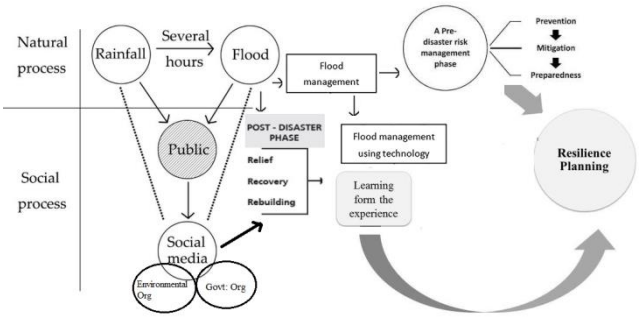
Global NEST Journal, Vol 24, No 2, pp 234-247

Disaster risk management: Focused to flood hazard and its impact in Pakistan

Sanjrani Manzoor A.[1], Wajidi A.[1], Wagan S.A.[1], Riaz S.[2,*], and Siddique M.[1]
[1]HANDS-Institute of Development Studies, Karachi, Pakistan
[2]Department of Social Work, University of Karachi, Pakistan
Received: 13/12/2021, Accepted: 25/02/2022, Available online: 02/03/2022
*to whom all correspondence should be addressed: e-mail: sakriaz@uok.edu.pk
https://doi.org/10.30955/gnj.004223

Graphical abstract



Abstract

Recently, weather and climate related extreme circumstances such as droughts, heat waves, bushfires and floods are increasing around the world. South Asian countries, that have the highest annual average number of people physically affected by natural hazards mostly by floods. Most popular flood risk areas are urban areas because there is rapid urbanization infrastructure and uncontrolled development. It results in more people being vulnerable to floods than ever before. Pakistan is positioned within a hazard-prone region and is exposed to several kinds of natural disasters such as earthquakes, cyclones, landslides, droughts and floods but still it lacks proper disaster management policies. Floods in Pakistan bring a great destruction both in urban and rural areas. This paper focuses on some of the key benefits that may be achieved in presence of a proper disaster management framework or policies and also it proposes latest technologies to deal with hazards.This paper also demonstrates a simple concept that may be adopted and implemented immediately, that may help to minimize the impact economically, socially and environmentally.

Key words: Flood disaster, Disaster risk reduction, Floods risk management,, Water-borne diseases, Impact of floods on agriculture, Flood awareness

1. Introduction

These years, the frequency of natural disasters has been increasing, which has brought great impact on communities (Azar and Rain, 2007). Weather and climate related extreme events, such as droughts, floods, heat waves, and bushfires, are increasing around the globe (Raikes *et al.*, 2019). According to the new Global Assessment Report (UNDRR, 2019), climate change is the reason for a major driver of disaster-related losses, since it amplifies disaster risk and hampers development. The number of people at risk has been increasing each year in those developing countries which have high poverty levels, lack of facilities and lack of proper disaster management policies. It makes them more vulnerable to disasters (Shah *et al.*, 2020; Shah, *et al.*, 2020). Several disasters occurred around the globe during 1995 to 2015 but floods, which have accounted for nearly half of all disasters, and droughts, which have affected the most people globally especially in rural areas. These are two of the most common disasters with which governments must deal (Raikes *et al.*, 2019).

Rapid population growth, urbanization, unmanaged expansion of infrastructure and uncontrolled development are the most common factors that result in more people being vulnerable to natural hazards than ever before (Rafiq and Blaschke, 2012). South Asian countries, that have the highest annual average number of people physically affected by natural hazards particularly floods. Most urban cities in the region are now regarded as popular flood risk areas (Pervin, 2019). Pakistan is ranked as 4th most vulnerable in the world against natural disasters because of its geological and geographical location (Aziz, 2016). Due to natural disasters, Pakistan has undergone extreme transformations with respect to population and economic conditions (Rafiq and Blaschke, 2012). The burden of natural disasters in Pakistan can be underlined by the fact that they have been responsible for the deaths of 6037 people in the period from 1993 to 2002 (Rafiq and Blaschke, 2012). Pakistan is one of the most vulnerable countries against disasters both natural and manmade, and still it lacks proper disaster management policies (Rafiq and Blaschke, 2012; Aziz, 2016), this is the reason Pakistan has experienced a variety of both natural and man-made disasters. More than 80 000 people died and

3.5 million lost their homes in a single event: the earthquake of 8 October 2005. Flood in 2010 around the country and flood in Karachi city were the worst one. In those years, flood resulting in loss of life, leave millions homeless, loss of the infrastructure and property, business loss and destruction of the environment (Shah *et al.*, 2020; Abid *et al.*, 2020).

Flood hazards require a prompt response to minimize adverse effects and provide a forum for a faster recovery. In order to reduce risks to the population from flood, it is necessary for government authorities to determine particular locations and time periods for flood hazard, degree of severity for flood hazard, and the level of exposure to the flood hazard (Lele *et al.*, 2018). The relationship between flood disasters and the risk of human trafficking has been documented in the literature but still there is gap, new policies should be made, and latest technology should be applied to reduce and to avoid or re-route the flood hazard. This paper focuses on some of the key benefits that may be achieved in presence of a proper disaster management framework or policies and also proposed a latest technology to deal with hazards.

2. Disaster risk management (DRM)

The disaster risk management cycle is one of a recognized methods for managing disaster events and their impacts (Rana *et al.*, 2021). In addition, disaster management requires consideration of governance and management. Governance refers to "the system of institutions, mechanisms, frameworks i.e policy and legal matters, and other related arrangements to coordinate, guide and oversee disaster risk reduction" (Raikes, *et al.*, 2019). In 2015, 197 countries agreed to the Sendai Framework for Disaster Risk Reduction – the follow-up agreement to the Hyogo Framework (HFA) for Action 2005–2015. The Sendai Framework for Disaster Risk Reduction 2005-2015 (Sendai Framework) was the major agreement of the development agenda and provides Member States with concrete actions to protect development gains from the risk of disaster. In 2005, the Hyogo Framework of Action (HFA) 2005-2015 played a fundamental role in initiating a strategic and systematic approach to build the resilience of nations and communities (Shah *et al.*, 2020; Stoklosa *et al.*, 2021). It was updated for 2015-2030 again. The substantial reduction of disaster risk and losses in lives, livelihoods and health and in the economic, physical, social, cultural and environmental assets of persons, businesses, communities and countries (Wisner, 2020; Saunders *et al.*, 2020).

Regarding disasters, according to different risk policies, practical implications are required, in part, why disaster management and planning need particular consideration in the developing countries at different policy scales (from local to national). In order to reduce vulnerabilities and risks of hazards, more strategic and systematic efforts are needed at global and national levels (Shah *et al.*, 2020; Joyce *et al.*, 2009). Due to limited resources, what measures should be taken to improve effectiveness at different phases of the disaster management cycle (Aziz, 2016; Abdur Rehman Cheema, 2016). The Sendai Framework for Disaster Risk Reduction put four priorities for addressing disaster risk: (i) recognize disaster risk; (ii) build up disaster risk governance; (iii) finance in disaster risk reduction; and, (iv) develop preparedness for response and to "Build Back Better" in recovery and restoration (Saunders *et al.*, 2020; Reduction, U.N.O.f.D.R., 2015).

There are several tools and techniques related to information technology mentioned in Table 1 which are used in disaster risk management (DRM) in different phases (Tim *et al.*, 2017; Troy *et al.*, 2008). In recent times, technology has been employed to fast-track disaster relief efforts, see Table 1. For instance, drones and robots have been used to locate survivors and transmit information to emergency teams (Sharma, *et al.*, 2021). In addition, land-based sensors, including radar sensors, collect similar data along the coastline (Taohidul Islam and Chik, 2021). This system, called the Web-enabled Awareness Research Network, can help save lives and limit the impacts of natural disasters (Sakurai and Murayama, 2019; Alexander, 2014).

Recent development of AI technologies would enable disaster managers to analyze those recorded data and create an alert. An AI platform which can detect water rise from social media posts has already been developed (Gupta, 2018). Currently, Satellite remote sensing (RS) is one of the primary support tools for disaster management. It is being applied by different countries, see Table 1. In 2006, the Sentinel Asia (SA) initiative was established as a collaboration between regional space agencies and disaster management agencies, applying space technology (including representative satellite remote sensing) and Website-Geographical information system (Web-GIS) technology to assist in disaster management of the Asia–Pacific region (Kaku, 2019). This technology has been widely used in different disaster management phases. Some case studies and its result are shown in Table 1. Advance and faster technology is required which can save the nation and avoid such disaster events.

3. Floods in Pakistan and its impact

3.1. Disaster risk profile of Pakistan

Pakistan is positioned within a hazard-prone region and is exposed to several types of natural disasters such as earthquakes, cyclones, floods, landslides and droughts. Rapid urbanization infrastructure, population growth, and uncontrolled development can be considered as the most common factors that result in more people being vulnerable to natural hazards than ever before. Climate change poses one of the biggest threats that Pakistan faces. Over the past 50 years, Pakistan's annual mean temperature has increased by 0.5°C (by 0.9°F) and is expected to rise by 3-6°C (by 5.4-10.8°F) by the end of this century, increasing the risk of widespread droughts (Rafiq and Blaschke, 2012; Saira Yamin, 2020). Pakistan is one of the most vulnerable countries against disasters both

natural and manmade, and still it lacks proper disaster management policies (Rafiq and Blaschke, 2012; Aziz, 2016), this is the reason Pakistan has experienced a variety of both natural and man-made disasters like earthquakes in 2005 and 2015 and widespread flooding in 2010 (Abdur Rehman Cheema and Muhammad Imran, 2016). Pakistan was on the top of affected countries by flood in 2020, around 400 people died in floods and flash floods in 2020, see Figure 1 (Buchholz, 2020). In addition, big city karachi during 2020, the floods were caused by record monsoon rains, which were inadequately drained by poorly maintained drainage systems in the city. The resulting floods caused deaths and destruction of infrastructure and properties in the city. Karachi experienced its heaviest rains in almost a century, killing people (Babar, *et al.*, 2021; Ajani and van der Geest, 2021).

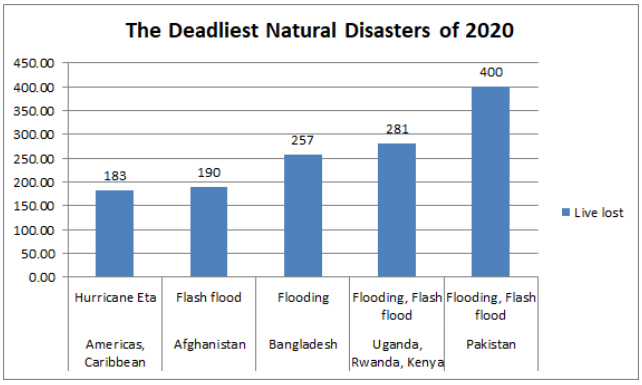


Figure 1. The Deadliest Natural Disasters of year 2020 (Modified from (Buchholz, 2020)).

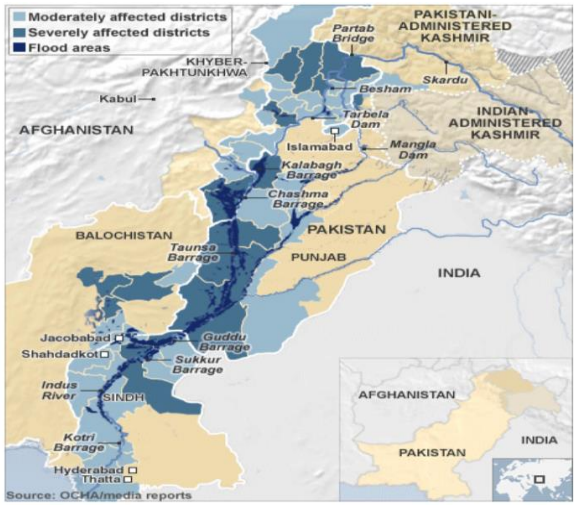


Figure 2. Flood affected areas of Pakistan, Source: ochaonline.un.org/MediaCentre.

Regarding floods, Pakistan is one of the five South Asian countries that have the highest annual average number of people who are physically affected by floods. Figure 2 shows flood affected areas of Pakistan. Climatic trends in most regions show a major increase in rainfall, its frequency and its intensity. Flash floods and landslide hazards take place frequently in the northern mountains. It is hard to predict over the mountainous areas of the Upper Indus Basin (Shrestha, 2019). The alluvial plains of the Indus river system formed as flood plains and remain vulnerable to recurrent flooding. Hill torrents tend to affect the hilly districts located in the northern and western parts of Pakistan while Districts along the Indus plain are particularly affected by riverine floods (Rafiq and Blaschke, 2012). Riverine floods arise during the summer monsoons.

In addition, urban areas also are affected by flood because rapid and unplanned urbanization. Subsequently, the overwhelming impacts of urban flooding have increased recently, further enlarged by the changing climatic patterns resulting in more numerous flooding (Rana, *et al.*, 2021). In 2020, Karachi city was hit badly by flood. In 2021, Islamabad city was hit by flood. Urban areas of Pakistan need more attention for their infrastructure to avoid and control flooding.

3.2. Floods in Pakistan

In Pakistan, floods are caused due to several reasons such as heavy rains, strong winds and tides in coastal areas, river overflows, dam breakage or ice-melting etc. There have been 67 reported flooding events in Pakistan occurring since 1900 with a clustering of 52 events of various severity in the last 30–40 years (Webster *et al.*, 2011), few of them are shown in Table 2. In the last few decades, climate change has emerged as an important driving force behind floods in Pakistan, primarily by affecting glacier-melting, and by interfering in summer monsoon patterns (Looney, 2012). Pakistan is generally subject to periodic flooding of rivers. Pakistan's economy is greatly affected by the floods, as the economy grews on average at a rate of 2.9 % per year during the last five years (Abdul Rehman *et al.*, 2015; Doocy *et al.*, 2013). Disaster management and rescue operations that are carried out during floods or after incident, pose an additional economic burden on the government (Ahmad and Afzal, 2020). On average, inland floods cost an estimated loss of 1% of total GDP per year in Pakistan (Zaidi, 2012). In addition, the burden of floods in Pakistan can be underlined by the fact that they have been responsible for the deaths of several thousand people in the period from 1992 to 2020 (Rafiq and Blaschke, 2012), see Table 2.

Figure 3. Floods in Pakistan in different Provinces (source: un-spider.org).

Table 1. Disaster management using technology around the world

Country	Disaster Management Phase	Case studies	Used satellite data and technology	Progression level	Reference
Kingdom of Bhutan	Preparedness	Glacial lake outburst flood (GLOF) early warning in Bhutan	– Advanced Land Observing Satellite (ALOS)/ Advanced Visible and Near Infrared Radiometer-2 (AVNIR-2) – Hazard mapping	Actual operation level (education and training) Demonstration level (GLOF early warning system)	(Scapozza et al., 2019; Gurung, et al., 2017; UNDP, 2019; Kaku 2019)
Indonesia	Preparedness	Wildfire early detection and control in Indonesia	– Terra and Aqua/ Moderate Resolution Imaging Spectroradiometer (MODIS) – Hotspots detection	Demonstration level	(Kaku 2019; Nigel Sizer et al., 2014; RUMONDANG, 2020; Atwood et al., 2016; Pijush Samui, 2018)
Japan	Response	The 2011 Great East Japan Earthquake	– ALOS/AVNIR-2, Phased-Array L-band Synthetic Aperture Radar (PALSAR) and others – Emergency mapping	Demonstration level	(Kaku 2019; Pijush Samui, 2018; Kaku, 2015; Koshimura and Shuto, 2015)
Nepal	Response	Large-scale flood in Nepal in August 2008	– ALOS/PALSAR – Emergency mapping	Demonstration level	(Kaku 2019; Pijush Samui, 2018; Dixit, 2009; Kaku, 2021;)
Nepal	Recovery	Large-scale flood in Nepal in August 2008	– ALOS/PALSAR – Emergency mapping	Demonstration level	(Kaku 2019; Pijush Samui, 2018; Dixit, 2009; Kaku, 2021;)
Philippines	Preparedness	Hazard mapping for lahars at Mayon volcano	– ALOS/PRISM Digital Surface Model (DSM) – ALOS/AVNIR-2 – Hazard mapping	Actual operation level	(Kaku 2019; Daag,2015; Slob et al., 1998)
Philippines	Preparedness	Landslide early warning system in the Philippines using GSMaP	– Global Satellite Mapping of Precipitation (GSMaP_NOW) – Real-time correction of GSMaP_NOW data – Radial Basis Function Network (RBFN)	Prototype level	(Kaku 2019; TanabeTana, 2016)
Philippines	Preparedness	Volcano and land subsidence monitoring using InSAR	– ALOS/PALSAR – Interferometric SAR (InSAR)	Demonstration level	(Kaku 2019; UN, 2020; Siriwardane-de Zoysa et al., 2021; Deguchi, 2014; Eco RC et al., 2020)
Kingdom of Thailand	Recovery	50-year long-term deluge in Thailand in October 2010	– ALOS/PALSAR – Emergency mapping	Demonstration level	(Kaku 2019; Pijush Samui, 2018; Wechsler, 2017; Marks and Thomalla, 2017)

The deadliest floods in Pakistan began in late July 2010, resulting from heavy monsoon rains in all provinces of Pakistan. Flash floods that devastated the Northern Areas of Pakistan in 2010 were a result of northwesterly shift of monsoon (Zaidi, 2012). It also affected Sindh, Punjab and, Balochistan regions of Pakistan, mostly the Indus River basin that led to a humanitarian disaster considered to be one of the worst in Pakistan's history (Ahmad and Afzal, 2020; Kirsch *et al.*, 2012; Jacquet *et al.*, 2016). Figure 3 shows floods in Pakistan in different Provinces.

The majority of the people were already living in abject poverty and some illegally residing in the floodplains of the river Indus. Physical damage from the floods was widespread, with 54.8% of households reporting damage to their homes. During the floods, households were stripped of their entire means of livelihood and their dignity. The government and the international community provided short-term relief responses and interventions to restore livelihoods (Deen, 2015). Over half (54.8%) of these were damaged beyond repair, 28.8% had significant but reparable damage, 10.9% minor but livable damage, and 5.6% with minimal damage (Jacquet *et al.*, 2016). Business was also greatly affected after 2010 flooding (Kirsch *et al.*, 2013). In addition, the floods in karachi city in the year 2020 were caused by record monsoon rains, which were inadequately drained by poorly maintained drainage systems in the city. The resulting floods caused deaths and destruction of infrastructure and properties in the city (Babar *et al.*, 2021; Ajani and van der Geest, 2021). Karachi experienced its heaviest rains in almost a century, killing at least 41 people. Flooding that resulted has completely inundated several neighborhoods, with the country's National Disaster Management Agency (NDMA) saying that hundreds of thousands of people are still trapped due to waterlogging in low-lying slums. Citizens have been without electricity and mobile phone connection for hours (SK, 2020). Weeks after historic rainfall, fractured local governance has left some sections of Pakistan’s largest city still recovering (Siddiqui, 2020). On 28 July 2021, heavy rains started after the cloudburst in Islamabad, Pakistan, caused flood situation in many parts of the federal capital and killed two people. Several vehicles were swept away in the floods and water entered the basement of houses and plazas in Sector E-11, F-10 and D-12. 116 mm of rain was recorded at the personal weather station in E-11/4 Islamabad (Davies, 2021). Recovery for disasters took a lot of time because of several concerned matters. Average monthly sale, damage to business facility, disruption in supply chain, damage to shelf items/inventory, past disaster experience, dependency on transportation, dependency on water, personal saving, damage to lifelines, knowing the recovery priorities, family and friends support, staff engagement and involvement in the recovery had significant impacts on the recovery time (Asgary *et al.*, 2012; Arai, 2012). Disaster risk management team should be active and particularly technology should be used to forecast the disasters.

3.3. Review of water-borne diseases break out after floods

Around the world, flood bring disturbance in communities. Though past experiences and hazard proximity significantly influence risk perception, but floods still bring some destruction (Rana *et al.*, 2020). Some of the past significant floods in different parts of the world such as Austria, Australia, Bangladesh, China, Canada, Czech Republic, England, France, Italy, Indonesia, India, Germany, Kenya, Mexico, Nepal, Pakistan, the Philippines, Taiwan, United States, Vietnam, and other communities had caused considerable economic and human lives losses. Flooding can pose a range of devastating impacts in both industrialized and developing countries (Brown and Murray, 2013; Shokri *et al.*, 2020). There are several types of diseases have been documented around the globe, see Table 3.

In Pakistan, during 2010 flooding, over 14 million people were directly affected by this record-breaking deluge. The devastating flood in 2010 that destroyed more than 10,000 schools throughout the country left more profound lessons (Shah *et al.*, 2020). Flood affected regions bring breeding grounds for pathogens which lead to the spread of diseases, especially children are expected to be affected (Mallett *et al.*, 2018; Lee *et al.*, 2020). In camps, the poor standards of hygiene for individuals displaced by the floods also bring this. It is important that those are working in team should be aware of the epidemiology of diseases that have historically seen a sudden upsurge after natural disasters and they should bring awareness to all affected people (Baqir *et al.*, 2012). Hepatitis, Cholera, Typhoid, and Dengue fever are mostly reported in flood, see Table 3 (Ahmed *et al.*, 2016). Articles published in the last several years documented seven major diseases to increase substantially in the aftermath of natural disasters (Baqir *et al.*, 2012; Ain Bhutto and You, 2021). They were then classified into acute and sub-acute settings (Mallett *et al.*, 2018). They were then classified into acute and sub-acute settings. Skin & eye infections, Diarrhea, and leptospirosis were identified in the acute setting while leishmaniasis, respiratory infections, malaria, and hepatitis were identified in the sub-acute setting (Baqir *et al.*, 2012; Ain Bhutto and You, 2021).

The impact of natural disasters on child health has been widely studied (Datar *et al.*, 1982; Mort *et al.*, 2018). Child health is not greatly influenced by flooding (Datar *et al.*, 2013; Hyung Lee *et al.*, 2020). In addition, excessive flood waters can catalyze the spread of diarrheal disease (Liu *et al.*, 2017), and other diseases (Alderman *et al.*, 2012), but some studies found that not greatly affected on child health (Sajid and Bevis, 2021). Excessive flood waters also bring damages in the region but also provide water to rice paddies and other agriculture. It leads in increasing food availability in the post-flood period. This may positively influence child health (Baqir *et al.*, 2012; Sajid and Bevis, 2021).

Table 2. Major Flood Events Witnessed In Pakistan (Modified from (Shah *et al.*, 2020; Buchholz, 2020; Commission, 2020; GFP, 2020))

Sr. No.	Year	Flooded area (km²)	Affected villages (No)	Lives Lost (No)
1.	1992	38,758	13,208	1008
2.	1994	5568	1622	431
3.	1995	16,686	6852	591
4.	2010	160,000	17,553	1985
5.	2011	27,581	38,700	516
6.	2012	4746	14,159	571
7.	2013	4483	8297	333
8.	2014	9779	4065	367
9.	2015	2877	4634	238
10.	2016	–	43	153
11.	2017	–	–	172
12.	2018	–	–	88
13.	2019	–	–	140
14.	2020		15,000	249

Table 3. Infectious disease transmission after flood events around the world (Brown and Murray, 2013)

Country	Studied year(s)	Infectious disease(s)
Canada	1975–2001	Diarrhea
China	1979–2000	Schistosomiasis
Bangladesh	1983–2007	Cholera, rotavirus, acute respiratory infection
Italy	1993–2010	Hepatitis A, salmonellosis, diarrhea, leptospirosis, leishmaniasis, legionellosis
Taiwan	1994–2009	Leptospirosis, melioidosis, enteroviruses, dengue fever, bacillary dysentery, Japanese encephalitis
Czech Republic	1997, 2002	Leptospirosis, Tahyna virus
Australia	1998–2001, 2011	Leptospirosis, Ross River virus
England	2000	Diarrhea
India	2001–2006	Leptospirosis
Indonesia	2001–2003	Paratyphoid fever
United States	2001, 2004	Diarrhea, leptospirosis
Germany	2005, 2007	Norovirus, leptospirosis
Guyana	2005	Leptospirosis
Mexico	2007, 2010	Leptospirosis, dengue fever
Sudan	2007	Rift Valley fever
Vietnam	2008	Conjunctivitis, dermatitis
The Philippines	2009	Leptospirosis
France	2009	Leptospirosis
Austria	2010	Leptospirosis
Pakistan	2010	Diarrhea, skin and soft tissue infection, conjunctivitis, respiratory tract infection, suspected malaria
Thailand	2012	Melioidosis

In Pakistan, evidence of both channels was examined. Floods increase incidence of morbidity (diarrhea and fever) as well as meal frequency in the post flood season (Sajid and Bevis, 2021). It is also found that floods increase dietary diversity (Cristiano *et al.*, 2020), but in many Pakistani districts with high rice harvesting intensity where flooding may predict favorable growing conditions. These mechanisms, (disease incidence and dietary adequacy) generally act against one another in every region of the world (Lee *et al.*, 2020; Huang *et al.*, 2019). Therefore, weak impact of floods on child health was documented (Sajid and Bevis, 2021). It was reported that up to 3.5 million children are at high risk from deadly water-borne diseases in Pakistan following the country's floods (BBC, 2020). In some parts, during 2010 flood disaster, cholera, typhoid, hepatitis, and dengue fever were reported in neighborhoods that were still flooded a week after the deluge started (Siddiqui, 2020). Baqir et al studied about impact of flood regarding diseases. Study demonstrated that Stagnant pools of flood water serve as ideal breeding grounds for pathogens that result in diarrhea and other waterborne infections. Cases of diarrhea, cholera and scabies have already been reported and an outbreak of cholera has been confirmed. The poor standards of hygiene in camps set up for individuals displaced by the floods also contribute to this. It is important that those involved in relief efforts are aware of the epidemiology of diseases that have historically seen a sudden upsurge after natural disasters. (Baqir *et al.*, 2012). Authorities should take immediate step regarding

this issue. Clean and pure environment should be provided to avoid such disease.

3.4. Flood disaster impacts on Pakistan's agricultural growth

Since 1950's, flood disaster always bring disturbance not only to people but also crops were destroyed. In 2010, 2011, 2012, 2013 and 2014 there was severe flooding, but it was reported that, 2010 flooding was one of the worst incident. Monsoon rains caused massive floods in Pakistan which killed nearly two thousand people and house damages were documented. Agricultural crops were greatly affected due to flood in Punjab, Sindh, Baluchistan, KPK, Gilgit Baltistan, and Azad Jammu. Flood affected area of crops in million hectares during 2010 are shown in the Figure 4 (NDMA, 2014). Additionally, flood waters recharge groundwater aquifers and add nutrients to soils improving fertility (Stratford *et al.*, 2015) but huge destruction of crops were documented. In 2010 flood disaster, the crops affected area of Punjab was 0.42 million hectares, Sindh was 0.30 million hectares, Baluchistan was 0.05 million hectares, Khyber Pakhtunkhwa (KPK) was 0.05 million hectares, and Azad Jammu & Kashmir was 0.01 million hectares. The total area of crops affected in 2010 was 0.84 million hectares (NDMA, 2014).

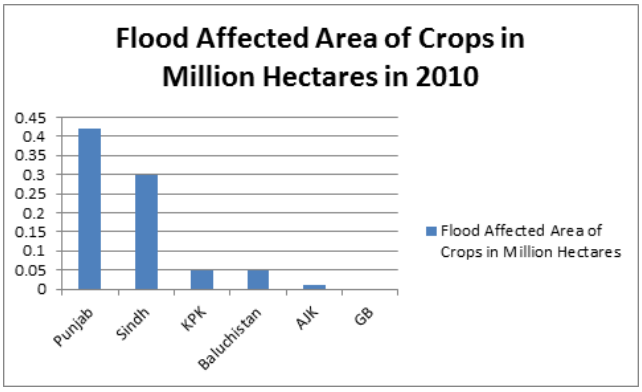


Figure 4. 2010 Flood Affected Area of Crops in Million Hectares (Data Source: NDMA Pakistan).

Agriculture accounts for 21% of Pakistan's GDP, 45 per cent of employment and 60 per cent of exports (Ahmad *et al.*, 2020). This disaster resulted in a loss of 2.5 million tons of rice, 7.5 million tons of sugarcane, 0.7 million tons of cotton and 0.3 million tons of maize (Saqib *et al.*, 2018; Ali Rahut 2020; Ahmad and Afzal, 2021). Because of this, Pakistan's economy was greatly affected during the last five years (Abdul Rehman *et al.*, 2015). These disasters had a massive cumulative effect on the economy of Pakistan. With Pakistan suffering a multitude of natural disasters each year, including floods, earthquakes, droughts, landslides and avalanches, a United Nations development agency is teaming up with State and provincial authorities to shore up the country's agriculture, among the sectors most affected (Pakistan, 2016). In addition, in Sindh province, Climate-smart agriculture (CSA) combined with community-based disaster risk reduction (DRR) measures present opportunities to mitigate the risks of natural hazards and extreme events whilst simultaneously promoting production gains and resource use efficiency, in both hazard and non-hazard situations. The effective implementation and mainstreaming of both CSA and DRR activities will be reliant on increased inter ministry collaboration, comprehensive training programmes for institutional capacity building at different levels, a set of clear roles and responsibilities, and context-specific technical knowledge of CSA and DRR actions (CSA, 2015). Farming community confronted with sundry type of risks while production and environmental risks are more significant (GD, 2017). Farms management decisions and operations are considerably influenced by farmers' perceptions and attitude to risks. Risk management issues specific to cereals crops not properly focused in developing countries specifically to Pakistan (Ahmad *et al.*, 2020; Ahmad and Afzal, 2021).

The flood-prone farming community is more vulnerable to these climatic risks and rely on traditional strategies for risk management (Ahmad and Afzal, 2021). Further, farmers prefer basic adaptation measures including changing crop varieties, input use and planting dates over advanced measures, such as planting shade trees, soil conservation, and crop diversification (Abid *et al.*, 2019). Among the five kinds of risks, biological and financial risks were conceived as high risk, followed by the climate, biophysical, and social risk (Khan *et al.*, 2020; Ahmad and Afzal, 2020). There is a need to adopt crop diversification based on developing research capacity for innovative crop varieties having resistance to floods and climate change affects (Ahmad *et al.*, 2020). Some significant policy measures, such as a more resilient scenario of climate change and floods, need to stimulate activities of enterprise diversification, opportunities of diversifying employment, and strengthening activities of off-farm employment for the sound livelihood of flood-prone farmers and to minimize severe affects of climatic risks (Ahmad and Afzal, 2021). After several past incidents and experiences, disaster risk management by Government and non-governmental organization NGOs were practiced properly and this is the reason that floods bring less impact currently.

3.5. Change in rural-urban linkages after flood event in Pakistan:

Regarding rural-urban linkages after flood event in Pakistan, different studies have given different concept that how do rural-urban linkages change after an extreme flood event?, It is generally accepted that flooding leads to changes in rural-urban linkages and affects rural vulnerability. Numerous theoretical frameworks on systemizing and assessing vulnerability were developed with varying level of scope and depth in terms of scale, dimensions, and components (Jamshed, *et al.*, 2020). Both concepts are known to be inter-dependent and inter-linked in disaster risk science as well as climate change adaptation literature (Jamshed *et al.*, 2019). Vulnerability and capacity assessment of hazard-prone communities is integral to the development of efficient disaster risk reduction strategies. The impact of flood or other hazards

on the linkages between spatial units i.e., rural and urban is still not clear but socioeconomic and spatial factors also drive changes in rural-urban linkages (Jamshed *et al.*, 2020). No doubt, mobility and use of credit, information and farm inputs increase after flooding. Main elements of rural–urban linkages (flow of people, information, finances, goods and services), components of vulnerability (exposure, susceptibility, and capacity), and factors (social, economic, institutional, infrastructural, spatial, and environmental), a unified framework has been noticed (Jamshed *et al.*, 2020; Jamshed *et al.*, 2021; Jamshed *et al.*, 2017).

Due to limited physical, social and economic resources, rural areas are highly vulnerable to floods. Understanding rural vulnerability is vital for developing effective disaster risk reduction (DRR) strategies (Jamshed *et al.*, 2020; Jamshed *et al.*, 2021). Urban areas and rural households depend on each other in some ways but less in others after a flood. Extreme flood incidents may lead to dramatic changes in societal processes and disrupt rural-urban linkages. It also affects rural vulnerabilities (Hamidi *et al.*, 2020). Changes in rural-urban linkages due to extreme flooding have been studied with evidence (Jamshed *et al.*, 2020; Jamshed *et al.*, 2021; Jamshed *et al.*, 2017), see Figure 5. Study (Jamshed *et al.*, 2019) investigated the impacts of a flood event on linkages between urban and rural areas of Pakistan especially socioeconomic and spatial factors that can influence changes in rural-urban linkages. Case studies were selected and analysis was conducted, the results show that flooding has severely affected rural communities directly and indirectly (Jamshed *et al.*, 2019).

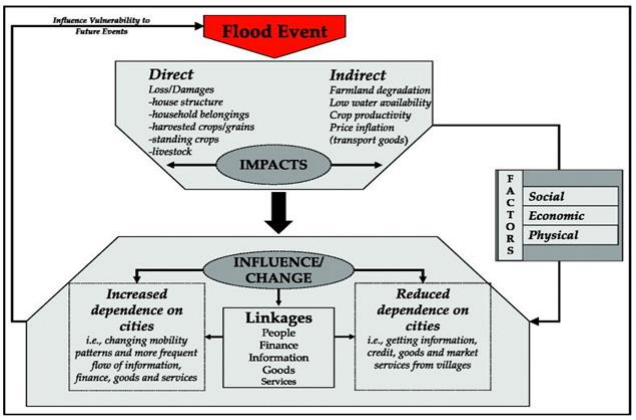


Figure 5. Rural-Urban linkage related to Flood event (Modified from Ali et al 2021).

In addition, rural linkages with cities can be changed by floods in several ways i.e., the flow of people, finance, information, goods and services between rural and urban areas (Jamshed *et al.*, 2019; Jamshed *et al.*, 2021). Most importantly, the research highlights that extreme flooding can both increase and decrease the dependence of rural communities on cities in different ways (Jamshed *et al.*, 2020; Jamshed *et al.*, 2021). This indicates that linkages between rural and urban areas need to be strengthened in order to reduce flood-related vulnerabilities (Jamshed *et al.*, 2021). There should be study in deep for regional planners and disaster managers to establish synergies for developing integrated flood risk management and development strategies.

3.6. Benefits of floods

Ecological research has documented floods are an important resource for many communities and freshwater ecosystems, see Figure 6. It may come as a surprise to the common reader that floods bring some benefits to the nature (Ming *et al.*, 2007). There are many benefits of flooding despite its immediate ill effects, For the farmers and the people in the agricultural sector, It helps them in long run by providing the nutrients to the soil that were lacking, It makes the soil more fertile and increases the agricultural production . Additionally flood waters recharge groundwater aquifers (Stratford *et al.*, 2015; Alves *et al.*, 2018). Floods nourish riverine forests which are home to important wildlife species, such as hog dear (Ming *et al.*, 2007).

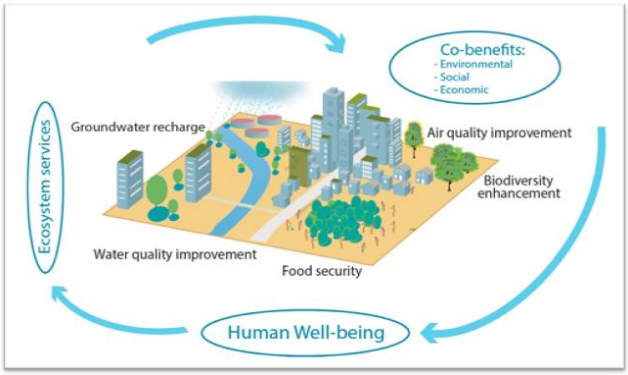


Figure 6. Links between flood, ecosystem services, human well-being, and co-benefits (Modified from Alida et al 2018 (Alves *et al.*, 2018)).

Floods also feed wetlands which provide an important habitat for many resident and migratory waterfowl species in addition to several aquatic species. Flood waters also provide spawning sites for several fish species (Talbot *et al.*, 2018). There may be the relocation of fishes and the organisms living in the water bodies. The flooding may improve the ecosystem, new predators and preys are introduced to the areas, balancing the aquatic population. (Stratford *et al.*, 2015). Agricultural research has demonstrated that excessive flood waters provide water to rice paddies and other agriculture, increasing food availability in the post-flood period. This may positively influence child health (Sajid and Bevis, 2021).

4. Disaster risk management and preventing flood disaster in Pakistan

Disaster risk management (DRM) lean towards to the impacts that disasters have on living things are not solely depends on their exposure to the hazard, but also their capabilities are accountable (Rafiq and Blaschke, 2012; Blaikie, *et al.*, 1994; Cutter, 1996; Nicholls *et al.*, 2015). Natural hazards need a speedy response to reduce contrary effects and offer a forum for a quicker recovery (Shokri *et al.*, 2020) because such happenings breed a huge number of casualties (Cutter, 1996). Relationship

concerning natural disasters and the risk of human trafficking has been documented in the literature (Munawar *et al.*, 2021). There is extensive recognition that these events are devious for traffickers seeking to exploit individuals experiencing heightened economic vulnerability and lack of administration protection (Stoklosa *et al.*, 2021; Gurung and Clark, 2018; Walz *et al.*, 2021). Flood risk management is organized differently across countries and regions and has frequently evolved over time, driven by cultural and historical aspects as well as the scale and real impact of flood risk experienced (Aslam, 2018; Driessen *et al.*, 2018). The closest worldwide legal studies that cover some aspects of the flood legislations are those focusing on disaster risk management (DRM) disaster risk reduction (DRR) and climate change adaptation which has primarily emerged over the last two decades (Driessen *et al.*, 2018; Oxley 2011; Vanderlinden *et al.*, 2015), see Figure 7. The formal legislation system of countries plays vital role in setting out rules and frameworks for flood risk management (Mehryar and Surminski, 2021). These lean towards to regulate (prohibit, obligate or permit) flood-related decisions, responsibilities and actions (Driessen *et al.*, 2018). Figure 7 shows examples of tools, techniques and measures to minimize in flood-prone areas. The left over risk after implementation of these techniques are known as the residual risk. Some of these actions are taken at the federal, state, and local levels, while others are taken by the homeowners and businesses at risk (Glass, 2013; USACE, 2006; Jain *et al.*, 2012). Such kind of management should be implemented in Pakistan.

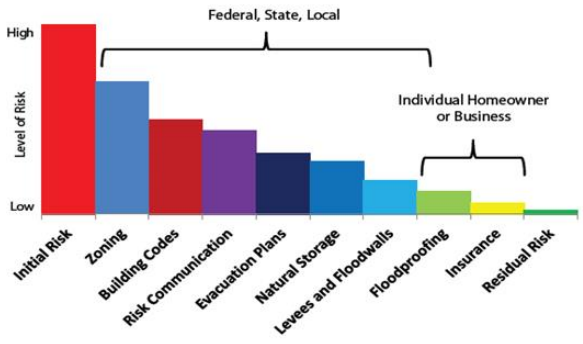


Figure 7. Flood Risk Management (Modified from USACE 2006 (USACE, 2006)).

The world resources institute demonstrated that, Pakistan is among the top 15 countries exposed to the risk of river floods. In addition, climate change is expected to further expand flood-prone areas (USACE, 2006) because Pakistan is also among the topmost vulnerable countries in the changing global climate. The ecological and climate change issues stand at the bottom of our priorities. Our hydrological system oscillates between droughts and floods, which are only getting worse (Akram and A. Hamid, 2015). It was reported that around 715,000 people are affected by floods in Pakistan every year. If flood risk management does not take any action, the number is expected to rise to 2.7 million people by 2030 (Arai, 2012; Akram and A. Hamid, 2015). It should be acknowledged that flooding is a systematic natural feature of Pakistan's hydrology and it keeps important ecological and socio-economic roles. Recognition of the challenge is the first step towards mitigation to avoid more intense effect due to natural and man-made factors. Changing dynamics of riverine flooding is highly needed (GD, 2017). In Pakistan, disaster preparedness is higher for floods than other disaster events (Shah *et al.*, 2020). The authorities constantly monitor and deliver information on any emergency crisis. However, due to lack of technical skills and equipment, it is hard to deal with large-scale disaster events such as the 2010 floods. There is a need to establish the capacity to respond to the emergency crisis on the time. In the affected regions, effectively relocation, rescue, and rehabilitation of the victims promptly is first important action because delayed response of government and NGOs during crisis further worsened the condition of the victims. The suffering of the community is increased, if there is no clean drinking water, food, and shelter. Lack of coordination between government and NGOs can bring bad results (Arai, 2012; Akram and Hamid, 2015; Shah *et al.*, 2020).

Pakistan's current flood management system comprises of flood policy and strategy, flood institutions, flood laws, flood planning and flood management measures (Aslam, 2018). In broad view, strategy comprises of three basics; (i) flood planning, (ii) flood preparedness, and (iii) flood fighting and post-flood operations. The flood strategy is implemented through arrangement of structural and non-structural measures. In addition, the main elements of flood policy consist of "upgraded flood forecasting and warning system, developed maintenance of existing flood infrastructure, advancement of new water storages, amended watershed management, advancement of flood retardation structures, improvement of operational rules for reservoirs, enforcement of laws for flood plains protection and flood zoning". Pakistan's community-based disaster risk management and livelihoods programme should take reasonable steps to reduce loss of life, and asset and stimulate livelihood resilience during life-threatening natural disasters such as flooding (Munawar *et al.*, 2021). Regarding flood disaster risk-related knowledge, 68% of respondents experienced flood disasters between 2010 and 2014, and houses were flooded and damaged by 65% and 46% of the respondents, respectively (Shah *et al.*, 2020). They should take lesson and follow disaster risk management. The generic disaster management framework is available and can be used in Pakistan to initiate a basic program and to create public awareness and a step forward to mitigate the impact of disasters (Aziz, 2016; GD, 2017). The ideas of experts should be taken into consideration for supplementary planning. Experts either from academic institutions (i.e. universities), or from disaster management organizations at national/provincial level or from research and development institutions (PMD, Pakistan Space and Upper Atmosphere Research

Commission [SUPARCO], Geological survey of Pakistan (GSP) etc.), their suggestions should be considered.

5. Social awareness about flood and its impact

Most people in flood affected regions do not know when they would be able to resume their livelihoods, as the flood has a severe impact on people's homes, livelihoods and assets (Aznar-Crespo *et al.*, 2021). Most people are not well aware, the immediate impacts of flooding not only include loss of human life, destruction of crops, damage to property, loss of livestock but also impact on health conditions owing to waterborne diseases because floods have large social consequences for communities and individuals. (Rufat *et al.*, 2015).

Social awareness about floods and its impact is very important. Many authors emphasize that in order to improve public knowledge and skills in disaster prevention and relief, disaster reduction has to put more attention also on strengthening community-based disaster education (Chou and Wu, 2014). Network organizations may deliver message by texting on the phone numbers to related areas and give full information about flood and its impact on life. People should be educated about the diseases which attack on people after flood. They should be educated about medicine that which medicines should be available to avoid such diseases. To realize a clear understanding of hazard and risk in a region is a hard task for the people living there because they do not want to relocate. Trust in risk communication sources is inevitable for advanced disaster risks communication (Samaddar *et al.*, 2012). They do not listen to authorities (Bignami, 2018). In risk communication process, the role of local leaders is unimportant because the local community does not have much trust in local leaders (Samaddar *et al.*, 2012). Government should take step to relocate the areas where flood flow so that big losses should be avoided. In addition, Government should arrange agricultural program for farmers that which crops are suitable in flood risk areas.

Social media is the main bridge for enhancing communications between government agencies and people (Bignami, 2018). They cares most about community's interest (Samaddar *et al.*, 2012). Any stage of the user experience with the platform can be shared via social media. Using social media, an awareness-oriented process can be structured to establish a set of indicators for the increase of knowledge linked to flood hazards. With this, it is possible to measure community disaster awareness actions and competence in the area of hazard knowledge (Bignami, 2018). New ways which are easily available for all have to be explored to prompt the active participation of citizens in community affairs related to such disasters. In addition, community social awareness and engagement can be considered. It can increase the chances not only for successful emergency preparedness, but also the social cohesion that can be tapped after future disasters.

6. Conclusions

This study concluded that country like Pakistan which is highly at risk of disasters both natural and manmade should have strong disaster management policies and implementation on it. As about 68% of Pakistan's population lives in rural regions and they depend on crops production so policies should be adopted for agricultural growth. Flood brings community disturbance regarding loss of life, house damages, waterborne disease and it hurts the economy of Pakistan deeper with serious economic wounds. Despite great advances in medicine over the past few decades, after flood happens, affected regions are lack of medical stock. The interplay between flooding and diarrhoeal disease in Pakistan is a very important consideration in the context of the overlapping challenges of health, development and climate change. These are particularly problematic for developing countries like Pakistan where resources are limited and the infrastructure weak. In addition, losses of ecosystem services are generally not reported from previous events. Even though, sometimes flood is beneficial for this. It is also concluded that unfortunately, awareness of these conditions is something that is lacking in the general population. It is, therefore, imperative that this is promptly addressed in order to prevent a repeat of the humanitarian crisis currently being witnessed in much of the country. 2010 flood was major incident and 2020 year in karach city, and 2021 in Islamabad city, still same situation, past experience and knowledge should be adopted. Social media should be active during these events because it is the best tool. Prompt recovery and response is needed. The recent flood would be a basic cause of unemployment due to the damages to the income and commercial resources and in addition to inflation, may supplement to the already existing poorness in the region, therefore this thing should also be considered.

7. Recommendation

It is recommended that social awareness program should be promoted. Knowledge about disasters and impact should be delivered to the community, especially affected regions. It is also recommended that technology should be used such as satellite remote sensing for disaster management support. It is also recommended that for effective and sustainable flood management, the Government of Pakistan needs to improve and approve flood policy and laws along with their effective implementation. It is important to integrate flood management that includes flood prevention, preparedness, mitigation and vulnerability reduction into national development policy, plan and program. It is also necessary to adopt a governance approach based on a capable, accountable and responsive government empowered by the decentralisation of authority and resources from central government and supportive of local initiatives in partnership with private sector and civil society organisations.

References

Abdul Rehman L.J., Du Y., Khatoon R., Wagan S.A., and Nisar S.K. (2015), Flood disaster in Pakistan and its Impact on Agriculture Growth (A Review). *Journal of Economics and Sustainable Development*, **6**(23).

Abdur Rehman Cheema A.M., and Imran M. (2016), Learning from the past: Analysis of disaster management structures, policies and institutions in Pakistan. *Disaster Prevention and Management*, **25**(4).

Abid M., et al. (2019), Farmer perceptions of climate change, observed trends and adaptation of agriculture in Pakistan. Environmental Management, **63**(1), 110–123.

Abid M., et al. (2020), Disaster preparedness for metro projects: a social-cognitive perspective of Pakistan. *Geoenvironmental Disasters*, **7**(1), 30.

Ahmad D. and Afzal M. (2020), Climate change adaptation impact on cash crop productivity and income in Punjab province of Pakistan. *Environmental Science and Pollution Research International* **27**(24), 30767–30777.

Ahmad D. and Afzal M. (2020), Flood hazards and factors influencing household flood perception and mitigation strategies in Pakistan. *Environmental Science and Pollution Research*, **27**(13), 15375–15387.

Ahmad D. and Afzal M. (2021), Flood hazards and agricultural production risks management practices in flood-prone areas of Punjab, Pakistan. *Environmental Science and Pollution Research International*.

Ahmad D., Afzal M. and Rauf A. (2020), Environmental risks among rice farmers and factors influencing their risk perceptions and attitudes in Punjab, Pakistan. *Environmental Science and Pollution Research International*, **27**(17), 21953–21964.

Ahmed T., et al. (2016), Water-related impacts of climate change on agriculture and subsequently on public health: a review for generalists with particular reference to Pakistan. **13**(11), 1051.

Ahmed T., Zounemat-Kermani M., and Scholz M. (2020), Climate change, water quality and water-related challenges: a review with focus on Pakistan. **17**(22), 8518.

Ain Bhutto S.U. and You X. (2021), Spatial distribution of microplastics in Chinese freshwater ecosystem and impacts on food webs. *Environmental Pollution*, 118494.

Ajani A. and van der Geest K. (2021), Climate change in rural Pakistan: evidence and experiences from a people-centered perspective. *Sustainability Science*, **16**(6), 1999–2011.

Akram N. and Hamid A. (2015), Climate change: A threat to the economic growth of Pakistan. *Progress in Development Studies*, **15**(1), 73–86.

Alderman K., Turner L.R., and Tong S. (2012), Floods and human health: A systematic review. *Environment International*, **47**, 37–47.

Alexander D.E. (2014), Social media in disaster risk reduction and crisis management. *Science and Engineering Ethics*, **20**(3), 717–733.

Ali A. and Rahut D.B. (2020), Localized floods, poverty and food security: empirical evidence from rural Pakistan. **7**(1), 2.

Alves A., et al. (2018), Combining co-benefits and stakeholders perceptions into green infrastructure selection for flood risk reduction. **5**(2), 29.

Arai T. (2012), Rebuilding Pakistan in the aftermath of the floods: disaster relief as conflict prevention. *Journal of Peacebuilding & Development*, **7**(1), 51–65.

Arai T., (2012), Rebuilding Pakistan in the aftermath of the floods disaster relief as conflict prevention. *Journal of Peacebuilding & Development*, **7**(1), 51–65.

Asgary A., Anjum M.I., and Azimi N. (2012), Disaster recovery and business continuity after the 2010 flood in Pakistan: Case of small businesses. *International Journal of Disaster Risk Reduction*, **2**, 46–56.

Aslam M. (2018), Flood management current state, challenges and prospects in Pakistan: a re-view. *Mehran University Research Journal of Engineering and Technology*, **37**(2), 297–314.

Atwood E.C., et al. (2016), Detection and characterization of low temperature peat fires during the 2015 fire catastrophe in indonesia using a new high-sensitivity fire monitoring satellite sensor (FireBird). *Plos One*, **11**(8), e0159410.

Azar D. and Rain D. (2007), Identifying population vulnerable to hydrological hazards in San Juan, Puerto Rico. *GeoJournal*, **69**(1), 23–43.

Aziz A. (2016), Need for disaster management inpakistan: a critical view. *Journal of Information & Communication Technology*, **10**(1), 58–64.

Aznar-Crespo P., et al. (2021), Adapting social impact assessment to flood risk management. **13**(6), 3410.

BabarM.S., et al, (2021), Impact of climate change on health in Karachi, Pakistan. *The Journal of Climate Change and Health*, **2**, 100013.

Baqir M., et al. (2012), Infectious diseases in the aftermath of monsoon flooding in Pakistan. *Asian Pacific Journal of Tropical Biomedicine*, **2**(1), 76–79.

BBC (2020), Millions of Pakistan children at risk of flood diseases. BBC: Pakistan.

Bignami D.F., Dragoni A. and Menduni G. (2018), Assessing and improving flood and landslide community social awareness and engagement via a web platform: the case of Italy. *International Journal of Disaster Risk Science*, **9**(4), 530–540.

Blaikie P., Cannon T., Davis I., and Wisner, B, (1994), At Risk: Natural Hazards. People's Vulnerability and Disasters (1st ed.).

Brown L. and Murray V. (2013), Examining the relationship between infectious diseases and flooding in Europe. *Disaster Health*, **1**(2), 117–127.

Buchholz K. (2020), The Deadliest Natural Disasters of 2020. Munich Re: Munich.

Chou J.-S. and Wu J.-H. (2014), Success factors of enhanced disaster resilience in urban community. *Natural Hazards*, **74**(2), 661–686.

Commission F.F. (2018), Annual flood report. 2018: Office of the Chief Engineering Advisor/Chairman Federal Flood Commission – Ministry of Water Resources, Islamabad, Pakistan.

Cristiano E., et al. (2020), Analysis of potential benefits on flood mitigation of a CAM green roof in Mediterranean urban areas. *Building and Environment*, **183**, 107179.

CSA (2015), Climate-Smart Agriculture for Disaster Risk Reduction in Sindh, Pakistan. Food and Agricultural Organization of UN: Sindh, Pakistan.

Cutter S.L. (1996), Societal responses to environmental hazards. **48**(150), 525–536.

Cutter S.L. (1996), Vulnerability to environmental hazards. *Progress in Human Geography*, **20**(4), 529–539.

Daag A.S. (2015), *Utilizing GIS-based Disaster Information for Disaster Risk Reduction in the Philippines*. Philippine Institute of Volcanology and Seismology (PHIVOLCS).

Datar A., et al. (2013), The impact of natural disasters on child health and investments in rural India. *Social Science & Medicine (1982),* **76**(1), 83–91.

Davies R. (2021), Pakistan – Deadly Flash Floods Hit Islamabad After 'Cloudburst', in floodlist.

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

Deguchi T. (2014), Deformation monitoring in the metro Manila using ALOS/PALSAR. *SPIE Remote Sensing*. **9243**. SPIE.

Dixit A. (2009), Kosi Embankment breach in Nepal: need for a paradigm shift in responding to floods. *Economic and Political Weekly*, **44**(6), 70–78.

Doocy S., et al. (2013), Household economic and food security after the 2010 Pakistan floods. *Food and Nutrition Bulletin*, **34**(1), 95–103.

Driessen P.P.J., et al. (2018), Governance strategies for improving flood resilience in the face of climate change. **10**(11), 1595.

Eco RC R.K., Sulapas J.J., and Morales Rivera A.M. (2020), Lagmay AMF, disaster in slow motion: widespread land subsidence in and around metro manila, philippines quantified by insar time-series analysis. *JSM Environmental Science & Ecology*, **8**(1).

GDC. (2017), World data service (NGDC/WDS).

GFP. (2020), Floods in Pakistan.

Glass C.E., (2013), Chapter 7 - Dangers from Floods, in Interpreting Aerial Photographs to Identify Natural Hazards C.E. Glass, Editor. Elsevier: Oxford. p. 111-122.

Gupta A.T. (2018), A software system proposing the processing of crowdsourced data to monitor a flood event: an A.I. Approach. *Open Water Journal*, **5**(2).

Gurung A. and Clark A.D. (2018), The perfect storm: The impact of disaster severity on internal human trafficking. *International Area Studies Review*, **21**(4), 302–322.

Gurung D.R., et al, (2017), Lemthang Tsho glacial Lake outburst floo (GLOF) in Bhutan: cause and impact. *Geoenvironmental Disasters*, **4**(1), 17.

Hamidi A.R., Zeng Z., and Khan M.A. (2020), Household vulnerability to floods and cyclones in Khyber Pakhtunkhwa, Pakistan. *International Journal of Disaster Risk Reduction*, **46**, 101496.

Huang L., et al. (2019), Balancing social, economic and ecological benefits of reservoir operation during the flood season: A case study of the Three Gorges Project, China. *Journal of Hydrology*, **572**, 422–434.

Hyung Lee M., et al. (2020), 49.12 The association between child and parent mental health disorders in families exposed to flood and/or dioxin. *Journal of the American Academy of Child & Adolescent Psychiatry*, **59**(10, Supplement), S249.

Jacquet G.A., et al. (2016), Health Care Access and Utilization after the 2010 Pakistan Floods. *Prehospital and Disaster Medicine*, **31**(5), 485–491.

Jain R., et al. (2012), Chapter Six - Environmental Assessment Methodologies, in Handbook of Environmental Engineering Assessment, R. Jain, et al., Editors, Butterworth-Heinemann: Boston. p. 177–209.

Jamshed A., et al. (2017), Changes in vulnerability and response capacities of rural communities after extreme events: case of major floods of 2010 and 2014 in Pakistan. **4**(3), 1750013.

Jamshed A., et al. (2019), Assessing relationship between vulnerability and capacity: An empirical study on rural flooding in Pakistan. *International Journal of Disaster Risk Reduction*, **36**, 101109.

Jamshed A., et al. (2020), A conceptual framework to understand the dynamics of rural–urban linkages for rural flood vulnerability. **12**(7), 2894.

Jamshed A., et al. (2021), How do rural-urban linkages change after an extreme flood event? Empirical evidence from rural communities in Pakistan. *Science of The Total Environment*, **750**, 141462.

Joyce K.E., et al. (2009), Remote sensing data types and techniques for lahar path detection: A case study at Mt Ruapehu, New Zealand. *Remote Sensing of Environment*, **113**(8), 1778–1786.

Kaku K. (2019), Satellite remote sensing for disaster management support: A holistic and staged approach based on case studies in Sentinel Asia. *International Journal of Disaster Risk Reduction*, **33**, 417–432.

Kaku K. (2021), *A Holistic Case-Study Approach to Applying Satellite Remote Sensing to Disaster Management*. U.K.

Kaku K., Aso N., and Takiguchi F. (2015) Space-based response to the 2011 Great East Japan Earthquake: Lessons learnt from JAXA's support using earth observation satellites. *Internation al Journal of Disaster Risk Reduction*, **12**, 134–153.

Khan N.A., et al. (2020), Modeling food growers' perceptions and behavior towards environmental changes and its induced risks: evidence from Pakistan. *Environmental Science and Pollution Research International*, **27**(16), 20292–20308.

Kirsch T., et al. (2013), Satisfaction with the humanitarian response to the 2010 Pakistan floods: a call for increased accountability to beneficiaries. *Emergency Medicine Journal*, **30**(7), 565–571.

Kirsch T.D., et al. (2012), Impact of the 2010 pakistan floods on rural and urban populations at six months. *PLoS Currents*, **4**, e4fdfb212d2432-e4fdfb212d2432.

Koshimura S. and Shuto N. (2015), Response to the 2011 Great East Japan Earthquake and Tsunami disaster. **373**(2053), 20140373.

Lee J., et al. (2020), Water-related disasters and their health impacts: A global review. *Progress in Disaster Science*, **8**, 100123.

Lele S., et al. (2018), Adapting to climate change in rapidly urbanizing river basins: insights from a multiple-concerns, multiple-stressors, and multi-level approach. *Water International*, **43**(2), 281–304.

Liu X., et al. (2017), Projected burden of disease for bacillary dysentery due to flood events in Guangxi, China. *Science of The Total Environment*, **601–602**, 1298–1305.

Looney R. (2012), Economic impacts of the floods in Pakistan. *Contemporary South Asia*, **20**(2), 225–241.

Mallett PhD L.H. and Etzel MD P., and Ruth A. (2018), Flooding: what is the impact on pregnancy and child health? **42**(3), 432–458.

Marks D. and Thomalla F. (2017), Responses to the 2011 floods in Central Thailand: Perpetuating the vulnerability of small and medium enterprises? *Natural Hazards*, **87**(2), 1147–1165.

Mehryar S. and Surminski S. (2021), National laws for enhancing flood resilience in the context of climate change: potential and shortcomings. *Climate Policy*, **21**(2), 133–151.

Ming J., et al., (2007), Flood mitigation benefit of wetland soil — A case study in momoge national nature reserve in China. *Ecological Economics*, **61**(2), 217–223.

Mort M., et al. (2018), Displacement: Critical insights from flood-affected children. *Health & Place*, **52**, 148–154.

Munawar H.S., et al. (2021), Post-flood risk management and resilience building practices: a case study. **11**(11), 4823.

NDMA (2014), NDMA Annual Reports 2010-2014. The Natural Disaster Management Authority. Government of Pakistan; 2010-2014. Pakistan.

Nicholls R., et al. (2015), Chapter 2 - Developing a Holistic Approach to Assessing and Managing Coastal Flood Risk, in Coastal Risk Management in a Changing Climate B. Zanuttigh, et al., Editors. Butterworth-Heinemann: Boston. p. 9–53.

Nigel Sizer A.L., Minnemeyer S., Higgins M., Stolle F., Anderson J., and Lawalata J. (2014), *Preventing Forest Fires In Indonesia: Focus On Riau Province, Peatland, And Illegal Burning*. World Resources Institute, 10 G Street NE, Suite 800, Washington DC 20002.

Oxley M. (2011), Field note from Pakistan floods: Preventing future flood disasters. J Jàmbá: *Journal of Disaster Risk Studies*, **3**(2),11.

Pakistan U. (2016), UN agricultural agency helps Pakistan cope with natural disasters such as floods, quakes, droughts. UNICEF Pakistan: Pakistan.

Pervin I.A., et al. (2019), Adapting to urban flooding: a case of two cities in South Asia. *Water Policy*, **22**(S1), 162–188.

Pijush Samui D.K.a.C.G., (2018), *Integrating Disaster Science and Management: Global Case Studies in Mitigation and Recovery*. 1st Edition ed.

Rafiq L. and Blaschke T. (2012), Disaster risk and vulnerability in Pakistan at a district level. *Geomatics, Natural Hazards and Risk*, **3**(4), 324–341.

Raikes J., et al. (2019), Pre-disaster planning and preparedness for floods and droughts: A systematic review. *International Journal of Disaster Risk Reduction*, **38**, 101207.

Rana I.A., et al. (2020), Characterizing flood risk perception in urban communities of Pakistan. *International Journal of Disaster Risk Reduction*, **46**, 101624.

Rana I.A., et al. (2021), An approach to understanding the intrinsic complexity of resilience against floods: Evidences from three urban communities of Pakistan. *International Journal of Disaster Risk Reduction*, **63**, 102442.

Rana I.A., et al. (2021), Disaster management cycle and its application for flood risk reduction in urban areas of Pakistan. *Urban Climate*, **38**, 100893.

Reduction U.N.O.f.D.R. (2015), *Sendai Framework for Disaster Risk Reduction 2015–2030*. UN/ISDR.

Rufat S., et al. (2015), Social vulnerability to floods: Review of case studies and implications for measurement. *International Journal of Disaster Risk Reduction*, **14**, 470–486.

Rumondang T. (2020), *The Burning Issue: Fighting Forest Fires With Technology*. Jakarta Globe: Jakarta.

Saira Yamin S.H. (2021), Pakistan-Disaster Management Reference Handbook.

Sajid O. and Bevis L.E.M. (2021), Flooding and child health: Evidence from Pakistan. *World Development*, **146**, 105477.

Sakurai M. and Murayama Y. (2019), Information technologies and disaster management – Benefits and issues. *Progress in Disaster Science*, **2**, 100012.

Samaddar S., Misra B.A. and Tatano H. (2012), Flood risk awareness and preparedness: The role of trust in information sources. in 2012 IEEE International Conference on Systems, Man, and Cybernetics (SMC).

Saqib E.S., et al. (2018), Factors determining subsistence farmers' access to agricultural credit in flood-prone areas of Pakistan. *Kasetsart Journal of Social Sciences*, **39**(2), 262–268.

Saunders W.S.A., et al. (2020), Progress toward implementing the sendai framework, the paris agreement, and the sustainable development goals: policy from Aotearoa New Zealand. *International Journal of Disaster Risk Science*, **11**(2), 190–205.

Scapozza C., et al. (2019), Glacial lake outburst flood hazard assessment by satellite Earth observation in the Himalayas (Chomolhari area, Bhutan). *Geographica Helvetica*, **74**(1), 125–139.

Shah A.A., et al. (2020), Disaster risk management insight on school emergency preparedness – A case study of Khyber Pakhtunkhwa, Pakistan. *International Journal of Disaster Risk Reduction*, **51**, 101805.

Shah A.A., et al. (2020), Looking through the Lens of schools: Children perception, knowledge, and preparedness of flood disaster risk management in Pakistan. *International Journal of Disaster Risk Reduction*, **50**, 101907.

Shah I., *et al.* (2020), Institutional arrangement for disaster risk management: Evidence from Pakistan. *International Journal of Disaster Risk Reduction*, **51**, 101784.

Shah S.M.H., et al. (2020), A review of the flood hazard and risk management in the South Asian Region, particularly Pakistan. *Scientific African*, **10**, e00651.

Shams S. (2020), Urban flooding — who is responsible for Karachi's woes? Pakistan.

Sharma K., et al. (2021), A disaster management framework using internet of things-based interconnected devices. *Mathematical Problems in Engineering*, **2021**, 9916440.

Shi Z., et al. (2018), 8 - Performance-based renovation design of aging sewers, in Structural Resilience in Sewer Reconstruction, Z. Shi, et al., Editors. Butterworth-Heinemann. p. 325-386.

Shokri A., Sabzevari S. and Hashemi S.A. (2020), Impacts of flood on health of Iranian population: Infectious diseases with an emphasis on parasitic infections. *Parasite Epidemiology and Control*, **9**, e00144.

Shrestha M.S., et al. (2019), Chapter 13 - Review of Hydrometeorological Monitoring and Forecasting System for Floods in the Indus Basin in Pakistan, in Indus River Basin S.I. Khan and T.E. Adams, Editors. 2019, Elsevier. p. 309–333.

Siddiqui J. (2020), In Karachi, Flooding Lays Bare City's Governance Issues. The United States Institute of Peace USA.

Siriwardane-de Zoysa R., et al. (2021), The 'wickedness' of governing land subsidence: Policy perspectives from urban Southeast Asia. *Plos One*, **16**(6), e0250208.

Slob S., et al. (1998), Volcanic hazard mapping in the Philippines using remote sensing and GIS. *Remote Sensing*. **3496**. SPIE.

Stoklosa H., et al. (2021), Mitigating trafficking of migrants and children through disaster risk reduction: Insights from the Thailand flood. *International Journal of Disaster Risk Reduction*, **60**, 102268.

Stratford C., et al. (2015), A simple model to quantify the potential trade-off between water level management for ecological benefit and flood risk. *Ecohydrology & Hydrobiology*, **15**(3), 150–159.

Talbot C.J., et al. (2018), The impact of flooding on aquatic ecosystem services. *Biogeochemistry*, **141**(3), 439–461.

TanabeTana R. (2016), *Sentinel Asia Success Story in the Philippines, Status Report*. Colombo, Sri Lanka.

Taohidul Islam S.M. and Chik Z. (2011), Disaster in Bangladesh and management with advanced information system. *Disaster Prevention and Management: An International Journal*, **20**(5), 521–530.

Tim Y., et al. (2017), Digitally enabled disaster response: the emergence of social media as boundary objects in a flooding disaster. **27**(2), 197–232.

Troy D.A., et al. (2008), Enhancing community-based disaster preparedness with information technology. **32**(1), 149–165.

UN (2020), Use of DinSAR and SBAS to monitor activity of the Taal volcano.

UNDP. (2019), *Glacial Lake Outburst Flood (GLOF) 'Reducing Risks and Ensuring Preparedness'*. Hotel Olathang, Paro, Bhutan.

UNDRR G. (2019), *Assessment Report on Disaster Risk Reduction*. Geneva, Switzerland.

USACE. (2006), Risk Analysis for Flood Damage Reduction Studies. Washington, D.C.

Vanderlinden J.P., et al. (2015), Chapter 5 - Nonstructural Approaches to Coastal Risk Mitigations, in Coastal Risk Management in a Changing Climate B. Zanuttigh, et al., Editors. Butterworth-Heinemann: Boston. p. 237–274.

Walz Y., et al. (2021), Disaster-related losses of ecosystems and their services. Why and how do losses matter for disaster risk reduction? *International Journal of Disaster Risk Reduction*, **63**, 102425.

Webster P.J., Toma V.E. and Kim H.-M. (2011), Were the 2010 Pakistan floods predictable? **38**(4).

Wechsler M. (2017), Fifty years of natural disasters in Thailand Bangrak, Bangkok.

Wisner B. (2020), Five years beyond Sendai—can we get beyond frameworks? *International Journal of Disaster Risk Science*, **11**(2), 239–249.

Zaidi S.S.u.H.a.S.S.Z. (2012), Flooded economy of Pakistan. *Journal of Development and Agricultural Economics*, **4**(13), 331–338.