Chapter 4
Flood Risk and Reduction Approaches in Pakistan

Atta-Ur-Rahman and Rajib Shaw

Abstract Globally, flood is a recurrently occurring damaging phenomenon. In terms of flood related damages, approximately 90 % is reported from the developing countries, where poverty is a major risk factor and holding low resilience. Pakistan has no exception to it, where flood is a frequently occurring adverse event. Pakistan is one of the flood prone countries in the world because of its physical and climatic characteristics. The Indus plain is occupied by more than 120 million population, where agriculture is a major source of livelihood earnings. Majority of them are poor section of the society and tenant cultivators. During the span of 67 years (1947–2013), on average of 4-year, a severe flood hit the country. The increasing population, degradation of ecological environment and the changing climate scenario have further multiplied the risk of flood disasters. It has been estimated that Pakistan is suffering from frequent flood disasters and so far 11,239 human lives were lost, out which 1,985 is reported from the super-flood of 2010. It was a century worst flood, where 20 million people were affected and over 100,000 km^2 (1/5th of the country total area) inundated and ≈US$ 10 billion economic loss was registered. Since the inception of Pakistan 1947, efforts have been made for building resilience through various flood reduction approaches. The existing flood reduction strategies range from structural to non-structural measures. This chapter provides a review of risks associated with flash and river flooding in Pakistan. It also gives an analytical discussion on the historic flood events and their adverse impacts. In addition, the flood risk reduction approaches undertaken so far in Pakistan have also been discussed.

Keywords Flood risk • Flood causes • Impacts • Flood reduction strategies

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4.1 Introduction

Historically, rivers and other large bodies of water have played a pivotal role in the development of civilization. Floodplains with fertile alluvial soil has always encouraged settled agriculture and enjoyed a long history of settlement (Khan 2003). Globally, flood is the recurrently occurring damaging phenomenon. Flood encompasses from a wide range of unpredictable, highly localized flash floods to anticipated and widespread river floods. Therefore, floods considers among the worst natural disasters affecting society. However, in terms of flood related damages ≈90 % is reported from the developing countries, where poverty is a major risk factor and holding low resilience (Douben 2006; Rahman 2010). Similarly, societal vulnerability to flood damages is a function of land use, land values, human occupancy and population (Tariq 2013). All together flood accounted for about 30 % of all natural disasters and 40 % of the fatalities (Rahman 2010). However, floods may also bring benefits as it recharge the ground water and deposit fertile silt (Khan and Rahman 2003).

Pakistan is one of the flood prone countries, because of its physical and climatic characteristics (Fig. 4.1; Khan 2003). In Pakistan, flood is one of the serious and recurrent extreme natural events (Khan and Rahman 2003). During the span of 66 years (1947–2012), on average of 4-year, a severe flood hit the country (Rahman 2010). The discharge in river Indus and its tributaries is subjected to seasonal fluctuations. It is high in summer due to melting of snow, glacier and summer monsoon rainfall (Rahman and Khan 2013). However, the discharge remains low in winter due to retarded ablation of glaciers and precipitation in the form of snow over the catchment area of Indus river system. The Indus plain is occupied by more than 120 million population and agriculture is a major source of their livelihood earnings (Tariq 2013). Majority of them are poor section of the society and tenant cultivators. It is evident that the increasing population, degradation of ecological base and the changing climate scenario have further multiplied the risks of flood disasters.

From time-to-time Indus River and its tributaries overflow the levees and cause heavy damages to human lives, standing crops, agricultural land, infrastructure and other properties (Rahman 2010; Khan and Iqbal 2013). It is estimated that Pakistan has been suffered from frequent flood disasters and in past 20 mega flood events, 11,239 human lives were lost, out which 1,985 is reported from the single event of super-flood 2010 (UNDP 2012; Tariq 2013). It was a century worst flood, where 20 million people were affected and over 100,000 km^2 (1/5th of the country total area) inundated and ≈US$ 10 billion economic loss was registered (FFC 2012). Scientific evidence indicated the increasing extreme precipitation events, which implies that heavy flood events will become more frequent in future (GoP 2013). Parallel to this, exposure and vulnerability to floods have increased due to over urbanisation in the flood-prone areas, even without taking climate change into considerations; flood related damages are expected to further increase (Tariq 2013).

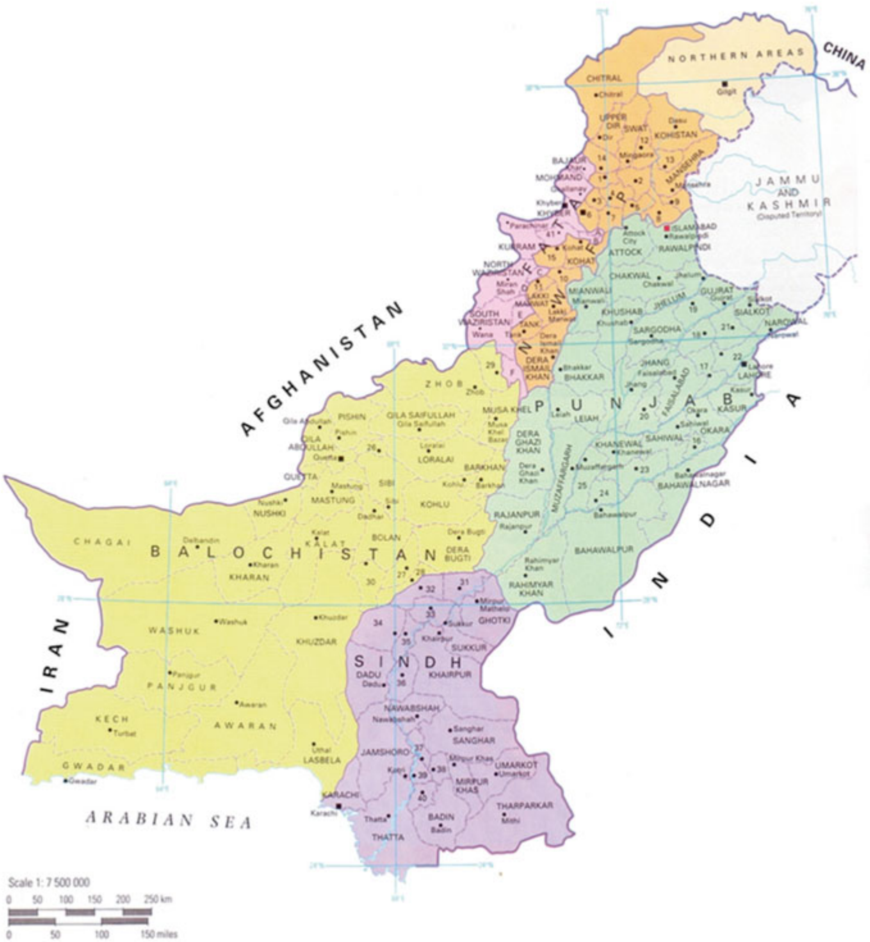

Fig. 4.1 Administrative regions of Pakistan (Modified after Khan 2008)

Since the inception of Pakistan (1947), efforts have been made for building flood resilience through various risk reduction approaches. At selected places, flood related line agencies have constructed water reservoirs, barrages, embankments and guided head spurs, to ensure flood water within the channel. But due to limited budget, it is economically and technically impossible to confine water within the channel. The existing flood reduction strategy ranges from structural to non-structural measures (Rahman and Khan 2013). This chapter provides a review of historic flood events and their adverse impacts. It also elaborates the risks associated with flash and river flooding in Pakistan. In addition, the flood risk reduction approaches undertaken in Pakistan have been analysed in the final section.

4.2 Physical Settings of Pakistan

In Pakistan, large variations exist both in terms of climate and physiography (Kazi 2014). Physically, Pakistan can broadly be classified into five physiographic units, formed by various geomorphological processes in the past. (1) The Himalaya, Karakorum and Hindu Kush form the north and north-western part of the country. Almost 60 % of the country is mountainous, which mostly lies in the north, north-west and western part. The world renowned peaks of K2 (8,611 m in Karakorum), Nanga Parbat (8,126 m in Himalaya) and Tirich Mir (7,706 m in Hindu Kush) lies in these mountains. These lofty mountains experiences long winter and receive heavy precipitation in the form of rain and snow. This is the region which hosts thousands of glaciers and a major source of perennial water for Indus river system. Some of the large glaciers are occupying area of more than 100 km^2 (*Siachen glacier in Karakorum*). Flash flood is a typical feature of this region. (2) Baluchistan plateau forms the south-western portion of the country and comparatively dry in nature. Hill torrents and associate flood is a landmark feature of this physiographic unit. (3) Potwar plateau is located south of sub-Himalayas and physically bordered by Jhelum River in the east and Indus in the west, while Salt range lies in the south. (4) Indus basin making almost 40 % of the country area and support more than 60 % of the country population.

Indus is a longest river of about 3,100 km with a total drainage basin of about 1 million km^2 (Khan 2003). The catchment area spread over Tibet, China, Afghanistan, India and Pakistan. Out of the total catchment area, 65 % form the Indus basin of Pakistan (Kazi 2014). Throughout the river course, right from its origin (lake Mansarwar in Tibet), Indus River passes through narrow gorges in Karakorum and Himalayas, and enters into a wide Indus plains and ultimately empties in the Arabian sea (Khan 2003). Throughout its course, Indus River receives several tributaries both from right and left banks. The major right hand tributaries are Jhelum, Chenab, Ravi, Sutlej and Beas, whereas Kabul River is a notable right hand tributary. The Indus plain occupies almost all the province of Punjab and major part of the Sindh province.

Continental type of climate is prevailing in the Indus plain, whereas highland climate is reported from the northern and western mountains (Fig. 4.2). There are extremes in rainfall and temperature both daily and seasonally. During winter, most often temperature falls below dew point, whereas in summer the ever highest recorded temperature is 53.5 °C, which was recorded on 26th May 2010 at Mohenjo-Daro, Sindh (Rahman and Khan 2013). Similarly, arid to semi-arid type of condition is prevailing over 60 % of the country area and less than 10 % area has humid to sub-humid climate. In Pakistan, rainfall occur in two well-marked seasons i.e. monsoon (summer) and western depression (winter). Eastern half of the country receive maximum rainfall from monsoon, whereas the western half in winter from western depression. In addition to this, the northern half of the country receives more rain as compared to southern half. It means that the amount of rainfall decreases as one move southward. The record breaking ever highest one day rainfall is 620 mm, which was received on July 24, 2001 at Islamabad. Murree is the humid station, which receive on average 1,789 mm annually.

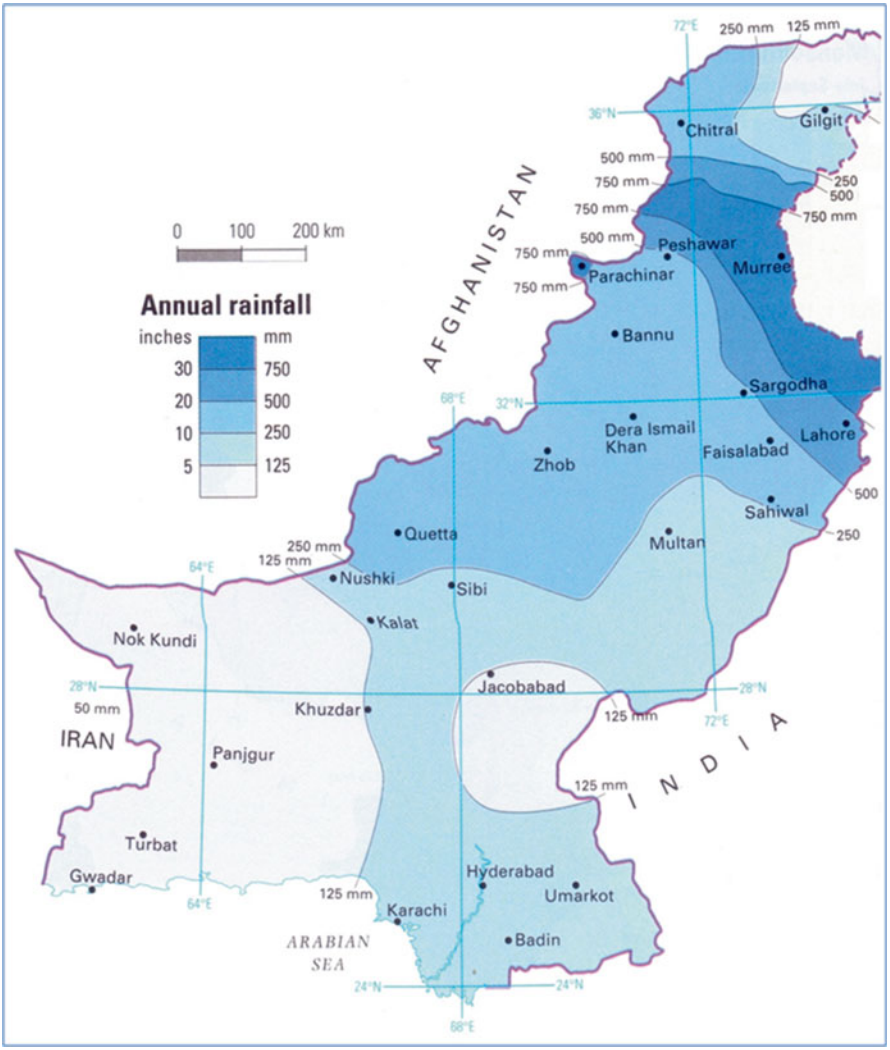

Fig. 4.2 Rainfall distribution in Pakistan (Modified after Khan 2008)

4.3 Types of Floods in Pakistan

Flood is any abnormal rise of water level, which overflow the levees and inundate the adjoining areas (Rahman 2010). There are several types of floods depending upon the physiography, tectonics, climatic condition and sources of water. Some of the major types of floods include riverine floods, pluvial/urban floods, flash floods, coastal floods and barrier lake floods (Kazi 2014). These floods are caused by a variety of factors that range from physical to human intensifying factors. Heavy and prolonged rainfall remained the major contributor in the inland flood occurrence.

Pakistan is exposed to frequent riverine floods, flash floods and coastal floods. Historical records shows that Pakistan has experienced almost all types of floods but in terms of frequency and magnitude river and flash floods dominates over all other kind of floods. Therefore, in this chapter focus has been made on riverine and flash floods, which poses more risk than other types of floods in terms of damages to lives and property.

4.3.1 River Floods

In Pakistan, river flooding is a type of inundations, which occur in Indus, Jhelum, Chenab, Ravi, Sutlej and Kabul river systems (Khan 2003). However, the hilly terrain has a flash flood characteristic, whereas the coastal area has a risk of tsunami. Largely, it is catered by existing flood forecasting and early warning system, established under the flood forecasting division (FFD), Lahore. The Indus plain has a long history of river flooding. Floods in the Indus River and its tributaries is evident to be the most devastating (Tariq and Van-De-Giesen 2012), because downstream Chashma Barrage, the might Indus enters into the gentle sloping floodplain and meandering throughout the course till it falls into the Arabian Sea. In addition to this, high population density, poverty, farmland, infrastructure and concentration of economic activities are the major risk factors. According to Federal Flood Commission (FFC), in the past 35 years more than US$ 210 million has been spent on flood mitigation under different programmes. In response to flood damages, no significant decrease in the farmland inundation has been registered (Tariq and Van-De-Giesen 2012).

4.3.2 Flash Floods

Flash flooding is an extreme natural event throughout the mountainous region of Pakistan. It is a recurrently occurring phenomenon. Flash flood is more disastrous and occurs within 6 h of heavy/prolonged rainfall. The Himalaya-Karakorum-Hindu Kush (HKH) region is more susceptible to flash floods. However, flash floods are also reported from the Sufaid Koh, Waziristan hills, Sulaiman, Kirthar and Makran ranges. In mountain system, it is the physiographic and climatic conditions, which leads to hydro-meteorological disasters. Particularly in the HKH region, the torrential rainfall is some-time supported by cloud bursting, thunder storms, heavy melting of snow/ice and glaciers. Eventually, it increases the intensity and magnitude of flash floods. Forecasting of flash flood is difficult and provides short time for preparedness such as early warning and response. In Pakistan, no flash flood warning system exists except for nullah Lai, which was established in 2001, after massive flash flood that hit Rawalpindi and adjoining areas. The north-western of Pakistan is more susceptible to flash floods and almost every year heavy casualties have been registered. Such sudden flashy water pick up the silt, sand and in effect cause damages to human lives, standing crops, infrastructure and other property.

4.4 Case Studies

4.4.1 Flash Flood in Rawalpindi Nullah Lai (Punjab Province)

Nullah Lai is a hill torrent flowing through Islamabad and Rawalpindi. Margallah hills are the catchment area of nullah Lai. During monsoon, it is flooded almost every year, but in the past one decade the flood of 2001 and 2008 is remarkable. On 23rd July 2001, a record rain of 620 mm was occurred at Islamabad in just 10 h. As a consequence, a havoc urban flood occurred in the twin cities (Islamabad-Rawalpindi) and a total of 74 lives were lost, ≈400,000 people were affected, 742 livestock were perished, 1,087 houses were fully damaged and 2,448 partially (WMO 2004). Another terrible situation was occurred on 5th July 2008, when a torrential rainfall of 104 mm was recorded at Islamabad in just 100 min and 162 mm in 5 h. Eventually, it has caused a disastrous flood in nullah Lai. Besides massive damages to urban property, 3 precious lives were also lost. It has prompted the Government to establish Flood Forecasting and Early Warning System for Nullah Lai.

4.4.2 Flash Flood in Karachi and Thatta (Sindh Province)

In July 2003, the province of Sindh was severely affected by heavy monsoon rainfall and caused flash and urban floods in major part of Karachi, Thatta and Badin. In Karachi, 284 mm rain fell in just 2 days, which generated massive urban flood and disastrous situation in the city. Similarly, heavy rainfall was also recorded in other parts of the province. In Thatta, 404 mm rainfall was recorded in just 2 days, which as a result caused flash floods in the district. In Sindh province, due to July 2003 flash floods, a total of 484 human lives were lost and around 4,476 villages were affected.

4.4.3 Flash Flood in Rajanpur, Punjab

On August 2, 2013, flash flood hit the Rajanpur district of Punjab province. A total of 17 Union Councils were affected in the three tehsils of district Rajanpur. The eastern part of the district frequently affected by river flooding in Indus, whereas the western section of the district is exposed to flash floods generated in the Suleiman ranges. Heavy monsoonal rainfall has been blamed as the major factor responsible for flash floods in the district. Flash flood has inundated the area up to 8 ft. The available reports reveal that early warning was not issued and there were absolutely lack of preparedness for such disastrous flash flood. According to District Disaster Management Authority, besides structural and other economic damages, 2 precious human lives were also lost and approximately 150,000 people were affected.

4.4.4 Flash Floods in Peshawar, Khyber Pakhtunkhwa

On 14th August 2002, the heavy rainfall occurred around Warsak. Sources also indicate that several cloud bursts was also noticed in the area. A total of about 500 mud houses were collapsed and 930 partially damaged when heavy flash flood hit the five union councils namely Mathra, Panam Dheri, Kafoor Dehri, Shahi Bala and Ghari Sherdad. Similarly, on 4th August 2008, another flash flood hit the northern part of the district. There was a torrential rainfall in the catchment area of *Thara* and *Chorai* hill torrents originating from the Khyber hills. A total of about 50 villages were affected and approximately 700,000 people were affected. Besides this, 12 people were also killed due to flash floods.

4.5 History of Flood Events in Pakistan

The territory of Pakistan has a bad history of flood events. During 1841 a heavy flood hit the Indus basin, when a Glacier blocked the Shyok River in Karakorum and subsequent breaching of Glacial Lake Outburst Flood (GLOF) has caused disastrous flood in the down-stream area. Similarly, during the British period in 1929 another deadliest flood occurred in the Indus river, when Indus river was choked-up by the moraines near Roykot (Diamir district), Gilgit-Baltistan Province (Table 4.1). The bursting of this temporary water reservoir has caused heavy floods in the Indus basin. Since 1947, Pakistan has experienced severe flood events with various magnitude and frequency. All the four provinces including FATA, Gilgit-Baltistan and Azad Jammu & Kashmir has been hit by riverine, flash, urban and coastal floods.

The major river system including Indus, Chenab, Ravi, Sutlej, Kabul and Swat rivers have a long history of flood events and resultant damages (Table 4.1). In the upper Indus basin, the flood water after inundating the contiguous areas often return to the main river. However, in the lower Indus plain (Sindh province), which is flowing at a relatively higher elevation than the adjoining lands, spills water do not return to the main river channel (FFC 2012). This is one of the major reasons behind the excessive flood losses in the lower Indus plain. Although, flood protective embankments has been provided along the major section of Indus River in the Sindh province and at many locations in the upper parts of the country (GoP 2012). As in this part of the country, flooding has been a regularly occurring phenomenon with various intensities.

Table 4.1 Historic flood peaks in major rivers

Dam/Barrage site	Design capacity (Cusecs)	Highest recorded year	Highest recorded flow (Cusecs)
Indus River			
Tarbela	1,500,000	1929	875,000
Jinnah	950,000	1942	950,000
Chashma	950,000	1958	950,000
Taunsa	1,000,000	1958	789,000
Guddu	1,100,000	1976	1,199,672
Sukkur	900,000	1976	1,161,000
Kotri	875,000	1956	980,000
Jhelum River			
Mangla	1,230,000	1929	1,100,000
Rasul	850,000	1929	1,000,000
Chenab River			
Marala	1,100,000	1957	1,100,000
Khanki	800,000	1957	1,066,000
Qadirabad	900,000	1992	948,530
Trimmu	650,000	1959	943,000
Panjnad	700,000	1992	744,152
Ravi River			
Jassar	–	1988	582,000
Shahdara	–	1988	576,000
Balloki	225,000	1988	399,000
Sidhnai	175,000	1988	330,000
Sutlej River			
Suleimanki	325,000	1955	598,872
Islam	300,000	1955	493,000
Kabul River			
Warsak	–	2010	250,000
Nowshera	–	2010	300,000

Source: GoP (2012)

4.6 Causes of Floods

In Pakistan, flooding in the Indus River system is one of the major frequently occurring hazards. It normally occurs in summer season (July–October). Summer monsoon rain has been the major cause of floods together with the heavy melting of snow, ice and glaciers in the catchment areas. Monsoon currents originate from the Bay of Bengal and proceed towards the Himalayan foothills depression and cause heavy rainfall. Such heavy rainfall led to flash floods in the hilly areas and river floods in the lower reaches.

The cause of floods in river Indus varies at upper reach and lower reach. The floods in the upper Indus generally result from heavy precipitation in the hilly catchment area in Himalayas and Hindukush which have limited valley storage. There is significant snow melt contribution. Occasionally, floods have been caused by formation and collapse of temporary natural dams either by glacial movement like the GLOF of Shyok river in 1841 or by the landslides like the one in 1929 that blocked the Indus near Roykot (FFC 2012). The upper reaches of all these rivers passes through mountainous territory, with a concentration of population in the valleys. Heavy rainfall in these areas usually generates massive flash floods in the headwater regions.

The lower Indus basin receives combined flows of the upper Indus and tributaries Jhelum, Chenab, Ravi and Sutlej. The floods in this reach occur in August, but could also occur from July to October and the river can be in high flood for a period exceeding 1 month (Sheikh 2004). In the lower Indus basin, the river system meandering and sloping gently, causing overflow of water that adversely affects the population and agriculture land lying in the active floodplains.

4.7 Flood Management Legislations and Institutions

4.7.1 National Calamity Act 1958

The National Calamities Act of Pakistan 1958 was the only legal document to regulate the relief, rehabilitation and reconstruction. This was only the reactive legal document functioned throughout the country for a long time. Under this regulation, there was an emergency relief cell within the cabinet division. Again it is refereeing just relief /compensation in either disaster or post-disaster phase. Under the Calamity Act, in each province there were relief commissioners, who supervised and coordinate the relief and rehabilitation efforts. Few provinces have also developed Disaster Plan such as NWFP Disaster Plan 1978, where list of hazards are available to which the province is susceptible (Rahman 2010). Similarly, it has also elaborated the Government line departments and their primary and secondary responsibilities in the disaster phase. The Provincial Board of Revenue has been made responsible of collecting damages data and record of compensation.

4.7.2 UNISDR and HFA (2005–2015)

The United Nations General Assembly has created UNISDR (International Strategy for Disaster Reduction) in 1999. The secretariat of UNISDR is the focal point in the UN system for the coordination of disaster risk reduction and implementation of the international disaster risk reduction – the “Hyogo Framework for Action 2005–2015: Building the resilience of nations and communities to disasters”. It was adopted under the “Hyogo Declaration” in the World Conference on Disaster

Reduction, held in Hyogo prefecture Kobe, Japan in 2005. Its core areas includes ensuring disaster risk reduction (DRR) is applied to climate change adaptation, increasing investments for DRR, building disaster-resilient cities, schools and hospitals, and strengthening the international system for DRR. UNISDR's vision is based on the three strategic goals of the Hyogo Framework for Action: integrating DRR into sustainable development policies and planning, developing and strengthening institutions, mechanisms and capacities to build resilience to hazards, and incorporating risk reduction approaches into emergency preparedness, response, and recovery programmes. The UNISDR introduced new concept to shift from a reactive to a proactive approach HFA (2005–2015) signed by 168 countries including Pakistan.

4.7.3 National Disaster Management Ordinance – 2006

After 2005 Kashmir earthquake and HFA, the Government of Pakistan was stimulated towards institutionalisation for disaster risk reduction. There was high time for capacity building of the disaster related agencies at national, provincial, district, local and community level. As after the earthquake, numerous challenges emerged and encounter the situation. Keeping in view this alarming state the president of Pakistan promulgated the National Disaster Management Ordinance (NDMO) in 2006 (GoP 2011). Under this ordinance, National Disaster Management System was introduced in the country. Similarly, the National Disaster Management Commission (NDMC) was established at the national level. The NDMC was assigned the task of preparing guidelines, policies and plan for DRR. Eventually, the National Disaster Management Authority (NDMA) was established in 2007.

4.7.4 National Disaster Management Authority

The National Disaster Management Authority (NDMA) was established in 2007. The NDMA was held responsible for coordinating, implementing and monitoring body for DRR in the country level. Under the Ordinance (now Act), the National Disaster Risk Management Framework (NDRMF) was prepared by the NDMA in March 2007 (GoP 2012), which serves an overall guideline for disaster risk management at national, provincial and district levels. This necessitates NDMA to directly interact/ communicate with all stakeholders, including Ministries, Divisions, and Departments. In March 2010, the NDMA formulated the National Disaster Response Plan (NDRP) for identifying specific roles and responsibilities of the key relevant stakeholders in emergency response including Standard Operation Procedures (SOPs). In addition to this, the NDMA, in collaboration with national and international partners had been in the process of strengthening the DRM system in the country.

4.7.5 National Disaster Management Act 2010

The Pakistan National Disaster Management Ordinance was approved by the parliament in December 2010 and became the Act called as Pakistan National Disaster Management Act (DMA) 2010. The DMA has established three levels for the disaster risk management in the country i.e. national, provincial and district levels. National disaster management authority is working at federal level, provincial /state disaster management authority at provincial/state level and district disaster management authority/unit at the district level.

4.7.6 Provincial Disaster Management Authority

The National Disaster Management Ordinance insisted for the establishment of a Provincial Disaster Management Commission (PDMC) as well as Provincial Disaster management Authority (PDMA) to cope with the challenges of Disaster Management in a professional and efficient manner. Both the Organizations have been mandated to effectively set up a system to look after disasters and calamities whether natural or man induced and coordinate with the key players. Previously the Provincial Relief Commissionerate had been responsible for the relief, compensation and rehabilitation of people affected by natural disasters. With the establishment of PDMA, the functions of the Relief Commissionerate have been incorporated into the new Organization.

4.7.7 District Disaster Management Authority/Unit

In order to involve local organization in DRR planning and implementation, district disaster management authority (DDMA) has been in the process of establishing at district level. In Khyber Pakhtunkhwa, there is district disaster management unit instead of authority. As per plan, the Head of the local council at the district level shall be the chairperson, Deputy Commissioner /District Coordination Officer as secretary, whereas District Police Officer and Executive District Health Officer are the ex-officio members. The power and function of District Authority include preparation of district disaster management plan, coordinate and monitor the implementation of the National Policy, Provincial Policy, National Plan, Provincial Plan and District Plan. In addition to this, DDMA shall ensure that the vulnerable areas in the district are identified and measures have been taken for their prevention and mitigation at district level (GoP 2012).

4.7.8 Federal Flood Commission

Prior to 1977, flood mitigation was the concern of respective provincial Governments. However, the heavy floods of 1973 followed by flood-1976 has prompted the provincial Governments to raise the issue at federal level that planning and execution of flood mitigation is beyond their carrying capacity (Rahman 2010). As a consequence, in 1977 the Federal Flood Commission (FFC) was established to tackle the flood issue at federal level. The key responsibility of FFC include: Preparation of National Flood Protection Plans; Approval of flood control schemes prepared by Provincial Governments and concerned Federal Agencies; Review of flood damages to flood protection infrastructure and review of plans for restoration and reconstruction works; Measures for improvements in Flood Forecasting and Warning System; Standardization of designs and specifications for flood protection works; Evaluation and monitoring relating to progress of implementation of the National Flood Protection Plans; Preparation of a Research Program for flood control and protection; and Recommendations regarding principles of regulation of reservoirs for flood control (GoP 2011).

4.7.9 Pakistan Meteorology Department and Flood Forecasting Division

The Pakistan meteorological department provide services of flood forecasting and early warning together with the generation of weather data and its dissemination to the relevant agencies. The Pakistan Meteorology Department has so far installed 97 weather stations all over the country to record rainfall and other weather elements. One of the core areas of Pakistan Meteorology Department is the Flood Forecasting division. This division is fully equipped with Doppler radar to remotely sense and measure the quantitative precipitation over the catchment area of major river systems. Such 10-cm Radar facilities are available at Lahore and Mangla, whereas 5-cm radar at Sialkot, Islamabad, Dera Ghazi Khan, Rahim Yar Khan and Karachi, which cover almost all the catchment area of major river systems in Pakistan. The Flood Forecasting Division is also applying mathematical model on Indus river system for computing the stream hydraulics and to identify vulnerable areas for issuance of early flood warning.

4.7.10 WAPDA

WAPDA activities impinge on the sector in a number of ways. WAPDA has traditional responsibility for the investigation design, construction and operation of the major storage works in Pakistan. WAPDA also held responsible to maintain gauges at various site and disseminate the discharge data to FFD for analysis and early warning.

4.7.11 Provincial Irrigation and Drainage Authority

The Provincial Irrigation and Drainage Authority (PIDA) is headed by a respective Secretary, and technically supported by two Chief Engineers responsible for development and Operation & Maintenance. PIDA's also records discharge at their respective jurisdictions, which they share with the FFD for analysis and onward dissemination. At provincial level, construction of flood protective embankment and spurs is the direct responsibility of PIDA but if budget accede certain limit then they seek approval of FFC.

4.7.12 Other Players

Beside the above mentioned major implementing agencies, health department, animal husbandry department, communications and works (C&W) department, Pakistan railways, home department (Tele-communication, Police, Civil defence), food department, directorate of social welfare, finance department, information department, education department, law department, Telephone and telegraph department, public health engineering department, and army are other key role players in disaster situation (Rahman 2010). After the receipt of information of disaster occurrence, the control centre of concerned department at provincial, divisional, district and sub-divisional level shall have at all times ready to respond and execute their emergency plan. They must also send their rescue and evacuation team to the affected area for rescue operation, emergency assessment of losses and net requirement.

4.8 Impacts of Floods

Historically speaking, floods remain the major catastrophic events that has resulted enormous damages to life and property. During 1931 flood, 3.7 million human lives were lost in China (Rahman 2010). The records show that number and trends of hydro-meteorological events is gradually increasing since 1985 (MunichRe 2010). Despite all these disadvantages man has clung to the river, because of the fertile land as well as irrigation and navigation facilities.

In Pakistan, flood is one of the serious and recurrent extreme natural events (Khan and Atta-ur-Rahman 2002). The discharge in river Indus and its tributaries is high in summer due to melting of snow, glacier and summer monsoon rainfall and low in winter. From time to time Indus River and its tributaries overflow the natural levees causing heavy damages to human and animal lives, standing crops, agricultural land, infrastructure as well as housing and other properties (Fig. 4.3; Rahman 2010). Whenever, major flood disaster occurred, it swept away rural and urban settlements and have caused human deaths and rendered thousands of people homeless. It is estimated that Pakistan has been suffered from frequent flood disasters and in past 20 mega flood events, 11,239 human lives were lost (Table 4.2), out which 1,985 is reported from the single event of super-flood 2010 (UNDP 2012; Table 4.3). It was a century worst flood, where 20 million people were affected and over 100,000 km^2 (1/5th of the country total area) inundated and ≈US$ 10 billion economic loss was registered (FFC 2012).

Fig. 4.3 2010-flood damages in Khyber Pakhtunkhwa

Table 4.2 Flood damages in Pakistan, 1950–2012

Year	Number of lives lost	Number of villages affected	Flooded area (sq. km)
1950	2,190	10,000	17,920
1955	679	6,945	20,480
1956	160	11,609	74,406
1957	83	4,498	16,003
1959	88	3,902	10,424
1973	474	9,719	41,472
1975	126	8,628	34,931
1976	425	18,390	81,920
1977	848	2,185	4,657
1978	393	9,199	30,597
1981	82	2,071	4,191
1983	39	643	1,882
1984	42	251	1,093
1988	508	1,000	6,144
1992	1,008	13,208	38,758
1994	431	1,622	5,568
1995	591	6,852	16,686
2010	1,985	17,553	160,000
2011	516	38,700	27,581
2012	571	14,159	4,746

Source: Federal Flood Commission (2012)

Table 4.3 Province-wise summary of flood damages and losses during 2010 flood

Province	Deaths	Injured	Houses damaged	Population affected
Baluchistan	54	104	75,596	700,000
Khyber Pakhtunkhwa	1,156	1,198	284,990	3,800,000
Punjab	110	262	497,700	6,000,000
Sindh	411	1,235	876,249	7,274,250
A.J.K	71	87	7,106	200,000
Gilgit-Baltistan	183	60	2,830	100,000
Total	1,985	2,946	1,744,471	18,074,250

Source: National Disaster Management Authority, Islamabad

Scientific evidence indicated the increasing extreme precipitation events, which implies that heavy flood events will become more frequent in future (GoP 2013). Parallel to this, exposure and vulnerability to floods have increased due to over urbanisation in the flood-prone areas, even without taking climate change into considerations; flood related damages are expected to further increase (Tariq 2013).

4.9 Flood Risk Reduction Approaches in Pakistan

In Pakistan, the existing flood risk reduction approaches has been the result of a long history of flooding experience. In Pakistan, the aim of flood risk reduction is to save lives and reduce damages. In this regard, government has been taking interest in implementing both structural and non-structural strategies (Table 4.4; Fig. 4.4). The existing flood reduction strategy ranges from structural to non-structural measures (Khan et al. 2011; Rahman and Khan 2013). Structural measures are those physical measures which are applied to minimize or alleviate potential impacts of hazards by construction of hazard-resistant structures (FFC 2012). Structural measures are usually cost-intensive and take long time to implement. Whereas non-structural measures refer to policies, plans, awareness, capacity building and provision of information for reducing risk and related impacts. At national level following flood risk reduction approaches were found:

4.9.1 Structural Measures

Since the inception of Pakistan, maximum stress remained on the structural flood management approaches, but the limited structural measures have so far not reduced the flood damages to a greater extent (Table 4.4). In Pakistan, the structural measures include water reservoirs, flood protective embankments, flood dikes, guided

Table 4.4 Province-wise, existing flood protective infrastructures, 2012

Province	Embankment (Km)	Spurs (No)
Punjab	3,334	496
Sindh	2,424	46
Khyber Pakhtunkhwa	352	186
Baluchistan	697	682
Total	**6,807**	**1,410**

Source: GoP (2012)

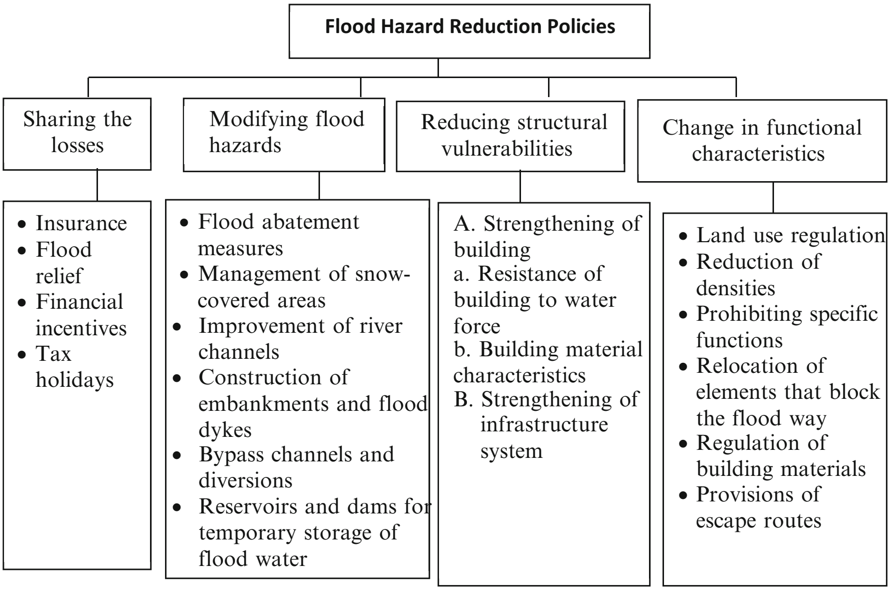

Fig. 4.4 Flood hazard reduction policies (Modified after Rahman 2010)

head spurs, and flood diversion channels (Rahman 2010). Generally, the structural measures are adopted where flood problems emerges. Nevertheless, the structural mitigation approaches are very expensive and beyond the financial capability of developing countries like Pakistan (Rahman and Khan 2011; Rahman and Salehin 2013). Therefore, the structural strategy is subject to the availability of finances and its subsequent implementation. While mitigating flood losses in critical areas, the structural approaches have largely reduced the flood damages (Tariq and Van-de-Giesen 2012). This could have been the most viable solution for flood risk reduction if implemented throughout the critical breaching areas of river system. However, it is not feasible both economically and technically. As throughout the length of river, numerous irrigation channels have been taken out for agricultural practices. Application of such strategy would hinder the economic activities throughout the floodplains (GoP 2012).

4.9.1.1 Channel Modification/Link Canal/Flood Relief Channels/Diversion Channel

These schemes have received little attention in the past, although there are examples of flood relief channel or link canals on the rivers. These channels intercepting the flow of main river (GoP 2012). Channels enlargements and channels straightening are more common in Pakistan and have adopted this measure as a flood alleviation strategy.

4.9.1.2 Embankment and Spur/Dyke

Embankment and spur/dykes schemes have been utilized more than any other structural measure in Pakistan. The rapidly rising flood inherent in the country added to the necessity to prevent flood water spreading much further than the main channel, because of the high degree of urban development and fertile agriculture land have encouraged the employment of such levee system (GoP 2012). Therefore, this scheme has a long history and can be found throughout the country on a variety scale.

4.9.1.3 Flood Water Reservoir

Reservoirs have never been built in Pakistan for the sole purpose of flood alleviation. However, some multi-purpose reservoirs do operate in order to ensure the most efficient over all water management (Khan and Rahman 2003). Thus, maximum flood retention capacity in autumn is progressively reduced during the winter and spring, so that increased water level are available both for power generation and for river regulation purposes in summer.

4.9.2 Non-structural Measures

In Pakistan, the flood risk reduction policy recognizes the importance of non-structural approaches. Non-structural measures are relatively less expensive and the effects of reduction in human casualties can be realized sooner. The non-structural or behavioural group of schemes generally requires a greater involvement of the floodplain inhabitants and extends from the more passive use of loss-bearing and public relief funds towards active policies of flood insurance, flood warning and floodplain zoning. Non-structural approaches are not very effective in flood risk reduction (Tariq 2013). Its efficiency varies from place to place and it largely depends upon the availability of resources, accessibility and community awareness (Rahman 2010). The following non-structural approaches have been reported from the country.

4.9.2.1 Flood Forecasting and Early Warning

Flood Forecasting Division (FFD), Lahore is the only national agency responsible for flood forecasting and its dissemination to the warning centres (GoP 2012). FFD receive hydro-meteorological data from the various national and international sources, which is then analysed to produce flood forecasts, warnings and disseminate to various Federal/Provincial organizations and print/electronic media. Flood forecasting and early warning is necessary component of a comprehensive flood risk reduction strategy. Timely warning can reduce loss of life through evacuation from the flooded area; allow preparedness measures to be taken in advance to minimize damages to vital structures, and alert authorities responsible for maintenance and operation of flood control facilities.

The present flood forecasting division (FFD) call herself as of worth effectiveness and efficiently fulfil the country requirements. But the fact is that it doesn't cover the catchment area of all the rivers (Tariq 2013). The cursory example is the catchment area of Kabul and Swat rivers is beyond the carrying capacity of existing country radar system (Khan and Rahman 2003; Rahman 2010). It is therefore, during the super flood 2010, neither the prolonged heavy wet spell was forecasted and nor the early warning disseminated to the vulnerable community (Rahman and Khan 2011). That's why the highest number of human casualties and subsequent flood damages has been reported from the Swat and Kabul river basins (Rahman and Khan 2013). The existing organization set-up for flood forecasting and early warning is functioning. Therefore, radar coverage over the North Western mountains for catering the catchment areas of Kabul and Swat rivers need to be enhanced by the procurement of an additional Doppler RADAR of 10-cm at *Warsak*. This need further meteorological studies to take full advantages of the new radar and satellite data to improve quantitative precipitation measurement and forecast of rainfall in the upper catchment of Kabul and Swat rivers. Beside this, dissemination of early flood warning to the vulnerable communities is specially lacking in flood management planning, when assessed during field survey (Khan and Rahman 2002). Hence, the location of radar system will also provide a database for both forecasting and subsequent dissemination to the vulnerable communities. In addition to this, at the national level, since 1975, to some extent flood forecasting and warning system has been supporting flood preparedness and response.

4.9.2.2 Flood Emergency Response System

HFA-5 specifically focuses on strengthening disaster preparedness for effective response at all levels. In response to 2005 earthquake as well as 2010 and 2011 floods, the massive damages to life and property and the lack of response mechanism prompted the Government machinery to enhance response system for search, rescue and evacuation operation. The same was also highlighted in the National Disaster Management Act-2010, which instruct for the establishment of national disaster response force. In this regard, NDMA formulated the National Disaster Response Plan in March 2010 to enhance the country's ability to properly respond to disasters. The NDRP has become an official document and provides Standard Operating Procedures (SOPs) at national, provincial/state and district levels for emergency response. Furthermore, the Government of Pakistan has incorporated in NDMP (2012–2022) to establish a national emergency response system and capacity building for post-disaster recovery. Furthermore, there is utmost need for enhancing emergency response capacities at the community level. Flood relief are still very common response to the flood problem in Pakistan. In practice, flood relief are not very effective, because they rarely achieve even 10 % of the total reported losses. Such aid is usually limited to emergency relief such as shelter, food, medication and other essentials for the flood victims (Rahman 2010). In this measure the role of community is of key significance, they are the quick and much effective than Government.

4.9.2.3 Flood Abatement

Flood abatement policies like those of flood storage reservoir have never been tackled seriously as a means of reducing flood losses in Pakistan (Khan and Rahman 2005). Some flood dealing line agencies have considered the effectiveness of flood abatement approaches, but none of them implemented on large scale. Watershed management is one of the flood risk reduction strategies through which excessive runoff checked at the source. Lack of preference to this approach has encouraged the problem of erosion, which eventually caused siltation in dams and rivers and drastically reduced their carrying capacity. This need serious considerations both from national and local level authorities otherwise the problem will multiply in future.

4.9.2.4 Flood Insurance

Flood insurance measure is extensively adopted for flood loss-sharing in the developed world where flood insurance is directly sold by private companies without any direct Government control. The idea behind this mechanism is that those knowingly expose themselves to the flood risks should assume most of the financial burden (Smith 1996). Under such a system it is more likely that new development in flood-prone areas will occur only when the expected advantages exceed the total public and private costs. The most important weakness of this approach is its discrimination against the low-income communities. In Pakistan, flood insurance is not practiced. Because of 2 % of the country population is living below poverty line. In addition to this, 98 % population are Muslim and insurance is prohibited in Islam.

4.9.2.5 Real-Time Flood Preparedness

In flood management planning, there is absence of real-time flood fighting (Ali 2013). During super flood 2010, there was lack of flood preparedness plan to guide the peak discharge. At several places the breach was politicised (Shah et al. 2011). In the Swat and Kabul rivers, flood occurred from July 27 to 30th, and the same peak flood discharge reached Chashma barrage on 30th July. After 8 days, it reached Gudu (6th August) and Sukkur (7th August) barrage and after 23 days the peak discharge reached Kotri (21st August) barrage. This is really a long time of ≈550 h (23 days) for preparedness and flood fighting. In flood management planning, there is need to formulate standard flood preparedness plan for routing peak discharge at various critical breaching point from areas of high economic importance towards low socio-economic significance. This negligence is already been reported in 2010 flood inquiry report (Shah et al. 2011). The report further summarises that due to meagre flood preparedness measures, insufficient flood fighting arrangements and negligence in observing the standard operating procedures caused the breaching of the flood levees at the Jinnah and Taunsa barrages, this as a result has caused severe losses to Punjab. This weakness could be overcome by preparing a flood-fighting plan for critical locations with several options, and by discussing the plan with the communities and other stakeholders before the monsoon season (Ali 2013).

4.9.2.6 Land Use Planning

The purpose of land use regulation is to obtain the beneficial use of flood prone areas with a minimum of flood damage and little expenditure on flood protection (Rahman 2010). Such form of land use regulations is beneficial to mitigate flood hazards including reduction of densities, prohibiting specific functions, relocation of elements blocking the floodway, regulation of building materials and provision of escape routes. The most effective way to ensure that inappropriate development in the hazard prone area will not continue in future if land use regulation is prepared and subsequently implemented. Land use management is the latest trend to limit and control the occupancy in the hazard prone area. In Pakistan, the flood management machinery has initiated the preparation and development of flood zoning in 1988 but so far no proper attention has been given to complete.

4.9.2.7 Building Regulation

This policy has been considered as a major long-term instrument for reducing the adverse effects of flood hazard. It is implemented by using building codes legally to restrict certain types of development in areas of high risk. This can improve existing buildings or replace vulnerable ones gradually by more flood resistant constructions. In the case of new or/and expanding settlements, appropriate building codes must be stipulated. This should however, be helpful to reduce the risk when applied in combination with protective measures and land use zoning.

4.9.2.8 Flood Risk Mapping and Zoning

A flood risk map is a graphical representation of flood characteristics along with the topography (Mitchell 2003; Rahman 2010), while a flood risk map plots the associated potential damages. The prime objective of flood zoning regulations must be maximizing the net-benefits from floodplains, rather than aiming solely at minimizing flood damages (Tariq 2013). In Pakistan, there is lack of flood risk assessment and mapping. Although flood management policies in Pakistan recognize the importance of non-structural measures including land use planning and risk mapping but concrete steps need to be taken for its implementation.

4.10 Flood Risk Management

In Pakistan, flood risk management is carried out with an attempt to mitigate flood hazards. Flood is a complex issue and specifically calls for modern scientific experience on the part of planners. The nature of flood problem varies from province to province due to varying physiographic, climatic, demographic, and socio-economic characteristics (GoP 2012). Even the nature of catchment area varies from each other as discussed below:

In Sindh province, water once overflows the levees does not return back to the main channel. Therefore, inundation causes greater damages to wide areas and persists for a longer time even when flood is over. Moreover, Sindh is situated on a receiving end of drainage of all the rivers and if flood protection measures adopted in the upper reaches are not properly planned, severe damages are likely to occur in the Province (FFC 2012). In most reaches, flood protective embankments have been constructed on both sides of the river from Guddu to few kilometres short of Arabian Sea (FFC 2012).

Baluchistan province have arid to semi-arid climate. Most of the streams have inland drainage basin and very few fall into the Indus river system. Because of such physiographic and climatic characteristics, flash floods dominate in the region. Such floods are very destructive and cause severe damages to life and property. Government has also constructed structural measures to keep water within the channel limit. However looking to the vast undulating surface, it is hard to cater the vast region and mitigate flood with a limited financial resources.

In the province of Khyber Pakhtunkhwa, floods mainly occur in the Kabul, Swat, Panjkora, Chitral and Kurrum rivers. Most often these floods have flash flood characteristics. In addition to this, flash floods also occur in the seasonal hill torrents / nullah and heavy flow generate due to steep slope. In the entire province, riverbank erosion and changing river course are some of alarming issues for the floodplain managers. Due to short preparedness and lack of early warning, such floods cause severe damages. In critical breaching areas, marginal protective embankments and guided head spur have been constructed to mitigate the impacts of flood losses. Similar, the nature and characteristics of floods in Gilgit-Baltistan, FATA and AJK is not different than the province of Khyber Pakhtunkhwa.

The unprecedented increase in the frequency of weather related phenomenon is the direct cause of climate change. The experts co-related the three consecutive disastrous flood events of 2010, 2011 and 2012 with the changing climate consequences. The UN scientific committee on IPCC found that it is very likely that hot extremes, heat waves and heavy precipitation events will further intensify in future. The IPCC also warned that the floods of the kind that hit Pakistan in 2010 may become more frequent and intense in the future in the same region and other parts of the world (GoP 2011). Keeping in view the recent climate change scenario, the Government planning machinery has recently developed a long term Comprehensive Flood Management Plan (2012–2022), where stress has been made proactive approach. The country Flood Forecasting & Warning System will further be upgraded and expended by installation of new Weather Radars and expansion of Flood Telemetry Network Stations. All such efforts would help in flood forecasting and early warning system considerably and minimize future flood damages.

References

Ali A (2013) Indus Basin floods: mechanisms, impacts, and management. Asian Development Bank, 6 ADB Avenue, Mandaluyong City 1550 Metro Manila, Philippines

Douben KJ (2006) Characteristics of river floods and flooding: a global overview, 1985–2003. Irrig Drain 55:9–21

Federal Flood Commission (FFC) (2012) Annual flood report 2010. Government of Pakistan, Ministry of Water and Power, Federal Flood Commission, Islamabad

Government of Pakistan (GoP) (2011) Annual flood report 2010. Government of Pakistan, Ministry of Water and Power, Federal Flood Commission, Islamabad

Government of Pakistan (GoP) (2012) National climate change policy. Ministry of climate change, Government of Pakistan, Islamabad

Government of Pakistan (GoP) (2013) National disaster risk reduction policy-2013. National disaster management authority, Ministry of climate change, Government of Pakistan, Islamabad

Kazi A (2014) A review of the assessment and mitigation of floods in Sindh, Pakistan. Nat Hazards 70(1):839–864

Khan FK (2003) Geography of Pakistan: environment, people and economy. Oxford University Press, Karachi, p 260

Khan FK (2008) Oxford atlas of Pakistan. Oxford University Press, Karachi

Khan B, Iqbal MJ (2013) Forecasting flood risk in the Indus River system using hydrological parameters and its damage assessment. Arab J Geosci 6:4069–4078

Khan AN, Rahman A (2002) An evaluation of flood hazard reduction policies: a case of Kabul-Swat Floodplain, Peshawar Vale. PUTAJ Sci 9(1):1–14

Khan AN, Rahman A (2003) Floods related land disputes and its impact on the socio-economic environment: a case study of Kabul-Swat Floodplain, Peshawar Vale. J Law Soc 29(42):29–42

Khan AN, Rahman A (2005) An assessment of flood hazard causes: a case of Neelum Jhelum Valley, Muzaffarabad, AJK. Pak Geogr Rev 56(1):42–53

Khan B, Iqbal MJ, Yosufzai MAK (2011) Flood risk assessment of River Indus of Pakistan. Arab J Geosci 4:115–122

Mitchell JK (2003) European river floods in a changing world. Risk Anal 23(3):567–574

MunichRe (2010) Extreme weather events – signs of climate change? Geo Risk Research, NatCatSERVICE. http://www.munichre.com/en/media_relations/company_news/default.aspx?foid=2010-08-05. Accessed 24 Aug 2010

Rahman A (2010) Disaster risk management: flood perspective. VDM Verlag Publishing, Saarbrücken, 192 pp. ISBN 978-3-639-29891-8

Rahman A, Khan AN (2011) Analysis of flood causes and associated socio-economic damages in the Hindukush region. Nat Hazards 59(3):1239–1260

Rahman A, Khan AN (2013) Analysis of 2010-flood causes, nature and magnitude in the Khyber Pakhtunkhwa, Pakistan. Nat Hazards 66(2):887–904

Rahman R, Salehin M (2013) Flood risk and reduction approaches in Bangladesh. In: Shaw R, Mallick F, Islam A (eds) Disaster risk reduction approaches in Bangladesh. Springer, Tokyo/New York, pp 65–90

Shah MA, Shakir AS, Masood S (2011) A rude awakening. Report of the Judicial Flood Enquiry Tribunal, 2010. Judicial Enquiry Commission, Lahore

Sheikh MM (2004) Drought management and prevention in Pakistan. Pak Meteorol J 7(3–4):117–131

Smith K (1996) Environmental hazards: assessing risk and reducing disaster, 2nd edn. Routledge, London

Tariq MAUR (2013) Risk-based flood zoning employing expected annual damages: the Chenab River case study. Stoch Environ Res Risk Assess 27:1957–1966

Tariq MAUR, Van-De-Giesen N (2012) Floods and flood management in Pakistan. Phys Chem Earth 47–48:11–20

United Nations Development Programme (UNDP) (2012) Pakistan floods disaster 2010: early recovery. United National Development Programme 4th floor, Serena Office Complex, Islamabad, Pakistan

World Meteorological Organization (WMO) (2004) Integrated flood management: case study from Pakistan: Lai Nullah basin flood problem Islamabad–Rawalpindi Cities. The associated programme on flood management, Technical Support Unit, World Meteorological Organization and Global Water Partnership