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Extent of 2014 Flood Damages in Chenab Basin Upper Indus Plain

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Abstract

This chapter analyzes the extent of flood damages in the Chenab basin upper Indus plain. The upper Indus plain is a fertile area and supports millions of human population and diverse economic activities. Every year in summer, the combined action of monsoon rain water and meltwater (melting of snow and glaciers) augment rivers discharge leading to damaging flood. The study region is prone to floods. The upstream areas of Chenab basin are mountainous and experiences characteristics of flash floods, whereas riverine floods dominate the lower reach. In wake of observed climate change, there is a rising trend in temperature, which indicates the early and rapid melting of snow and glaciers in the catchment areas. The analysis reveals that the spatial and temporal scales of violent weather events have also been grown during the past three decades. The substantial increase in heavy precipitation events and rapid melting of snow in the headwater region, siltation in river channels, human encroachments on the active flood plain and bursting of embankments have further escalated the flooding events. Analysis further reveals that in the study region, almost every year, the floodwater overflows the levees and cause damages to standing crops, infrastructure and sources of livelihood, and incurs human casualties.

Keywords: flood, Chenab basin, damages, Indus plain

1. Introduction

Flood is destructive hydrometeorological hazard causing damages to life, infrastructure, and services [1–3]. Globally, flood disaster claims over 20,000 human lives and reflective property loss annually [4]. Various natural and anthropogenic factors generate riverine floods [5, 6]. The catchment characteristics including vegetation cover, shallow soil and

steep slope, and high intensity rainfall generate sharp peaks in short span of time which results in flood in the low-lying areas [7, 8]. Similarly, in the current scenario of climate change, the frequency and intensity of violent weather events and floods might become more prevalent. This has further increased vulnerability of the communities spatially distributed in the proximity of rivers [9].

Pakistan is exposed to devastating natural hazards including floods, earthquake, landslides, and droughts because of diverse topography and climatic conditions [10]. Floods have been common and disastrous in Pakistan [11]. Rainfall in monsoon period and melting of snow/glaciers in northern Pakistan are flood generating factors [12]. Monsoon is the major source of summer rainfall which contributes 50–75% of the total rainfall [13]. Monsoon season temporally extends from June to September in South Asia, but it brings more rain during July and August which results in disastrous floods [14]. Pakistan has faced flood events of various magnitude since 1950 but the catastrophic were in 1988, 1992, 2010, and 2014 [15]. The hydro-meteorological conditions, geography, and lack of standard structural measures in the Indus watershed are the main factors of flood genesis [16]. In 2010, Pakistan was hit century worst flood and anthropogenic activities in the fertile Indus plain further intensified its damaging nature. This destructive nature of flood has damaged buildings, infrastructure, and agricultural activities with huge economic loss [14]. About 1900 people died, affecting more than 20% of the total area and more than 14 million people with economic losses of tens of billions US\$. The spatial extent, depth, duration, and direct effect of flood were variable because of the spatial diversity in relief features and landforms, human land uses, population density, and anthropogenic activities. This was the most calamitous flood in Pakistan's flood history [15]. Similarly, high flood in river Chenab and Jhelum has been observed in September 2014 in which Chenab has attained peak of 0.45 million m³/s [16]. The purpose of this study is finding the extent of 2014 flood damages in Chenab basin.

In Pakistan, flood is one of the devastating natural hazards causing damages to lives, properties, agriculture, and infrastructure [15]. So far, 23 major flood events have been hit the country since its inception with disastrous consequences (**Table 1**). In September 2014, a heavy late monsoon wet spell further increased water discharge in the eastern tributaries of Indus river particularly Chenab river and generated an unprecedented flood in Azad Jammu & Kashmir (AJ&K) and Punjab both in terms of discharge and spatial extent. This flood damaged standing crops, physical infrastructure, and human settlements. As consequence, the national economy was affected adversely in direct and indirect ways [17]. The total human life losses were 368, affected population was above 2 million, and more than 120 thousands houses have been damaged partially or completely.

Agriculture sector was also severely affected by this flood by affecting over 4000 km² of arable land and 250 thousands farmers. The standing crops were damaged with an estimated recovery cost of 440 million US\$ [19].

Geographically, the study area extends from 73°43'40.8"E to 74°57'3.6"E longitude and 30°36'7.2"N to 32°49'40.8"N latitude (**Figure 1**). Administratively, the study area encompasses the districts of Sailkot, Gujrat, Jhang, Hafizabad, Mandibahudin, Sargodha and Gujranwala from Head Marala to Head Trimum along Chenab river. Chenab river is the main eastern

Sr. no.	Year	Life losses	Affected villages	Affected area
1	1950	2190	10,000	17,920
2	1955	679	6945	20,480
3	1956	160	11,609	74,406
4	1957	83	4498	16,003
5	1959	88	3902	10,424
6	1973	474	9719	41,472
7	1975	126	8628	34,931
8	1976	425	18,390	81,920
9	1977	848	2185	4657
10	1978	393	9199	30,597
11	1981	82	2071	4191
12	1983	39	643	1882
13	1984	42	251	1093
14	1988	508	100	6144
15	1992	1008	13,208	38,758
16	1994	431	1622	5568
17	1995	591	6825	16,686
18	2010	1985	17,553	160,000
19	2011	516	38,700	27,581
20	2012	571	14,159	4746
21	2013	333	8297	4483
22	2014	368	4065	9779
23	2015	238	4634	2877
Total		12,178	197,203	616,598

Source: [18].

Table 1. Major floods in Pakistan.

tributary of Indus river draining the basin [20]. In Pakistan, the total length of Chenab river is 274 km with catchment area of 41,656 km². It enters Pakistan at Marala Headwork. The annual average discharge of the river is 1.52 million m³.

Climatically, the study region is located in the monsoon region. The amount of winter rainfall is low, where in summer rainfall is maximum (**Figure 2**). From May onward, the amount of rainfall increases, and July-August receives the highest rainfall from monsoon, and then from September onward, the rainfall decreases. The temperature conditions are also variable across the year. December and January are the months with lowest temperature 21 and 16°C,

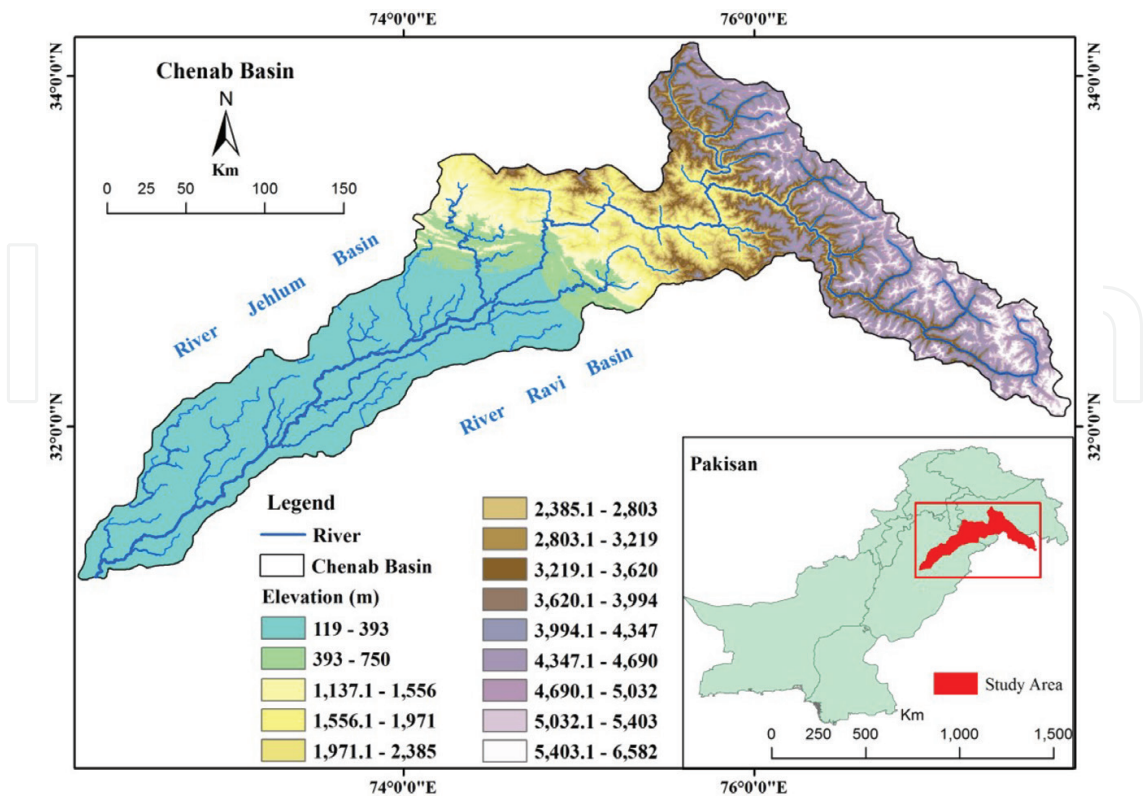


Figure 1. Location of the study area. Source: authors.

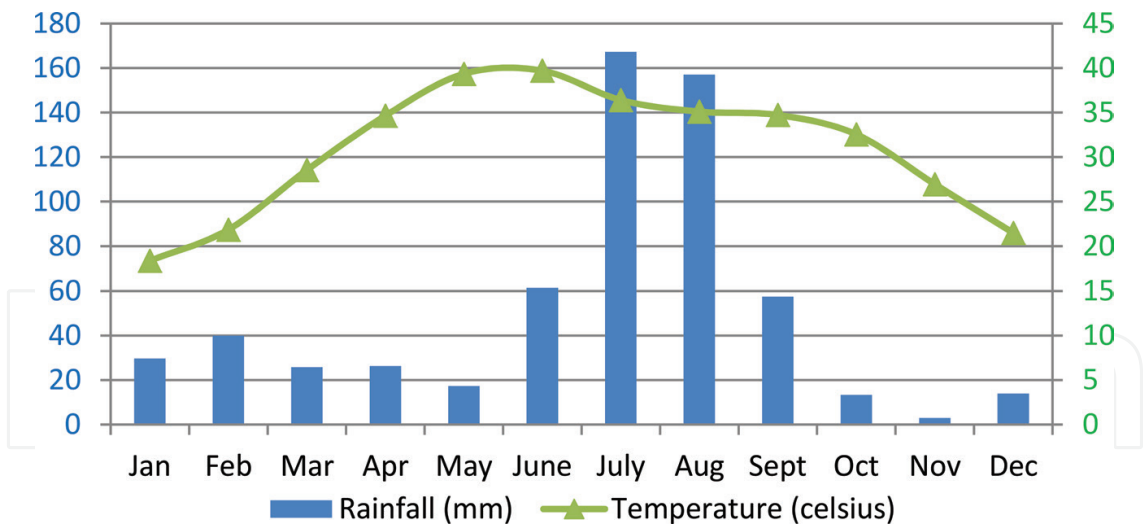


Figure 2. Mean monthly temperature and rainfall. Source: [21].

respectively. The temperature gains momentum from March onward and attains its maximum peak in May (40°C) and June (42°C). In July and August, the temperature falls due to monsoon rainfall.

The main activity of the people in the study area is agriculture because of the availability of fertile soil deposited by the river and water for irrigation through canals from the same river. The main cultivated crops are rice, sugarcane, maize, cotton, fodder, and beans. The local residents are earning their livelihood from agriculture. In most of the target area, houses

are made of bricks and mud which are nonresilient to flood. Similarly, on average monthly income of the surveyed household is less than 200 US\$. This situation has made the people more vulnerable living in the river proximity.

2. Data acquisition and analysis

The study is based on mixed approach. Primary data regarding the depth and spatial extent of flood were acquired in the field using community perception. Similarly, Global Positioning System (GPS) survey was conducted simultaneously to acquire the geolocation of places having different flood depth. Secondary data were collected from concerned government departments. Monthly temperature and rainfall data (2000–2015) and discharge data (1925–2015) were collected from Pakistan Meteorology Department (PMD). Flood damage data were collected from Provincial Disaster Management Authority (PDMA). The Shuttle Radar Topographic Mission (SRTM) Digital Elevation Model (DEM) having 30 m spatial resolution was downloaded from United States Geological Survey (USGS), which is a open source geodatabase.

Watershed modeling approach was applied to delineate Chenab basin in geographic information system (GIS) environment by using SRTM DEM as input data. Buffer analysis was implemented in GIS environment to delineate the flood minimum and maximum extent. The flood depth was geo-visualized by applying inverse distance weighted (IDW) techniques.

Similarly, descriptive statistical analysis was applied on temperature, rainfall, and discharge data to visualize the temporal trend and past flood events. Maps and tables were used to visualize the results.

3. Results and discussion

The study area is located in flood prone area. Every year flood caused huge economic loss due to direct damages in agricultural sector, housing sector, and infrastructure sector. Flood inundation has the potential to cause human fatalities, displacement of people, and environmental damage putting pressures on country's economy and economic development [22].

Flood is the abnormal behavior of river flow which results in the breaching of embankments and inundates the low-lying areas on both sides of the river. Heavy rainfall in summer season in the upstream areas together with meltwater (melting of snow and glaciers) increases discharge in the river and generate flood. The Chenab river has been showing such abnormal behavior, and in the 80 years many times its flow has crossed the magnitude of 20,000 m³/s (**Figure 3**).

3.1. 2014 flood event

In the first week of September 2014, unprecedented rainfall was recorded in Kashmir, Gilgit Baltistan, and many other parts of Pakistan, which has resulted heavy floods in Neelum river at Muzaffarabad, Hunza river at Gilgit, Chenab river at Marala and Jhelum river at Mangla. Parallel to this high discharge, India has also released 5600 m³/s in Chenab river, which has



Figure 3. Peak discharge at Khanki Headwork's, Alexandra Headwork's, and Qadirabad Headwork's (1925–2014). Source: [21].

brought devastating flood in the floodplain of Chenab. As a consequence, it has incurred 185 human losses and approximately 40,000 km² cropped land was inundated. During field survey, it was found that on 6th September high floods was reported in the upper part of Punjab especially in the districts of Jhelum, Gujrat, and Sialkot, and in the lower Indus plain, the severely affected districts were Jhang and Muzaffargarh Punjab province comprising vast plain areas, therefore, the flood inundated the adjacent areas.

The discharge in normal flood condition remains less than 2800 m³/s, whereas above 17,000 m³/s are exceptionally high flood. In the year 2014, peak discharge in river Chenab at Marala was 15,300 m³/s, at Qadirabad 16,000 m³/s, and at Khanki above 18,000 m³/s. Therefore, based on the PMD defined criteria, this flood was declared as high flood in Chenab basin after the disastrous flood in 1992.

The spatial extent of flood was variable in the selected reach of the river. The spatial extent of flood was demarcated on the map on both sides of the river on the bases of community perception. The maximum extent was 20 km, whereas the minimum extent was 10 km in the upper Indus plain (**Figure 4**). Similarly, the depth of flood was also spatially variable. The maximum depth (5 m) was found in district Jhang located in the lower reach of the study area. The extent and depth of flood has caused severe damages to standing crops, livestock, houses, and infrastructure.

The 2014 flood has affected most of the social and economic sectors including community physical infrastructure, housing, agriculture, and flood combating system. Community physical infrastructure sector was the leading affected sector (39.09%) with estimated economic damage of 0.17 billion US\$, followed by housing sector (28.67%) with estimated rehabilitation cost of 0.13 billion US\$. The standing crops were also severely affected by floodwater with estimated economic loss of 0.11 billion US\$ (**Table 2**).

3.2. Extent of damages

The study area is fertile agricultural land and canals are the main source of irrigation. Agriculture is the leading affected sector after infrastructure and housing. During flood,

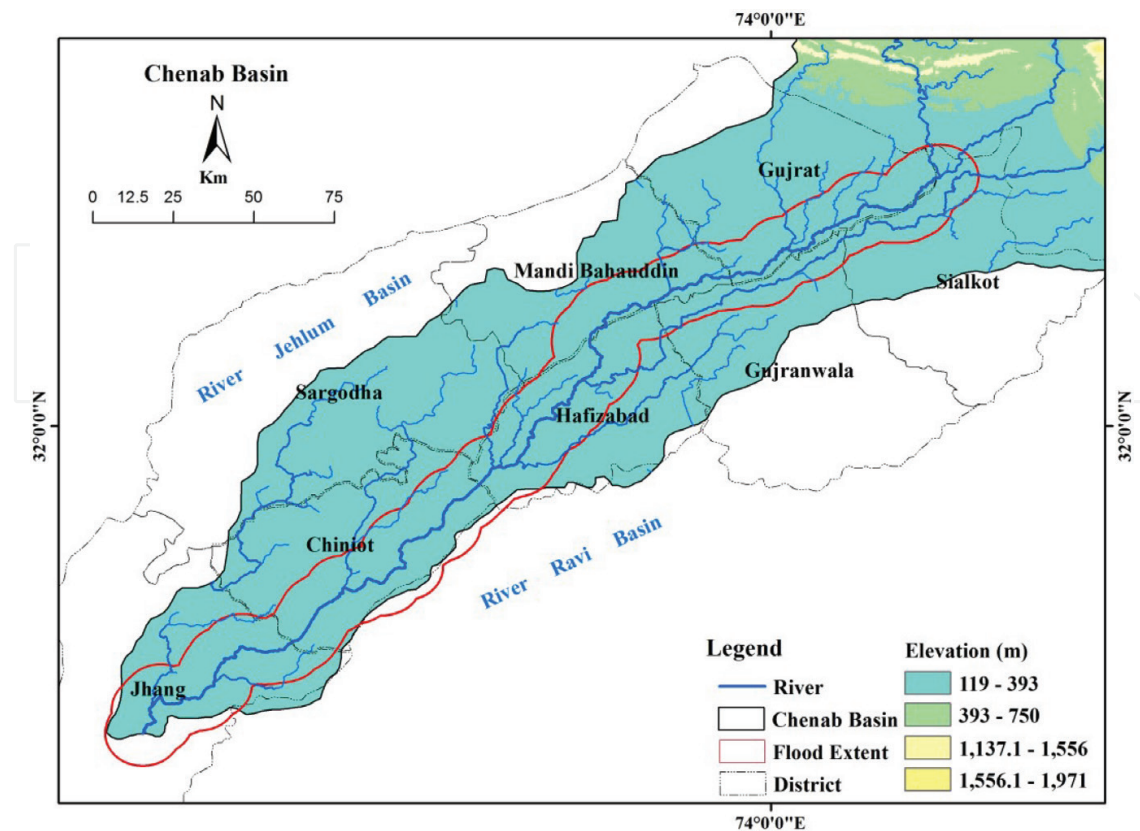


Figure 4. Spatial extent of 2014 flood. Source: authors.

Sectors	Damages (PKR billion)	Damages (US\$ billion)	Damages (in percentage)
Physical infrastructure	17.16	0.17	39.09
Housing	12.59	0.13	28.67
Agriculture	10.91	0.112	25.20
Livelihoods	11.14	0.03	6.24
Flood combating system	0.35	0.003	0.80
Total	52.15	0.445	100

Source [23].

Table 2. Sectors wise flood damages.

especially the standing crops of cotton, rice, and sugarcane were ready to harvest but the spatial extent floodwater into the crops left no choice for farmers rather than to protect their lives. According to an estimation of National Disaster Management (NDMA), the standing crops on about 4000 km² area were inundated by flood and damaged it completely. Extensive damages were reported in the districts of Jhang, Muzaffargarh, Multan, and Sargodha.

Damages to standing crops not only affected the farmer's livelihood but also have negative consequences on overall agricultural production. The 2014 flood has caused reduction in crop production particularly in rice around 0.217 million ton, in sugarcane 0.726 million tons, and

0.25 bales of cotton were lost. Beside this, seed stocks were lost, agricultural tools and equipment got damaged, irrigation channels were breached by flood or blocked by siltation and land erosion over some places further caused damages to land and standing crops affecting the agricultural sector [18].

Livestock is one of the important components of agricultural sector, considered as a secondary source of earning livelihood, and also fulfills the needs of food and nutrition of households. Significant losses of livestock were also observed due to the floods. In the study region, about 2000 of livestock were lost in the upstream areas, whereas buffalos (303), cows (256), and goats (381) were lost in low-lying areas in upper Indus plain.

In the study area, 2014 flood has also damaged the housing sector. The total number of completely damaged houses was higher than the partially damaged houses. According to the estimate of PDMA, approximately 9872 houses were completely damaged and 2894 houses were partially damaged. The damaged houses were higher in the districts of Jhang followed by Chinot.

Analysis reveals that most of the houses in the flood zone were made of (mud) non-resilient material. Flood surge has damaged directly the houses and its content, while the duration of floodwater has further intensified the impact of floodwater on houses. This is a time for disaster management authorities to rethink and plan again on sustainable way to protect human life and property by strengthening the flood combating system. Flood risk zonation is very important to highlight the high risk areas.

4. Findings and conclusions

The study shows that the 2014 flood was destructive in Pakistan and clearly depicts incapacity of disaster dealing machinery at the Federal, Provincial, and district level. This flood was caused by heavy rainfall over the Chenab basin particularly in upstream areas.

This study found the extent of 2014 flood damages in agricultural housing and infrastructure sectors. The 2014 flood was one of the devastating disasters and affected the socioeconomic setup in 16 districts in Punjab province. Out of the total affected districts eight were selected in this study located in upper Indus plain.

In the study region, the severely affected districts were Jhang, Sargodha, Gujranwala, and Hafizabad due to damages in agricultural and housing sector. Analysis reveals that the flood has damaged the social and economic life of people. Houses were damaged which not only cause social negative impact but economic as well. On the other hand, study area mostly comprises agriculture, and flood has destroyed completely all crops. Rice, sugarcane, and fodder are mostly affected. The damages to agricultural equipments and loss of livestock further increased the economic losses. To avoid the socioeconomic damages, it is necessary to build embankments along river, develop effective flood warning system, and develop a management cell based on community perception to combat flood.

Pakistan is a disaster prone developing economy and does not have sufficient resources and infrastructure to deal with and recover from devastating disasters. This situation has increased the exposure and vulnerability of communities. The strengthening of the disaster

risk management system is highly required in order to reduce exposure and vulnerability by capacity building. In this regard, expansion of structural and nonstructural mitigation measures is vital to enhance the efficiency of the flood risk management system. Flood hazard and risk zonation are also extremely important to identify high risk areas. Similarly, flood forecasting and early warning system are also required to be enhanced by increasing the weather radar network.

This is a time for disaster management authorities to rethink and plan again on sustainable way to protect human life and property by strengthening the flood combating system. Flood risk zonation is very important to highlight the high risk areas.

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