Chapter 3
Floods in the Hindu Kush Region: Causes and Socio-Economic Aspects

Atta-ur-Rahman and Rajib Shaw

Abstract This chapter focuses on the causes and socio-economic aspects of floods in the Hindu Kush region. In this chapter a special attempt has been made on the causes and impacts of super flood-2010. Hindu Kush is a high mountain system located in the immediate west of Karakorum and Himalayas. It is the greatest watersheds of Kabul, Swat, Panjkora, Chitral rivers in Pakistan and Afghanistan and Amu River in Central Asia and Afghanistan. There are several peaks acceding heights of 6,500 m a.s.l and therefore, it is a nourishment place of numerous glaciers and glacier milk. Hindu Kush region is vulnerable to frequently occurring hazards of floods, earthquake and landsliding. However, flood is a deadliest and recurrently occurring disaster. It is jointly caused by both physical and human intensifying factors. However, it is further intensified by the impacts of climate change. Nevertheless, the unusual heavy and prolonged rainfall and heavy melting of snow, ice and glaciers have been blamed as a major cause of floods. In the upper reaches, the flash flood characteristics dominate, while in the lower river floods governs the scene. In the upstream areas, flash floods are sudden and more destructive in nature. As a consequence such floods have incurred damages to sources of livelihood earnings, infrastructure and even human casualties. However, the flood-2010 has caused more than 400 fatalities in the Hindu Kush region and therefore considered as the century worst flood.

Keywords Causes • Climate change • Discharge • Flash floods • Hindu Kush • Impacts

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H.K. Nibanupudi, R. Shaw (eds.), *Mountain Hazards and Disaster Risk Reduction*, Disaster Risk Reduction, DOI 10.1007/978-4-431-55242-0_3

3.1 Introduction

Flood is one of the serious natural hazards worldwide (Rahman and Khan 2011). In the past decade, several countries including Bangladesh, China, India, Poland, Germany and Pakistan have been seriously affected by disastrous floods (Dong et al. 2009; Rahman and Khan 2013). In term of economic loss and spatial extent, flood is considered to be the most destructive natural disasters (Changnan 2005; Ali 2007). Linkage of extreme weather phenomenon with climate change is gradually increasing and will further intensify the hydro-meteorological disasters. Pakistan is one of the eleven countries, which are at high risk of hydro-meteorological induces disasters (Shepherd et al. 2013). Globally, the intensity and frequency of flooding events is increasing and expected to further intensify with the impacts of climate change (Rahman and Khan 2013). The IPCC has already warned about the increasing trends of glacier melting in the Himalaya-Karakorum-Hindu Kush (HKH) region and also projected to further accelerate in the future (IPCC 2007). Eventually, it will have serious implications on the runoff.

The Hindu Kush region lies to the north-east of Pakistan (Fig. 3.1). In the Hindu Kush River system, flooding has been a major hazard over the past couple of decades (Rahman and Khan 2013). When episode of flooding occurs, water overflows the channel and spills onto the adjacent floodplains and cause damages to human lives, standing crops, infrastructure and other property. In the Hindu Kush region, both river and flash floods are recurrently occurring natural disasters. Upstream Madyan, River Swat has flash flood characteristics. Similarly, up to Timargara River Panjkora presents typical feature of flash floods. Usually flash flood is caused by thunder and intense rain and often supplement by heavy snow and glacier melting. It mostly occur in the piedmont areas and difficult to forecast for dissemination of early warning and it is more damaging than river flooding.

In the Hindu Kush region, the recent episodes of 1992, 1995, 2001, 2005, 2008, 2010, 2011 and 2012 flood disasters indicate the increasing trend. During 2010-flood event, eastern Hindu Kush was a source region. Due to flash flood characteristics in the upper catchment area of Chitral, Panjkora and Swat valleys, heavy casualties and infrastructural damages have been occurred (Rahman and Khan 2010). It was found from the analysis that 4-day monsoon wet spell (27–30th July) was the major cause of 2010-flood event (Fig. 3.2).

In response, all the weather stations in the Hindu Kush region have recorded rainfall even higher than the monthly average. During this 4-day wet spell, heavy rainfall has been recorded in the Hindu Kush region such as at Saidu (338 mm), Timargara (269 mm), Dir (231 mm), Kalam (175 mm), Drosh (99 mm) and Chitral (60 mm). This anomaly of rainfall has been blamed as a major cause of flash floods in the upper catchment area and river flood in the down-stream areas in the Hindu Kush region. The flood forecasting division has issued much generalized flood

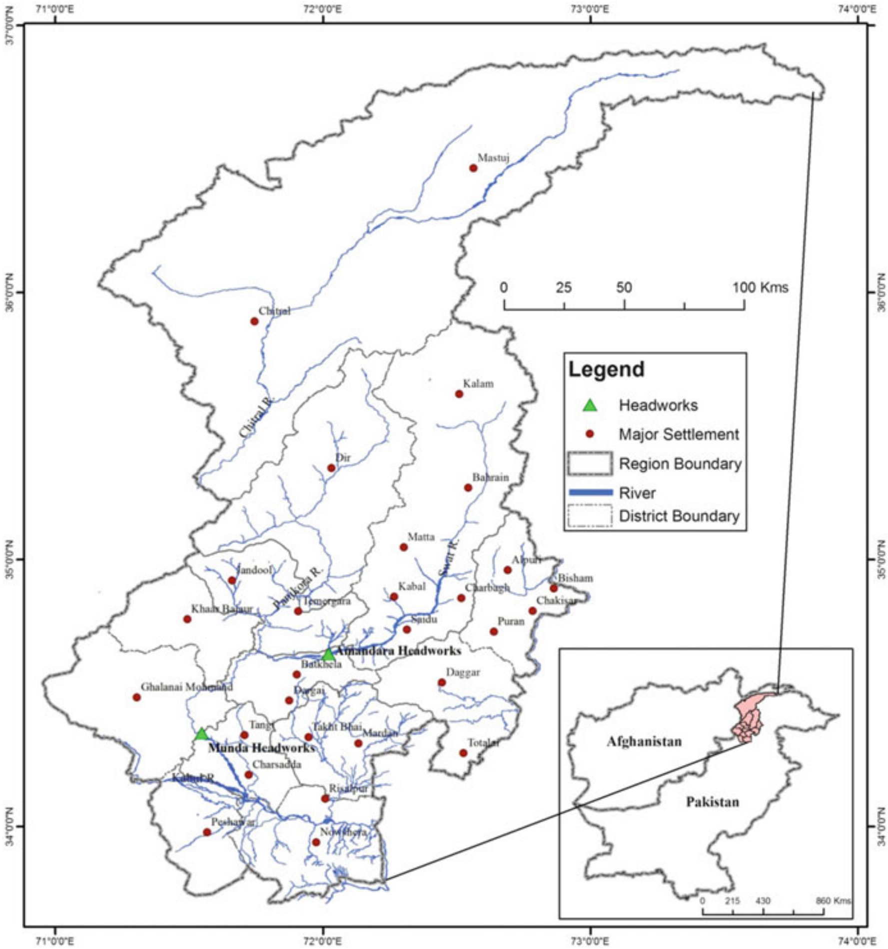

Fig. 3.1 Location of Hindu Kush region showing administrative boundaries and drainage system

warning on 21st June (40 days earlier) that flash flooding could occur from July to September in the northern part of the country. The fact is that the catchment area of Chitral, Kabul, Panjkora and Swat is beyond the reach of existing radar network (Rahman 2010). Therefore quantitative precipitation measure was not possible for the Hindu Kush region. It means that neither proper flood forecasting was undertaken nor early warning was issued to the vulnerable community. As a result, the 2010-flood has broken all the previous records in terms of rainfall, discharge and damages in the Hindu Kush region.

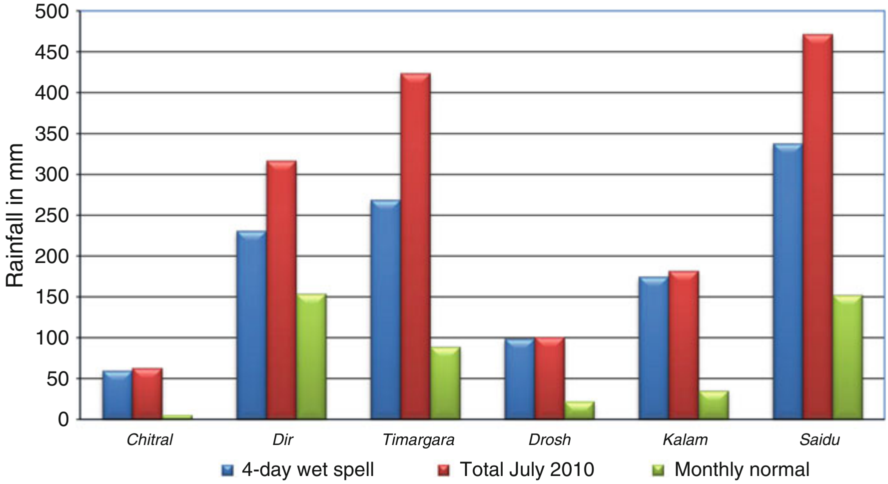

Fig. 3.2 Heavy wet spell in July 2010

3.2 Environmental Profile of Hindu Kush Region

Hindu Kush mountain system lies to the extreme west of great Karakorum and Himalaya ranges. Hindu Kush is a long mountain system of about 700 km and spread over north and north-west Pakistan and northeast and central Afghanistan. The Pakistani section is also called as eastern Hindu Kush. In this chapter focus has been made on the eastern Hindu Kush region. Physically, Hindu Kush mountain range is a rampart between south Asia and central Asia. Whereas Pamir Knot is the junction point of Himalaya-Karakorum-Hindu Kush (HKH) lies in district Chitral, Pakistan and around this spot the borders of Pakistan, China and Afghanistan meet. From Pamir knot, the Hindu Kush runs south-west ward and enters Afghanistan and Pakistan. Further south, Hindu Kush ranges merge with low altitude ranges in west Pakistan and east Afghanistan. Tirich Mir (7,708 m) is the highest point in the Hindu Kush mountain system located in district Chitral, Pakistan. Noshaq (7,000 m) and Istora Nal (7,000 m) are other renowned highest peaks. Generally, elevation of Hindu Kush decreases from north to south-west.

Several ridges extend from Hindu Kush, which forms fertile river valleys. The north-south parallel mountains have beautiful river valleys of Swat, Chitral and Dir. These river valleys support large population. River Swat divides the valley of Swat into two halves and enters into district Dir lower and Malakand. For the eastern Hindu Kush wide variety of data is available but in western Hindu Kush field data is a major limitation. The eastern Hindu Kush falls in Pakistan, while western mainly lies in Afghanistan. In the eastern Hindu Kush, five meteorological stations have been established namely, Chitral, Drosh, Dir, Timargara, Saidu Sharif, Malam Jabba and Kalam. However, long time-series data is available for Chitral, Drosh, Dir and Saidu Sharif. The temperature, rainfall and snowfall data have been used in this chapter. Similarly, there are several gauging stations on river Swat, Panjkora and Chitral, which provided 6-hourly discharge data. However, data pertaining to glacial budget, volume and fluctuation of Hindu Kush glaciers were another limitation. Digital elevation model (DEM) and hydrology network has been prepared from the SRTM image to project the surface feature of Hindu Kush region.

Numerous passes, high peaks, snow clad mountains, waterfalls, alpine meadows, coniferous forest, numerous springs, lakes, network of perennial streams, beautiful valleys and massive glaciers are the landmark features of Hindu Kush region. There are a total of 775 small and massive glaciers, out of which 233 are in the drainage basin of River Swat, which covers 224 km^2 areas (Ives et al. 2010). Similarly, 542 glaciers are located in the drainage basin of River Chitral, which occupied an area of about 1,904 km^2 (Ives et al. 2010). *Chiantar, Terich, Kurambar, Ushu, Utrot* and *Gabral* are some of the massive glaciers. These glaciers are permanent source of water for River Swat and Chitral. The Central Hindu Kush roughly forms a watershed between the Amu River (River Oxus) in the north (western Hindu Kush) and Chitral-Kabul-Swat river systems in the eastern Hindu Kush, north Pakistan. These rivers have deeply cut the Hindu Kush mountain system. All these glaciers are the source of small and large tributaries. The study area is surrounded by large number of peaks with 6,500 m a.s.l (Fig. 3.2). Therefore, it has snow clad mountains which receive precipitation in the form of snow during winter season.

Chitral River is one of the major rivers in the Hindu Kush region. It takes its origin from the *Chiantar* glacier and enters into Afghanistan at *Arandu*, where it is named as Kunar river and thence it confluence with Kabul river at Jalalabad (Afghanistan) and finally enters into Peshawar valley-Pakistan. Similarly, River Swat is another notable tributary taking its origin from the *Ushu*, *Utrot* and *Gabral* glaciers located in the Dir-Swat-Kohistan section of Hindu Kush region. Similarly, several gauging stations have been constructed on river Swat. Approximately 70 km upstream Munda head works and about 30 km down-stream Amandara headwork's, River Swat receive a major right hand tributary of River Panjkora. It takes its origin from upper Dir-Swat section of the Hindu Kush region. Panjkora is a Persian word where 'Panj' means 'five' and 'Kora' means 'rivers'. Throughout its course Panjkora receive five major tributaries and ultimately confluence with River Swat. Down-stream this confluence point, Munda Headwork's has been constructed to regulate water for irrigation purpose. Two canals have been taken-out for irrigation purpose from river Swat i.e. Upper Swat canal which irrigate large part of district Mardan whereas Lower Swat Canal irrigate section of district Charsadda.

In the Hindu Kush region, four seasons can be distinguished; winter is a long cold season, which extends from November and continue till March. This is the humid period when the higher elevations receive precipitation in the form of snow and the soil is under frozen condition; winter is followed by short spring season, which usually starts from mid-March and continue till the end of April; summer season is long and starts from May and continue up to mid-September. It is warm at higher altitude and hot at valleys and low lying areas; autumn is comparatively a short season and extends from September to October.

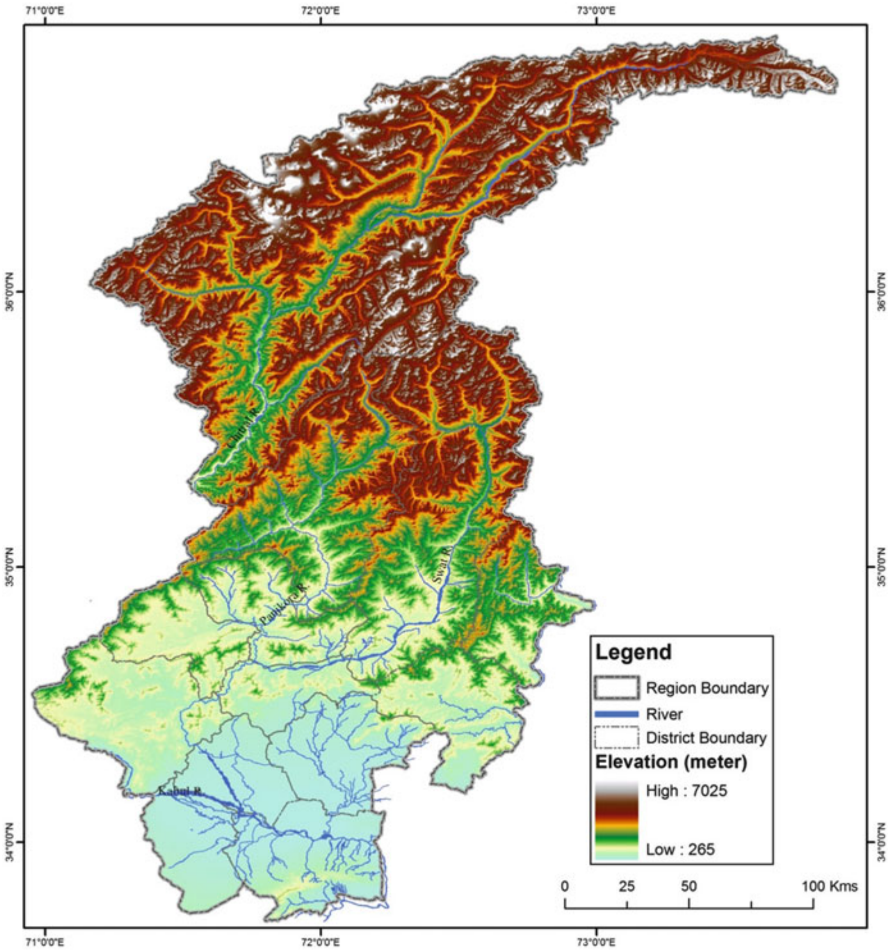

Fig. 3.3 Digital Terrain and drainage in Hindu Kush region

Administratively, the eastern Hindu Kush comprised of districts of Chitral, Dir Upper, Dir Lower, Swat, Shangla, Buner and Malakand. According to population statistics of Khyber Pakhtunkhwa 2009, out of total 25 districts, 25.30 % (6.05 million) of the province population is living in seven districts that falls in the eastern Hindu Kush. District Swat is the most populous district with a population of 1.8 million followed by Dir Lower (1.0 million) and least populous are Buner with a population of 0.417 million, Shangla 0.616 million and Malakand 0.647 million. In the eastern Hindu Kush, the literacy ratio is lower (28 %) than the provincial average (37 %). District-wise analysis indicates that district Chitral (40.30 %) and Malakand (39.59 %) have high literacy ratio as against Buner (22.60 %), Dir Upper (21.21 %) and Shangla (14.70 %). Nevertheless, the literacy is high among males (44 %) than the female (13 %).

The higher elevation of Hindu Kush has alpine meadows and pastures (Fig. 3.3). At several patches these meadows and pastures are used by the local population for livestock grazing during summer season. At higher elevations, the phenomenon of transhumance is regularly practiced, which is a seasonal movement of people with their livestock for a fix time in summer to use the high altitude pastures. In the Hindu Kush region, vegetation cover plays a significant role in the economy and contribution to soil conservation, minimizing siltation, regulate runoff and maintain ecological balance (Rahman and Khan 2013). Due to large variations in the physiography, climate, the vegetation cover ranges from alpine and coniferous forest to sub-tropical vegetation in the low lying areas. Below alpine meadows, there is a belt of alpine forest followed by coniferous forests. Pine, poplar, oak, willow and olive are the common tree species found in the region. There are some patches with thick forest cover, whereas in certain area sparse or no shaved area is also reported. This has been cleared either for agriculture or built-up area. In the past three decades, there has been a gradual decrease in the area under forest (Rahman and Khan 2013).

3.3 Causes of Floods in the Hindu Kush Region

Generally, floods are caused by variety of factors (Fendler 2008). However, excessive rainfall has been the cause of many flood events (Hunter et al. 2005; Ali 2007). Besides rainfall, heavy melting of snow, ice and glacier are supplementary causes of flood (Gupta and Sah 2008). Some time, floods are also intensified by numerous human factors such as human encroachments onto the channel limits, change in land use and deforestation (Rahman and Khan 2013).

Like rest of the flood prone regions, Hindu Kush is also vulnerable to frequent flood disasters due to its physiography and climate. The eastern Hindu Kush receives plenty of precipitation in winter, spring and summer. The amount of annual rainfall varies from station to station, however Dir is a humid station (1,400 mm) followed by Saidu (1,060 mm), Drosh (575 mm) and Chitral (471 mm). In the study area, the source of rainfall is western depression in winter/ spring and monsoon in summer. Therefore the western met stations (Chitral and Drosh) receive more rain from western depression and eastern stations (Dir, Timargara, Kalam, Malam Jabba and Saidu) from monsoon. In fact, this is the headwater region of numerous streams and rivers that enters into Pakistan. Generally, the summer monsoon rain is supplemented by heavy melting of snow, ice and glaciers (Rahman 2010). Eventually, the river discharge rises in summer and cause massive flash floods in the highland and river floods in the downstream areas. The evidence of flood causes reveals that in the Hindu Kush region, the role of physical factors dominant over the human ones. In literature, while assessing the causes of flood events, focus has been made on mere the role of temperature and precipitation. However, in this chapter attempt has been made on analyzing multi-parameters to explore the causes of floods in the Hindu Kush region.

3.3.1 Temperature and Floods

According to Inter-government Panel for Climate Change Assessment Report 5, the global surface temperature has increased since the late nineteenth century (IPCC 2014). Several studies also confirmed that the land surface temperature has also increased. Instrumental records show that the past three decades was warmer than the earlier decades. It has been estimated that in the atmosphere, warm temperature can hold more water vapor and thus intensify the water cycle, which as a result enhances the risk of floods (Rahman and Khan 2013).

At Chitral met station June, July and August are the hottest months, where maximum temperature reaches 37 °C. Contrary to this, December, January and February are the cold months and temperature usually falls below zero Celsius. At Drosh, June, July, August and even September are the hottest months and sometimes maximum temperature reaches at 39 °C. However, winter is colder than the Chitral. Dir is comparatively a cold station, where December, January and February are the coldest months, where minimum temperature falls as low as −3 °C. Similarly, June, July and August are the warmest months and some time the maximum temperature reaches 34 °C. As far as Saidu met station is concerned, June, July, August and September are the hottest months with maximum temperature of 38 °C. December, January and February are the cold months and it is only in January and December, the temperature falls below freezing only in December and January. Historical record shows that in the Hindu Kush region, high temperature remained a major driving force behind the increasing glacier and snowmelt that resulted high summer discharge.

3.3.2 Anomaly of Rainfall and Floods

With rising temperature, the saturation of water vapor in air also enhances. It has been estimated that there is 3.5 % increase in the specific humidity with a consistent increase of 0.5 °C surface temperature during the past 40 years. In the Hindu Kush mountain system, the climate is largely controlled by the altitude. During winter and spring, it is largely influenced by the westerly disturbances originating from the Mediterranean, Black and Caspian Sea, whereas during summer season the study area is influenced by monsoon originating from the Bay of Bengal. For this study, long-term data of four weather stations have been used namely Chitral, Drosh, Dir and Saidu. All these stations are located at different altitudinal and latitudinal position. In the Hindu Kush region, Chitral is a weather station located at latitude 35°51′N, longitude 71°50′E and altitude 1,497.8 m a.s.l.

At Chitral, the average annual rainfall (1981–2011) is 471 mm mainly received during spring and winter season (Fig. 3.4a). March is the humid month with average rainfall of 109 mm, whereas June and July are comparative dry months. Drosh is another station in district Chitral. It is located at an altitude of 1,464 m a.s.l and the

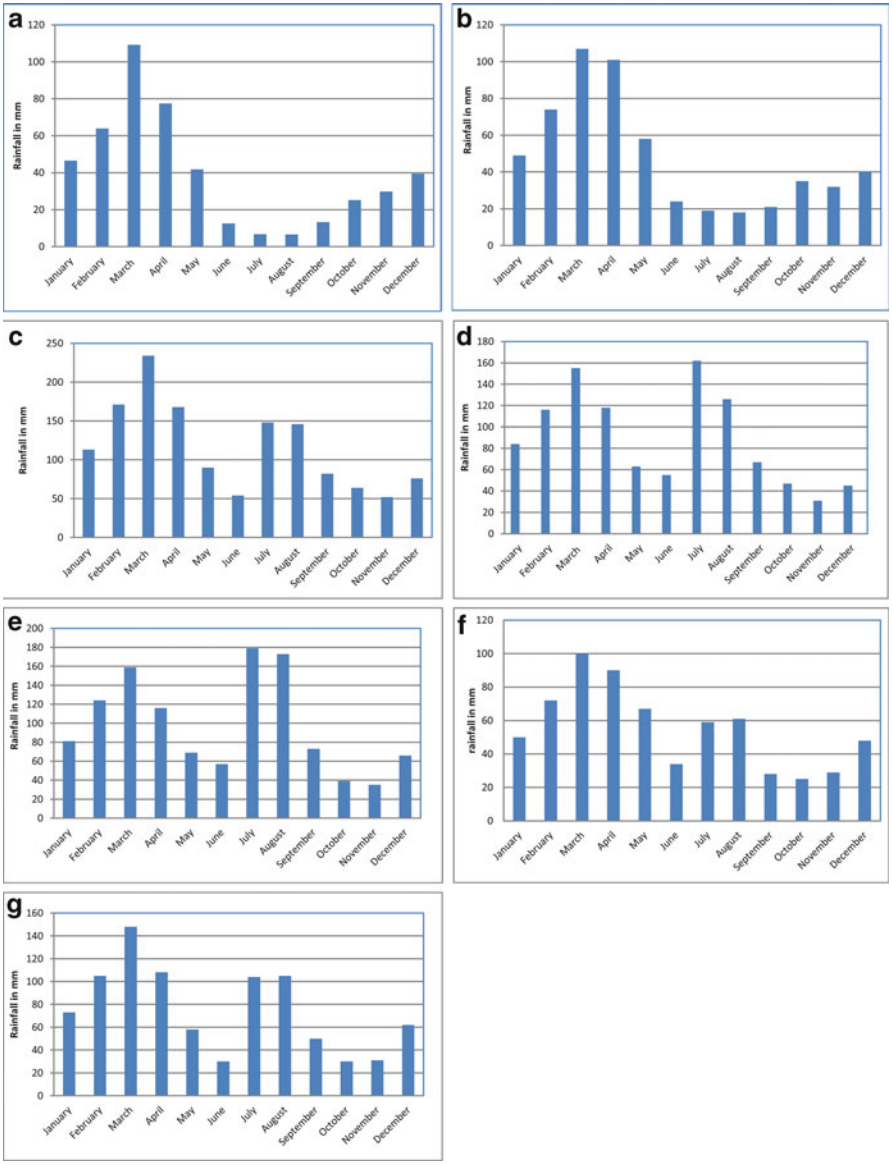

Fig. 3.4 (**a**) Average monthly rainfall at Chitral, 1981–2011, (**b**) Average monthly rainfall at Drosh, 1950–2011, (**c**) Average monthly rainfall at Dir, 1967–2011, (**d**) Average monthly rainfall at Saidu, 1974–2011, (**e**) Malam Jabba average monthly rainfall, (**f**) Average monthly rainfall at Kalam, (**g**) Average monthly rainfall at Timargara

absolute position is 35°34′N and 71°47′E. At Drosh, the average annual rainfall (1981–2011) is 575 mm mainly received during spring and winter season. Almost every month receive rainfall. February, March and April are the humid months with average monthly rainfall of 74, 107, and 101 mm, respectively (Fig. 3.4b).

In district Dir Upper, Dir is one of the important weather stations for which long-time series data is available. The geometric position is 35°12′N and 71°51′E, whereas the altitudinal location is 1,375 m a.s.l. Dir receives on average 1,400 mm per annum. The data (1967–2011) indicate that there is no month, which receive less than 50 mm rain (Fig. 3.4c). As compared to Chitral and Drosh, it is a humid station and receives precipitation both from monsoon and western depression. March is humid month and during winter the high altitude receives precipitation in the form of snow which later on in summer becomes part of the river runoff.

Saidu is a low altitude weather station in district Swat. The latitudinal position of Saidu station is 34°44′E, 72°21′N and altitudinal location is 961 m. The average annual rainfall (1974–2011) is 1,060 mm, mainly received during summer monsoon and spring (Fig. 3.4d). Almost every month receive rainfall. July and August are the summer humid months, whereas March and April are the spring rainy months. In district Swat, Kalam and Malam Jabba are the hilly met stations located in the north and south of Saidu, respectively. They are the humid stations and on average receive 1,131 mm (Kalam) and 1,316 mm (Malam Jabba), annually (Fig. 3.4e, f). Timargara weather station is located in the central part of district Dir Lower. It on average receives 865 mm rainfall, annually (Fig. 3.4g).

In the Hindu Kush region, every month receive certain amount of precipitation. In all the four met stations, winter and spring is humid and the high altitudes receive precipitation in the form of snow. It is because of this long cold humid condition, it hosts 775 glaciers. The analysis reveals that in all the four met stations heavy precipitation occur during January, February and March. However, Saidu receive comparative more rainfall during July and August (Monsoon period) because of its closeness to the monsoon source. It is during winter, that the higher elevations receive precipitation in the form of snow and its melting starts in April and reach to its climax during June, July and August. This snowmelt water is one of the contributions to river runoff. In addition to this, because of high summer temperature the melting of glaciers also increases. Hence, the glacier melt-water is another contributing factor which accelerates river discharge. However, heavy precipitation during summer monsoon has been considered as a major contributing factor of flash and river floods in the Hindu Kush region. It was also hypothesised that in summer heavy melting of snow, ice and glacier together with the monsoon rain led to heavy flood disasters in the Hindu Kush region.

3.3.3 Snow Melting and Runoff

Snow melting has the potential to accelerate the river runoff. In the Hindu Kush region, Dir, Kalam and Malam Jabba are relatively cold stations and receive precipitation in the form of snow during winter season and provide soil moisture in spring. However in summer, snowmelt feed the streams and eventually increases the river runoff. In district Swat, Saidu is a low altitude weather station, whereas Kalam and Malam Jabba are the hilly stations. Therefore, Kalam and Malam Jabba receive snowfall every year. According to Pakistan meteorology department, at Kalam 358 in. snowfall was recorded in 2005, 252 in. in 2006, 127 in 2007, 258 in 2008, 290 in 2009, 48 in 2011 and 72 in. in 2013. Similarly, at Malam Jabba 283 in. snowfall was registered in 2005, 231 in. in 2006, 255 in 2007, 164 in 2008, 48 in 2011 and 120 in. in 2013. As far as Dir station is concerned, 2 in. snowfall was recorded in 2005, 40 in. in 2006, 23 in 2008, 9 in 2009 and 12 in. in 2013. In the Hindu Kush region, usually snow melting starts in April and continue till end of the summer. However, high summer temperature further increases snow melting and provides enormous amount of water to the river system. In summer, the snow melt water join hand with monsoonal rainfall-runoff and in return cause heavy floods as in case of 2010-floods. In the year 2010, heavy snowfall was recorded in January and February at Malam Jabba, Kalam and Dir met stations. This significant amount of snow accumulation in winter was followed by high temperature in summer, which has accelerated the snow melting and contributed much to the increasing intensity and magnitude of 2010-flood (Rahman and Khan 2013).

3.3.4 Glaciers and River Runoff

Globally with few exceptions, there is continuous retreat of glacial budget in terms of length, area, mass and volume (IPCC 2014). Spaced based assessment of glaciers fluctuations in the Himalayas and Hindu Raj indicates that there is large variation in movement because of slope angle, regional temperature, precipitation and ice-flow (Sarikaya et al. 2013). Various studies indicates that Himalaya-Karakoram-Hindu Kush glaciers in north Pakistan are gaining mass (Hewitt 2005; Bishop et al. 2008), whereas other glaciers are losing mass (Bolch et al. 2012; Sarikaya et al. 2013). Since the current glacier ablations are out of balance and will continue to lose its mass. It has been estimated that during the past decade majority of the glaciers have lost most of their surface ice budget. Glacier melting is directly proportional to the temperature and therefore in summer melting of glaciers increases. Glacier stores water during wet and cold period and during warmer part of the year significant increase in melting occurs, which become part of the runoff. One of the typical characteristic of valley glacier is the consistent melting and perennial supply of water. In the Hindu Kush region, glaciers have substantial impacts on river discharge (Rahman and Khan 2013). The melting of Hindu Kush glaciers accelerate during summer season and decreases in winter. During summer, glacier-melt provide ample amount of water to river runoff, which eventually added to the heavy monsoon wet spells and contribute to the peak discharge.

3.3.5 Forest Cover and Runoff

According to Government of Pakistan, 4.9 % of the total area is under forest, out of which one-third lies in the province of Khyber Pakhtunkhwa (Rahman and Khan 2011). Most of these forests are reported from the high altitudes of Hindu Kush and Himalayas. Contrary to this, the State of the World forest report 2011 indicated that in Pakistan forest cover is mere 2 % and diminishing at an alarming pace (Qamer et al. 2012). In the Hindu Kush region, deforestation and degradation of natural resource base need serious attention of policy makers because large section of the population directly and indirectly depends on these natural resources for their livelihood (Qamer et al. 2012). Likewise, vegetation cover plays a major role in reducing the impacts of flood disasters, while deforestation has negative co-relation. In the study area, rapid deforestation and overgrazing in the catchment area have seriously affected the fluvial processes of almost all the river systems (Ali 2007; Rahman 2010; Rahman and Khan 2013).

During the past decade (2000–2010), it is estimated by the FAO that forest is ruthlessly degraded and hence there is close link between deforestation and 2010 havoc floods. The field survey and discussion with the elder community members revealed that major factors behind the deforestation is the supply of fuel wood, increasing population pressure on the fragile slopes, clearing of forest for agricultural land and supply of timber to the market for the sake of accomplishing the desires of the growing population (Rahman and Khan 2013). Some researchers are of the opinion that in the Hindu Kush region forest cover is decreasing at the cost of expansion in the farmland and physical infrastructure (Qamer et al. 2012). There are several cases, where the forest cover has been replaced by the built-up area. This has further accelerated the problem of soil erosion in the fragile watersheds. The analysis reveals that watershed management through forestation, control overgrazing and soil conservation are the key strategies to reduce high flood runoff and resultant damages in the Hindu Kush region.

3.3.6 Population Pressure and Floods

In the Hindu Kush region, population is growing at a faster rate than the national average. It is low in district Chitral (2.52 % per year) and maximum in Buner (3.86 %). As a result, the population density on a squire kilometer has been increased in the past 10 years (1998–2008) from 269 to 386. Some districts are densely populated such as district Malakand (680), Dir Lower (652), Buner (409)

Fig. 3.5 Swat valley, human encroachment onto the active flood channel

and Shangla (388). Because of this terrific increase in the population, it has put tremendous pressure on the scarce resources such as forest, water, pastures and land resources.

As the population grows the demand for food, shelter and other infrastructure also increases. In the Hindu Kush region, the poor section of the society has no choice but to purchase a low cost vulnerable land in the active floodplains. There is lack of land use regulation and enforcement. As a result the people are constantly encroaching onto the flood channel for agriculture, housing and other infrastructure development (Fig. 3.5). This in effect has reduced the channel wetted perimeter and reduced the rivers carrying capacity and in turn increased the river runoff. This human intervention has been observed throughout the active flood channels in the Hindu Kush region. During the event of 2010-flood, the human encroachment onto the floodplain has contributed much in intensifying the flood characteristics. It was particularly found true when assessed during field survey at Swat, Dir Upper, Dir Lower and Malakand.

3.3.7 Climate Change and Floods

The impact of climate change on hydro-meteorological disasters is much significant (Huss et al. 2008). This will lead to massive retreat of high mountain glaciers and would further accelerate the river runoff (IPCC 2007). Such changes are intensifying day-by-day and would have tremendous impact on the local, regional and global level environment. Eventually, the anticipated significant impact is the reduction in water resources in the glacial-fed valleys and its serious implications on the socio-economic condition of inhabitants (Hagg et al. 2007). The Hindu Kush region has no exception to it. With changing climate phenomenon, the distribution of rainfall, snowfall and temperature also intensified. Now-a-days, more intense rainfall occurs in short time and increases the runoff. Similarly, the snowfall distribution also changed due to climatic variability. Likewise, the global warming has also put tremendous pressure on the glacier melting which as a result increased river runoff. As river Swat and Chitral are mostly fed by the glacier melt and contributing much to the flood occurrence.

3.3.8 River Siltation and Floods

In the Hindu Kush region, river siltation is a challenge for the flood mangers (Rahman and Khan 2011). Nevertheless, the pace of siltation is quite high for the rivers originating from the Hindu Kush region (Khan 2003). It was confirmed during 2010-flood, when flashes water overflew the levees and deposited heavy load up to a maximum thickness of 2 m wherever it passed on including river beds, agriculture land, irrigation channels, roads and even in the houses. This significant siltation has aggraded the rivers and as a result reduced the river carrying capacity. This is partly attributed to the consistent deforestation in the upper catchment area of all the rivers. If there had been a good forest cover in the catchment areas, the impact of 2010 flood would have been much less (Rahman and Khan 2013).

3.3.9 Flood Level and Gauging Stations

In the eastern Hindu Kush region, several gauging stations were constructed during the British regime such as Nowshera, Amandara, Munda and Warsak. In the headwater region of river Swat, only long-term data is available for Munda and Amandara headwork's. Amandara is located close to Batkhela, district Malakand and a few kilometer down-stream Chakdara bridge. Downstream Amandara, river Swat receives river Panjkora, a major right-hand tributary dissecting the districts of Dir Upper and Dir Lower. After receiving river Panjkora, the river Swat then flows for almost 28 km until reaches Munda headwork's. In the Hindu Kush region, River Panjkora is notorious for devastating flash floods. Therefore, recently Government has established gauging station at Timergara to record the discharge and closely monitor the runoff fluctuations.

Kabul is the major river in the area. Before receiving a main tributary of river Swat, Warsak gauging station has been built on river Kabul, while receiving a left hand tributary of river Swat, the Nowshera gauging station has been constructed. Similarly, discharge data for the past 80 years of all the four stations has been obtained from the surface water hydrology wing, WAPDA house Lahore. At Warsak, a multi-purpose dam has been constructed on Kabul river, while on Swat river a Munda headwork's is constructed for irrigation purpose. These two water reservoirs work for the storage as well as diverting the access water for irrigation. However, Warsak dam has lost its carrying capacity due to sedimentation. Therefore, during heavy discharge it cannot accommodate enough water to protect the underlying areas from the flood effects.

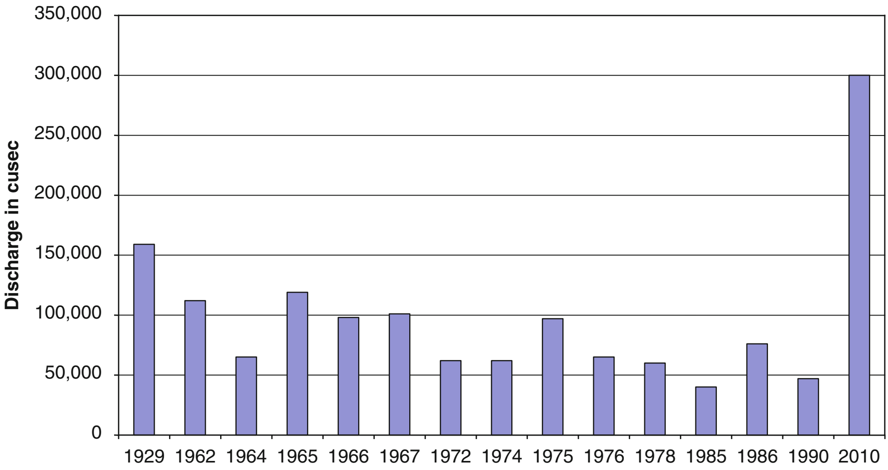

Fig. 3.6 Swat River, Highest recorded discharge at Munda, 1929–2010

In 1929, at Munda headwork's, a maximum of 170,000 cusec discharge was recorded, while in 2010, a record breaking discharge of 367,000 cusec was registered (Fig. 3.6). Eventually, it washed away Munda headwork's as it was designed for a mere 175,000 cusec. After reconstruction, the capacity was further enhanced to 275,000 cusecs. Similarly, at Amandara the peak runoff was recorded in 1929, 1983, 1992, 1995, 2001 and 2010 (Fig. 3.7). Nevertheless, at Amandara headwork's during 1929 (160,000 cusecs), August 1992 (126,709 cusec) and July 1995 (128,192 cusec) maximum discharge have been recorded. However, the 2010-flood has broken all the previous records and even destroyed Amandara headwork's. In July 2010, the discharge at Amandara exceeded 295,000 cusec (PDMA 2012; Rahman and Khan 2013).

In the Hindu Kush region, every month receive certain amount of precipitation. In all the four met stations, winter and spring is humid and the high altitudes receive precipitation in the form of snow. It is because of this long cold humid condition, it hosts 775 glaciers. The analysis reveals that in all the four met stations heavy precipitation occur during January, February and March. However, Saidu receive comparative more rainfall during July and August (Monsoon period) because of its closeness to the monsoon source. It is during winter, that the higher elevations receive precipitation in the form of snow and its melting starts in April and reach to its climax during June, July and August. This snowmelt water is one of the contributions to river runoff (Fig. 3.8). In addition to this, because of high summer temperature the melting of glaciers also increases. Hence, the glacier melt-water is another contributing factor which accelerates river discharge. However, heavy precipitation during summer monsoon has been considered as a major contributing factor of flash and river floods in the Hindu Kush region (Fig. 3.8). It was also hypothesised that in summer heavy melting of snow, ice and glacier together with

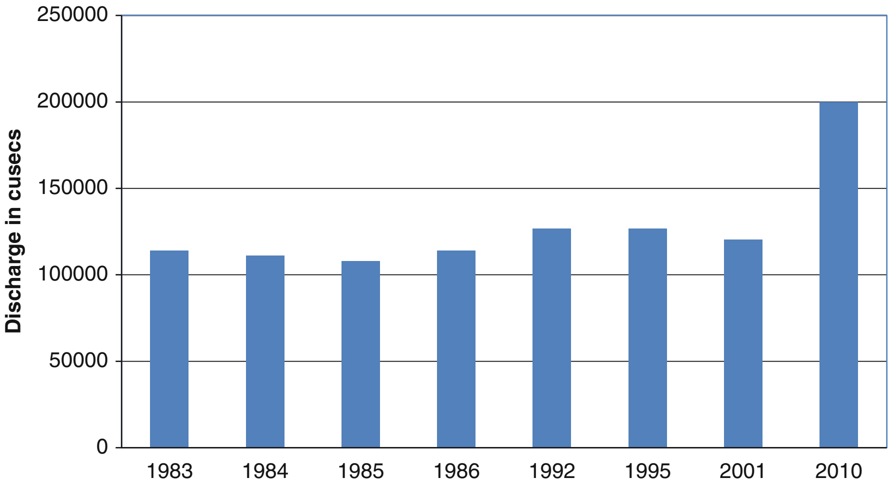

Fig. 3.7 Highest recorded discharge of river Swat at Amandara, 1983–2010

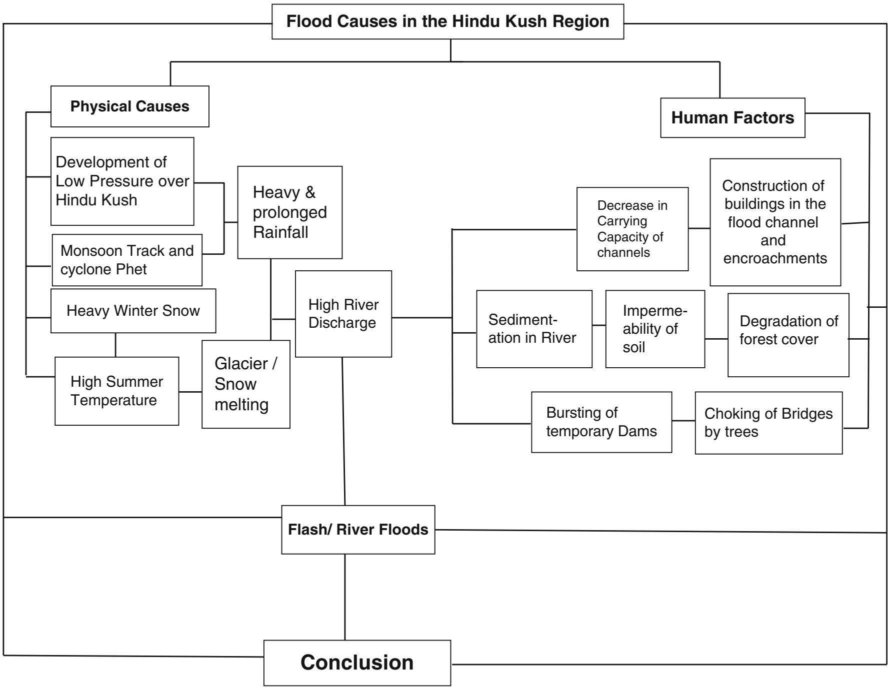

Fig. 3.8 Conceptual framework of flood causes in the Hindu Kush region

the monsoon rain led to heavy flood disasters in the Hindu Kush region. Figure 3.8 shows detail conceptual framework of flood causes in the Hindu Kush Region.

In the past, the tendency of heavy discharge of river Swat to some extent varied from that of river Panjkora. However, in 2010 there was heavy discharge in both the river system that is why the highest discharge was recorded at Munda. The reason of heavy casualties during 2010-flood is mainly due to the continuous 4-day wet spell over the eastern Hindu Kush and in effect all the tributaries flooded at the same time. In future, if the rainfall distribution over the headwater region of both the rivers repeated, once again it would have serious implications on the Hindu Kush region (Fig. 3.8).

3.4 Socio-Economic Aspects of Floods

In the Hindu Kush region, both river and flash floods are most frequently occurring hazards. Consequently, it undercuts foundations, vanish buildings, erode top soil, change course of rivers, damage bridges, destroy irrigation systems, uproot standing crops and cause both human and livestock casualties.

In the Hindu Kush region, almost every year flood has caused damages to people and their properties. However, the impact of 2010-flood is very damaging one. According to provincial disaster management authority (PDMA) of Khyber Pakhtunkhwa, during 2010-flood more than 1,015 precious human lives were lost, out which 427 is reported from the Hindu Kush region (Table 3.1). District-wise data reveal that maximum number of death casualties is reported from Shangla (162) followed by Swat (95), Dir Upper (77), Dir Lower (35), Chitral (21), Buner (19) and Malakand (18). Almost equal number of people was seriously injuries in the study region.

In the study area, a total of 22,143 houses were completely damaged during 2010-flood, out of which 14,463 in district Swat, 3,498 in district Shangla, 1,751 in Buner and 1,086 in Malakand. It means that the situation was quite worse in district Swat than rest of the districts. However, the affected households were more than the number of damaged houses. The affected households were more than 90,000 in district Swat, 30,071 in Dir Upper, 25,812 in Dir Lower, 11,950 in Shangla and 9,881 in Chitral. The impact of flood damages on housing is quite high. Primarily they were mostly settled in close proximity to the river bank and secondly built in the low lying areas. Thirdly, the structural measure carried out without proper planning rather they were made through ill basement and improper site selection. Finally, the building material was less resistant to flooding.

Besides this, during 2010-flood event in the Hindu Kush region a total of about 417 shops were also damaged with available goods. Similarly, 220 bridges were also washed away by the 2010-flood and the entire region was cut-off for several days from rest of the country. In addition to this, 186 schools and 83 health centers were also collapsed. In the Hindu Kush region, scarce agriculture land is also available, which to some extent fulfill the food requirements and support the

Table 3.1 Hindu Kush region, district-wise 2010-flood damages

District	Dead	Household affected	Houses damaged	Shops	Bridges	Education facilities	Health facilities	Cattle	Crops (acres)
Swat	95	90,665	14,463	161	21	69	13	–	34,470
Dir Lower	35	25,812	260	–	16	1	–	–	–
Malakand	18	6,441	1,086	224	7	17	48	2	35,000
Shangla	162	11,950	3,498	–	30	51	5	20	–
Buner	19	802	1,751	15	3	8	3	227	3,675
Dir Upper	77	30,071	655	–	104	40	14	2,720	25,000
Chitral	21	9,881	430	17	39	–	–	180	150
Hindu Kush region	427	175,622	22,143	417	220	186	83	3,149	98,295
Provincial Total	1,015	545,739	178,484	500	282	629	139	8,438	466,626

"–" Data not available. *Source*: Provincial Disaster Management Authority, Peshawar growing population. During 2010-flood events, approximately 100,000 acres standing crops were damaged in the Hindu Kush region with millions of dollar loss to the economy. Similarly, approximately 3,149 cattle were also perished due to the flooding event, out of which 2,720 is reported from district Dir Upper.

In the study area, the flood water entered into plain areas, spread-up and has caused serious damages. According to respondents, in the initial phase of 2010-flood disaster, the boats, motor-boat, vehicle tubes were used in search and rescuing people and their small movable properties. However, in the later stage of this massive flood disaster, the army personnel were also deployed to evacuate population. However, due to its sudden nature and flash flood characteristics, hundreds of human lives were lost and injured. The magnitude and scale of this severe 2010-flood was so destructive that according to field survey, none of the respondents experienced flood of this nature and magnitude in their lifetime (Rahman and Khan 2013). The 2010-flood is also called as a century worst flood both in terms of nature and magnitude.

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