to understand overall situation of natural disasters in the country [42]. The key aspect of promoting a risk reduction and disaster-resilient culture is the identification, assessment and knowledge of the hazards and the social, physical, economic, environmental vulnerabilities posed to modern societies. Hence, increased public participation coupled with an in-depth understanding of the environmental and technical risks would build disaster-resilient communities & societies and expanded network of risk-reduction at various levels, allowing communities to take actions based on the knowledge and awareness of the hazards [33]. During disaster situations, losses and impacts can be considerably reduced if government authorities, communities and individuals in disaster-prone areas are alert, well-prepared and aware of the situation and take pre-emptive measures to respond and effectively manage disaster [34].

Disaster management institutions of Pakistan at various tiers of government (federal, provincial and district) have been mandated to ensure protection of masses from the disasters, to which the members of civil society and local communities serve as the key actors in risk prevention. They need to work together, establish partnership and be encouraged and supported to achieve the goal of being flood-resilient. In order for this to happen, collaboration at regional, national and international levels is necessary in dissemination of experience, scientific and technical information and strategic coordination to support national development capabilities [32]. In this context, the United Nations [35] forum offers a platform for universal dialogue and leadership support in reduction of flood related disasters. It should promote working collaboration and strong nexus among the member countries to address flood issues occurring globally.

## 5. Discussions and Recommendations

Although, the government of Pakistan, via its federal, provincial and district level disaster management institutions, has taken some initiatives during the past few years for enhancing the capacity of government institutions and public communities at large, however, it is imperative to enhance cooperation and build synergies between these government institutions so as to enhance the effectiveness of their ongoing structural & non-structural programs, plans & initiatives and efforts, thereby ensuring that their collective disaster management skills, capabilities and resources are incorporated to come up with a broad-based national DRR framework and best utilized for the optimal benefit of the government institutions and subsequently contributing to the Pakistan's agenda of becoming a disaster resilient nation.

### *5.1. Recommendations to Government Authorities and Stakeholders in Pakistan*

As stated in the research methodology section, this study derives primary and secondary sources of information. Primary data sources included expert interviews with five key officials. Secondary data were achieved by reviewing and analyzing the existing research and institutional reports such as [6, 14, 21, 22, 29, 32, 33, 34, 38, 39, 40, 42 & 44]. Hence by reviewing and analyzing primary and secondary data sources and through the application of systems thinking tools & methodologies, a number of key factors contributing to risks of flooding and its effects were identified and pictorially illustrated in Figures 1-7 along with relevant stakeholders. Accordingly, following are some specific set of recommendations for various stakeholders including the government authorities for coping flood problems in Pakistan, enabling them to devise long-term flood disaster response strategies.

#### 5.1.1. Recommendations to Federal Government:

The federal government of Pakistan should:

- Allocate long term sustainable investment in DRR sector and spend funds in the re-organisation and strengthening of the disaster management institutions of Pakistan such as National Disaster Management Authority (NDMA), National Flood Forecasting Division (NFFD), Federal Flood Commission (FFC), Earthquake Rehabilitation and Reconstruction Authority (ERRA),

Emergency Relief Cell (ERC), Pakistan Meteorological Department (PMD), Pakistan Commissioner for Indus Waters (PCIW) etc. and mapping possible flood related future hazards.

- Build an environment that supports the creation, organization, storage, sharing, and application of DRR related knowledge (DRR knowledge management) in a manner to make most of the emerging research and new knowledge created in the DRR fields.
- Promote nation-wide DRR efforts in coordination with the government organizations, media, tertiary institutions, civil society, NGOs etc. aimed at training, educating and raising awareness among the public in general and vulnerable communities in particular.
- Develop roles, responsibilities and mandates of district, provincial and national level government organizations responsible for flood management, preparedness and reconstruction based on effective coordination of international actors during reconstruction and recovery phases.
- Review and update national plans and programs on flood risk management aimed at mitigating risks by enhancing the effectiveness of the flood protection and early warning systems, making them more efficient and robust.
- Review, update and build harmony on various parliamentary acts and legislative instruments governing flood risk reduction & management, particularly the National Disaster Management Act 2010, ERRA Act 2011, Local Government Ordinance 2001, Civil Defence Act 1952, National Calamities Act 1958 etc.
- Review its existing policy instruments and mechanisms on flood planning, management and control by developing and updating plans on i) national flood protection, ii) reconstruction and rehabilitation works, iii) improving flood forecasting & early warning systems iv) monitoring & evaluation of ongoing flood control projects etc.
- Improve and upgrade the installed flood early warning systems and facilities including weather communication equipment and weather radar system capabilities in all the provinces for accurate collection of real-time weather data and consequently enhancing flood awareness, preparedness and resilience.

- Make efforts to reduce crises vulnerability. The government should prepare a reconstruction plan that is based on climatic adaptation and DRR principles and includes necessary reforms to address underlying vulnerabilities of remote population.
- Consult civil society, affected people and communities while devising long-term plans on disaster preparedness, response and reconstruction.
- Inject priority funding on research and development in indigenous disaster risk reduction, thereby facilitating creation of new knowledge on disaster management and mitigation.
- Initiate public reforms and take concrete steps in abolishing strong feudalism culture by promoting a system of social justice and fair-play in Pakistani society in general and vulnerable & less-privileged communities in particular.
- Last but not the least, encourage all the federating units (provinces) to work in harmony for the collective interest of Pakistan as a state. The federal government should particularly empower the smaller provinces like Sindh, Balochistan and KPK in terms of their rights to self-determination and fair share of resources. This would revamp existing governance model thereby ensuring national peace and stability.

5.1.2. Recommendations to Provincial (State) Governments

Provincial government should extend its professional commitment to floods management by:

- Prioritizing preparedness to disasters thereby putting in place realistic contingency plans and ensuring well-repaired and appropriately maintained flood protection infrastructure.
- Capitalizing at community level and introducing awareness programs on Community Based Disaster Risk Management (CBDRM) through the development of CBDRM framework at provincial level in consensus local/district government for the increased ownership and participation of all the local stakeholders.
- Overhauling and upgrading existing flood control systems and early-warning capabilities installed at different locations in the provinces, thereby making best possible use of these technical capabilities.

- Investing in the state-of-the-art Early Warning Systems equipped with advance warning notifications to identify all kind of hazards based on the knowledge of risk, hazard monitoring & assessment and accordingly informing both the government authorities and public communities to take measures in overcoming frequently-occurring disasters.
- Improving disaster response capabilities of emergency response institutions at provincial level as at present these are quite low as compared to the response institutions at national level. This can be done by requesting the services of Pakistan Army, Civil Defence, Rangers, Para-military Forces, Federal Constabulary etc.
- Reviewing the utilization of natural lands in flood-prone areas so as to avoid risk of economic hazards caused by flood events.
- Last but not the least, prioritizing long-term vision on Disaster Risk Reduction (DRR) and reconstruction plans by investing in sustainable livelihoods and rural economies keeping in view the needs of the most vulnerable communities.

5.1.3. Recommendations to International & Local NGOs

International & local NGOs should help build long-term resilience from disasters in Pakistan by:

- Capacity building and reducing vulnerability using mainstream DRR principles with local organizations.
- Strengthening the nexus among disaster preparedness, response, emergency and reconstruction while developing mechanism of accountability to ensure establishment of best practices.
- Submitting a full commitment to accountability and transparency of operation by publishing their financial and expenditure reports.
- Sensitizing international media, international community and the governments in Pakistan and India to initiate dialogue and address issues governing water distribution crisis. Local NGOs and media organizations in both the countries, in particular, have a great potential to play their part in easing long-standing water tension between the two nuclear states. Being a lower riparian nation, Pakistan has always been in political conflict on water storage and distribution with its upper riparian, India. Hence, it would be in better interest of both the nations to act responsibly and

build consensus when it comes to construction of additional dams on their rivers and any other measures relating to their indigenous floods management.

- Lastly, motivating international community, in particular the pollution-contributing industrial economies to recognize and listen to the environmental challenges and concerns that Pakistan is faced with. Accordingly, help should be extended to Pakistan not only in terms of relief efforts in case of crises situation and also helping Pakistan develop a sustainable disaster management and control mechanism, enabling it to effectively cope and mitigate the impact of such catastrophes in future.

## 6. Conclusion

The floods of 2010 were among the worst-ever humanitarian crises that disturbed the indigenous eco-system balance of the country and left long-term catastrophic impact on the people of Pakistan. The Pakistani government and international community extended their maximum humanitarian efforts that vitally assisted millions of people, yet many of these financial support and relief efforts proved to be inadequate due to insufficient funds and poor coordination of repairs to the flood protection systems. Geographically speaking, Pakistan is situated on a disaster-prone belt with two tragic disasters (Flood and Earthquake) alone during the past ten years. Hence to mitigate the effects of flooding, DRR policies should be revised and appropriately implemented, as it was evident from the huge gaps during the floods situation in 2010. This undermined the efforts to improve overall food security and socio-economic prosperity. Hence, the investment and research in disaster management areas at country level would reap real benefits. To this end, understanding the social perception of the vulnerable communities and individuals would be critical towards adjusting their behaviors, communicating risks and implementing intervention strategies. Moreover, bringing communities into a system of decision-making would be central to achieving resilience and sustainability.

Overall, the solution to the flood problems in Pakistan lies in an integrated approach that involves active participation of all the relevant stakeholders. Therefore, Pakistan should devise policies, legislate and develop a broad-based DRR framework at national-level in consensus with all the stakeholders and sectors of the country. For this, a paradigm shift is required in resolving and

addressing flooding problems and ensuring the implementation of proposed DRR framework as a national priority.

Given the past statistics, disasters and hazards could inevitably be frequent in Pakistan due to factors such as climatic changes, rapid population growth, deforestation, disturbed indigenous eco-system balance, poor urban management etc. This implies for even more future disasters but the solution to these problems lies in being resilient enough in terms of disaster preparedness, risk reduction measures, post-disaster responses & recoveries.

## References

Thanks to two anonymous reviewers for their valuable comments, which helped us to improve the earlier version of the manuscript.

## References

[1] M. Ashfaq, Ehsanullah, Floods in Pakistan (lessons learned and way forward) in agriculture sector – a success story, Pakistan Engineering Congress. 32 *(*2011) 168–196.

[2] E. Krausmann, F. A. Mushtaq, Qualitative Natech damage scale for the impact of floods on selected industrial facilities, Nat. Hazards. 46 (2008) 179-197.

[3] E. James, Getting ahead of the next disaster: recent preparedness efforts in Indonesia, Dev. Pract. 18(3) (2008**)** 424-429.

[4] M. Mirza, Three recent extreme floods in Bangladesh: a hydro-meteorological analysis, Nat. Hazards. 28 *(*2003**)** 35-64.

[5] S. Qasim, M. Qasim, R. S. Shrestha, A. N. Khan, K. Tun, M. Ashraf, Community resilience to flood hazards in Khyber Pukhthunkhwa province of Pakistan, International Journal of Disaster Risk Reduction 18 (2016**)** 100-106.

[6] S. Deen, Pakistan 2010 floods- Policy gaps in disaster preparedness and response, International Journal of Disaster Risk Reduction, 12 (2015) 341-349.

[7] W.P. Cunningham., M. A. Cunningham, Principles of Environmental Science, Inquiry and Application. McGraw Hill, New York, 2002.

[8] K. A. Jha; R. Bloch, J. Lamond, Cities and Flooding: A Guide to Integrated Urban Flood Risk Management for the 21st Century. The World Bank, Washington DC, 2012.

[9] K. Anil, A. K. Gupta, S. S> Nair, Flood risk and context of land-uses: Chennai city case. *J. Geogr. Reg. Plan.* 3(12) (2010**)** 365-372.

[10] P. Amoateng, C. M. Finlayson, J. Howard, B. Wilson, A multi-faceted analysis of annual flood incidences in Kumasi, Ghana, International Journal of Disaster Risk Reduction. 27 (2018**)** 105-117.

[11] V. Meyer, C. Kuhlicke, J. Luther, S. Fuchs, S. Priest, W. Dorner, Recommendations for the user - specific enhancement of flood maps, Nat. Hazards Earth Syst. Sci. 12 (2012) 1701–1716.

[12] G. T. Cirella, E. Semenzin, A. Critto, A. Marcomini, Natural Hazard Risk Assessment and Management Methodologies Review: Europe, in: Sustainable Cities and Military Installations SE - NATO Science for Peace and Security Series C: Environmental Security. 2014, 329–358.

[13] H. R. Wallingford, Flood, Defra Risk to People - Phase 2. Defra /Environment Agency Flood and Coastal Defence R&D Programme, UK, 2006.

[14] LAWA, Recommendations for the Establishment of Flood Hazard Maps and Flood Risk Maps, Dresden, Germany, http://www.lawa.de/documents/LAWA_HWGK15062010_Text_Germany_ENG_f72_4d8.pdf , 2010 (accessed 12 Feb 2018)

[15] D. F. Zhang, The application of GIS technology in flood disaster risk assessment, Tianjin Science & Technology. 2 (2006) 41 - 43.

[16] B. E. Montz, The Generation of Flood Hazards and Disasters by Urban Development of Floodplains, Routledge Hazards and Disasters Series**.** 1 (2000) 116-127.

[17] V. Norén, B. Hedelin, L. Nyberg, K. Bishop, Flood risk assessment – Practices in flood prone Swedish municipalities, International Journal of Disaster Risk Reduction**.** 18 (2016*)* 206-217.

[18] Atta-ur-Rahman, A. N. Khan, Analysis of 2010-flood causes and associated socio-economic damages in Hindukush region, Nat. Hazards. 59 (2011) 1239-1260.

[19] M.A.U.R Tariq, V. D. N. Giesen, Floods and flood management in Pakistan. Phys. Chem. of the Earth. 47 (48) (2012) 11-20.

[20] S. Mahmood, A.U.H. Khan, Saifullah. Assessment of 2010 flash flood causes and associated damages in Dir Valley, Khyber Pakhtunkhwa Pakistan, International Journal of Disaster Risk Reduction. *16* (2016) 215-223.

[21] Finland Peer Review Report. Building resilience to disasters: Implementation of the Hyogo Framework for Action (2005-2015). http://ec.europa.eu/echo/files/news/20140717_FinlandPeerReport.pdf (accessed on 15 March 2018).

[22] A. Azad, H. McElhinney, Oxfam International Briefing Paper. Ready or Not - Pakistan's resilience to disasters one year on from the floods, OXFAM Policy and practice. 2011**,** 1-36

[23] Q.S. Ge, M. Zou,J. Y. Zhend, Integrated Assessment of Natural Disaster Risks in China. Beijing. Science Press, 2008.

[24] J. F. Liu, Y.H. Liang, G. B. Ma, Huaihe river valley flood risk assessment based on GIS, Journal of Anhui Agricultural Sciences. 38(5), (2010) 2510 – 2511.

[25] G.F. Liu, N. Li, The urban flood disaster loss assessment index system, Modern Agricultural Sciences and Technology. 22 (2008) 267 – 269.

[26] I. Andjelkovic, Guidelines on Non-Structural Measures in Urban Flood Management. Technical Document in Hydrology. 50 (2001)

[27] Economic and Social Commission for Asia and the Pacific, Guidelines on Participatory Planning and Management for Flood Mitigation and Preparedness, Water Resources Series, United Nations, 82 (2003)

[28] Global Water Partnership and World Meteorological Organization. Urban Flood Risk Management: A Tool for Integrated Flood Management Associated Programme on Flood Management. APFM Technical Document**,** Flood Management Tools Series. 11 (2006)

[29] European Environmental Agency (EEA). The DPSIR framework. https://www.eea.europa.eu/publications/92-9167-059-6-sum/page002.html (accessed on 16 March 2018).

[30] P. Kristensen, The DPSIR Framework, Workshop on a comprehensive/detailed assessment of the vulnerability of water resources to environment changes in Africa using river basin approach. (2004)

[31] S.A. Bempaha, A. O. Øyhusb, The role of social perception in disaster risk reduction: beliefs, perception, and attitudes regarding flood disasters in communities along the Volta River, Ghana, International Journal of Disaster Risk Reduction. 23 (2017) 104–108.

[32] E. Akmalah, N.S. Grigg, Integrated Flood Management Model Engaging Stakeholder to Overcome Institutional Problems in Jakarta, http://lib.itenas.ac.id/kti/wp-content/uploads/2013/06/D01-E-Akmalah-Integrated.pdf (accessed on 17 Jan 2018).

[33] A.F. Armah, D. O, Yawson, G. T. Yengo, J.O. Odio, E. K. A. Afrifa, Impact of Floods on Livelihoods and Vulnerability of Natural Resource Dependent Communities in Northern Ghana, Water**.** 2 (2010) 120-139,

[34] J. Ntajala, B.L. Lamptey, I.B. Mahamadou, B. L. Nyarko, Flood disaster risk mapping in the Lower Mono River Basin in Togo, West Africa, International Journal of Disaster Risk Reduction. 23 (2017) 93–103.

[35] UN International Strategy for Disaster Reduction, http://www.unisdr.org/who-we-are/international-strategy-for-disaster-reduction (accessed on 20 Dec 2017).

[36] National Disaster Management Authority. http://www.ndma.gov.pk/ (accessed on 05 Jan 2018).

[37] S. Cairo, ICA Pakistan 2017 - Flood Hazard 1950-2015. https://geonode.wfp.org/layers/geonode%3Apak_ica_floodrisk_geonode_apr2017, 2017 (accessed on 06 Jan 2018).

[38] Institute for Defence Studies and Analyses. Pakistan Floods: Causes and Consequences. https://idsa.in/idsacomments/PakistanFloodsCausesandConsequences_mbisht_190810 (accessed on 25 Nov 2018).

[39] The Guardian. Causes of the flooding in Pakistan. https://www.theguardian.com/world/2010/aug/12/causes-of-flooding-in-pakistan (accessed on 25 Nov 2018).

[40] Prevention Web - the knowledge platform for disaster risk reduction. Pakistan: flood risk assessment 2015. https://www.preventionweb.net/english/professional/maps/v.php?id=44455 (accessed on 25 Nov 2018).

[41] Pakistan Water Gateway. Floods in Pakistan. http://waterinfo.net.pk/?q=fip (accessed on 25 Nov 2018).

[42] UNDP, Pakistan. Localizing the Sendai Framework for Disaster Risk Reduction in Pakistan: Moving towards a more resilient Pakistan. http://www.pk.undp.org/content/pakistan/en/home/presscenter/pressreleases/2017/02/28/localizing-the-sendai-framework-for-disaster-risk-reduction-in-pakistan-moving-towards-a-more-resilient-pakistan.html

[43] Li, X., Sun,Y., Li, X., Gong, H. & Ma, Y. 'Flood Risk Assessment in Pakistan at 1km Grid Scale', 2011 International Conference on Multimedia Technology, Hangzhou, China. 2011

[44] National Disaster Management Authority, Pakistan. National Disaster Risk Reduction Policy 2013. http://www.ndma.gov.pk/plans/drrpolicy2013.pdf

[45] Powell, J. H., Hammond, M., Chen, A. S., & Mustafee, N. Human Agency in Disaster Planning: A Systems Approach: Human Agency in Disaster Planning. Risk Analysis. 38 (2018) 1-22

[46] Powell, J. H., Mustafee, N., Chen, A.S., Hammond, M. System-focused risk identification and assessment for disaster preparedness: Dynamic threat analysis, European Journal of Operational Research, 254(2) (2016) 550-564

[47] Wang W., Liu W., J. Mingers. A systemic method for organisational stakeholder identification and analysis using Soft Systems Methodology (SSM), European Journal of Operational Research, 246 (2) (2015), pp. 562-574.

[48] Ackermann, F., Howick, S., Quigley, J., Walls, L., Houghton. T. Systemic risk elicitation: Using causal maps to engage stakeholders and build a comprehensive view of risks, European Journal of Operational Research, 238 (1) (2014) 290-299

[49] Coyle. R.G. Systems dynamics modelling: A practical approach. Chapman & Hall, London, UK (1996)