MANAGING FLOODS IN PAKISTAN: FROM STRUCTURAL TO NON-STRUCTURAL MEASURES

By

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Abstract

Pakistan has history of floods. However, recent floods of 2010 and 2011 were the most devastating in the recent history of this region. Many researchers link these floods to anticipated climate changes. It is now projected that glacier melt in the Himalayas will increase flooding and rock avalanches and affect water resources in the next two to three decades. It is expected that due to increased variability of monsoon and winter rains and the loss of natural reservoirs caused by glacier melting as a result of climate change, the inter-annual and intra-annual variability of river flows will increase which may cause serious floods in future as well. In order to avoid serious losses, Pakistan needs to work on both structural and non-structural measures for flood protection. Pakistan needs to raise its storage capacity by 22 bcm by 2025 to meet the projected requirements. As non-structural measures, we need to enhance our flood forecasting and flood warning capacity which is currently very weak. Restoration of existing wetlands, proper planning of urban development, improving preparedness and relief services and increasing coordination between different provincial and federal departments involved in water management and flood protection are few steps that can significantly improve our capacity to protect and manage floods in the country.

Keywords: floods, Pakistan, structural measures, non-structural measures, climate change

Introduction

Irrigated agriculture in Pakistan is mainly confined to the Indus plains where it has been developed by harnessing principal water resources available to the country. Without assured irrigation supplies, these arid and semi-arid areas of Pakistan could not support any agriculture, as the evapotranspiration demand is high and rainfall is either meager or unreliable. Surface water resources of Pakistan are based on the flows of the Indus River and its tributaries (Jhelum, Chenab, Ravi, Sutlej, Beas on the east and Kabul River on the west). The Indus River has a total length of 2900 kilometers (Km) and a drainage area of about 966,000 sq. Km (Qureshi, 2005). The inflow to these rivers is mainly derived from snow and glaciers melt and rainfall in the catchment areas. The Indus Basin is underlain by an extensive unconfined aquifer which receives its direct recharge from natural precipitation, river flow, and seepage from the unlined canals and irrigation fields. The safe groundwater yield is 68 billion cubic meter (bcm) against average extraction of 56 bcm which virtually means that resource is diminishing for future (Qureshi et al., 2010).

Outside the Indus Basin most of the rivers are ephemeral streams, which only flow during the rainy season and do not contribute significantly to the surface water resources. However, these water resources are equivalent to 20% of the total water sources of the country. These are mostly located in economically backward areas. Therefore to ensure food security and reduce burden on irrigated lands, it is important to invest in spate irrigation structures in these areas to improve water access for agriculture. The potential lands that can be irrigated by spate irrigation are 7 million ha (Ahmad, 2009).

After the Indus Basin Treaty of 1960 between India and Pakistan, Pakistan was allowed exclusive use of three western rivers (Indus, Jhelum and Chenab) and India was entitled to three eastern rivers (Ravi, Sutlej and Beas). This treaty also provided provision for the construction of a number of link canals, barrages and dams on the Indus and its two tributaries. The Indus Basin irrigation system has now

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developed into the world's largest contiguous irrigation system. The existing surface water system which is now all weir controlled, consists of 4 storage reservoirs (Warsak, Chasma, Mangla and Tarbela), 16 barrages, 12 inter-river link canals, 2 syphons, 44 canal commands (23 in Punjab, 14 in Sindh, 5 in KP and 2 in Balochistan), 59,000 Km long irrigation canals and 107,000 Km long watercourses. Figure 1 shows the major sub-basins of the IBIS.

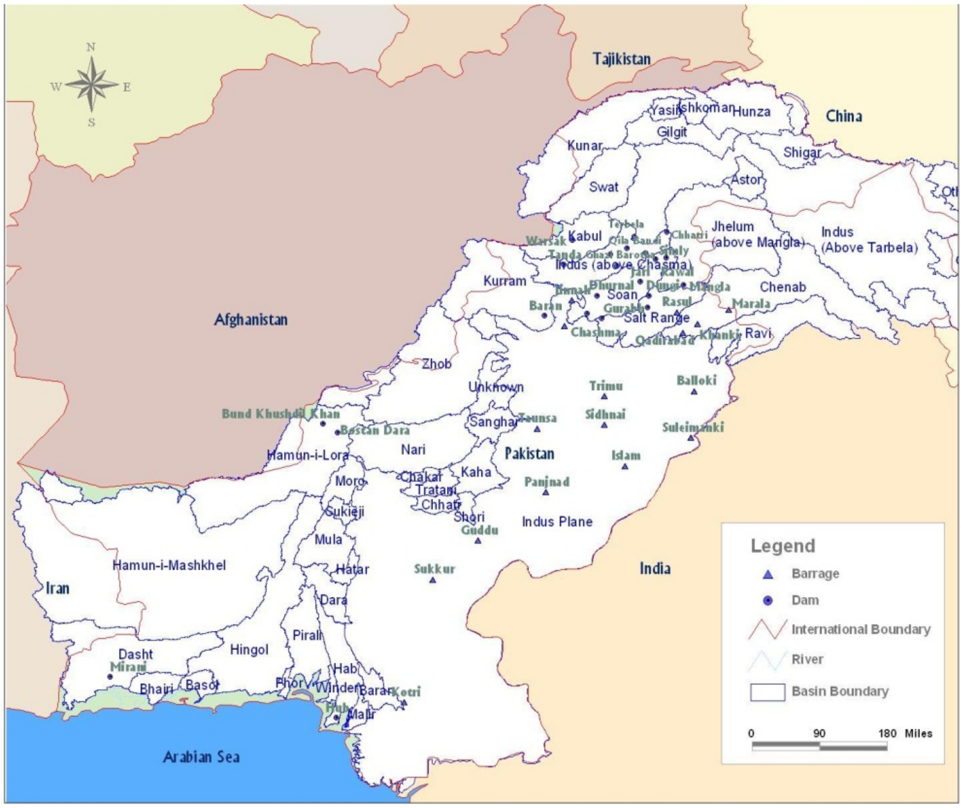

Figure 1.Major sub-basins of the Indus basin irrigation system (*Source: IWMI-Database*).

The Irrigation System commands a gross irrigable area of 17 million hectares (Mha), of which 14 Mha is culturable command area (CCA) to which water is allocated. The perennial canal supply is available to 8.6 Mha while the remaining area is entitled to irrigation supplies only during the summer (Kharif) season. In terms of the quantum of the surface water resources, the flows of Indus and its tributaries, available to Pakistan, are the most significant. The meager and highly variable flows of all others streams; offer only, a limited potential for adding to water availability. Although the surface flows of the Indus River and its tributaries available to Pakistan are quite significant, these are characterized by a great variation. Against the average annual inflow of 175 BCM, the historic data from 1922-97 indicates a high of 230 BCM (34% higher than average in 1960) and a low of 120 BCM (30% lower than average in 1975). About 65% of the total river flows comes from the Indus alone, while the share of Jhelum and Chenab is 17 and 19 percent, respectively. Apart from the large annual fluctuations, there are large seasonal variations in these flows. The average inflow during the six months of summer cropping season is 142 BCM whereas the flow in remaining six months of winter season is only 27 BCM.

Historical trends in river flow in Indus

The bulk of the Indus waters is derived from snow and ice melt. The glaciers of western Himalaya act as a reservoir for the Indus basin, capturing snow and rainfall and releasing it to rivers that flow into the plains. Most of the flow of the left bank tributaries, traversing the Punjab Province, is derived from snow melt during spring and summer with major contribution from monsoonal rains during the late summer. The glaciers of the Karakoram cover an area of about 16300 km^2, out of which about 13000 lie within

Pakistan. The major characteristic of the Indus basin is great spatial variability in precipitation. Surface air temperatures exhibit extreme spatial variability dependent primarily on elevation, but with strong seasonal and diurnal cycles.

The total water brought by monsoon rainfall and westerly winds is about 60 bcm. The renewable water resources for the Indus Basin System (IRS) are about 175bcm, fed largely by glacier and snow melt from the Hindukush-Karakoram-Himalaya (HKH) mountain ranges. The shares of main contributing rivers to the IRS in Pakistan are given in Table 1. Some 82% of the water inflows are during the summer months (April–September) and about 18% in the winter months (October–March). The summer flows in the Indus and Kabul rivers are dominated by snow and glacier melt, while those in Chenab by snow and glacier melt together with monsoon rains; Jhelum is mainly fed by snowmelt and rains from summer monsoon.

Table 1: Contribution of different rivers in the Indus River System (Source : GoP, 2003)

River	% of IRS Inflows	% Seasonal Distribution		Dominant source in Summer	Dominant source in Winter
		Summer	Winter		
Indus	44	86	14	Snow / Glacial Melt	Winter Rainfall + Baseflow
Chenab	19	83	17	Snow / Glacial Melt + Monsoon	Winter Rainfall + Baseflow
Jhelum	16	78	22	Snow / Glacial Melt + Monsoon	Winter Rainfall + Baseflow
Kabul	16	82	18	Snow/Glacial Melt	Winter Rainfall + Baseflow
Others	5	-	-	-	-

Climate change and flows in the Indus Basin

Climate change is also expected to affect the South Asian monsoon. The IPCC in its Third Assessment Report has reported that there will be increase in South Asian monsoon by 8-24%, which will bring additional water causing floods and damages to the infrastructure (Rasul et al., 2008). This requires that Pakistan should start preparing itself for possible future changes in climate change and its impact on Pakistan. Better water management would probably be the best strategy to cope with the projected climate changes and their impact on Pakistan’s agricultural economy and environment.

Pakistan is highly dependent on its water resources originating in the mountains of the upper Indus for sustaining its irrigated agriculture. Hence any variation in the available water resources through climate changes or other human interventions will lead to serious challenges of food security and livelihood of millions of poor. There are evidences that due to rise in temperatures, there will be excessive glacier melt of Karakoram Glaciers and flows of river Indus at Besham Qila will be excessive by about 50%, and thereafter there will be great reduction in flows and they will be reduced to about 40% of the year 2000 value by the end of century (Rees and Collins, 2004). The increase in flow during the second decade of the century will be 6.4 BCM annually and after that there will be a steady decline of 27 BCM in Besham Qila in the next 80 years (Figure 2).

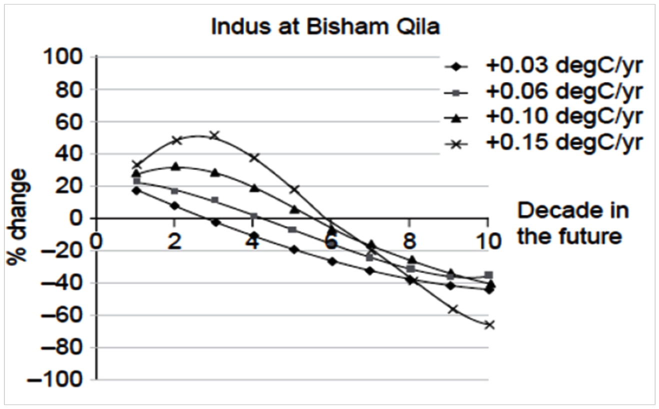

Figure 2: Projected changes in Indus River flows against different temperature changes (Rees and Collins, 2004)

World Bank (2005) also predicts 50 years of glacier retreat, after which river flows will increase. They predict that this will exacerbate flooding and drainage problems. Monsoon rainfalls are also expected to increase, but mostly through extreme storms. After the 50-year period of glacial retreat and with glacial reservoirs emptied, river flows are likely to be reduced by 40% in the Indus basin. This will have serious consequences for environment and food security. The studies done by Global Change Impact Studies Center (GCISC) have shown that temperature increases in both winter and summer will be higher in northern parts than in Southern parts of Pakistan. Moreover temperature increases in northern and southern parts will be higher in winter than in summer. The changes in rainfall patterns are not very clear. However, there are indications that precipitation amounts will increase in summer and decrease in winter in the southern parts of Pakistan.

These findings are based on the assumptions that the effect of rising temperatures on glacier melt will be in line with the global projections. They have suggested that Pakistan should make necessary investments to make the infrastructure adaptive to these changes including preparedness plans for humans and animals and changes in land use (World Bank, 2005). However, these findings have been challenged by Archer and Fowler (2008). They have shown that summer temperatures, which are key for the snow melt has been falling despite rise in winter temperatures. Hewitt (2005) noted that there is ample evidence of glacier expansion mainly in high level glaciers in the central Karakoram. This shows that the effects of climate change on glaciers and on river flow in the western HKH are not clear.

Floods in the Indus Basin of Pakistan

Globally, the number of great inland flood catastrophes during the last 10 years (1996-2005) is twice as large, per decade, as between 1950 and 1980, while related economic losses have increased by a factor of five. Dominant drivers of the upward trend of flood damage are socio-economic factors such as economic growth, increases in population and in the wealth concentrated in vulnerable areas, and land-use change. Floods have been the most reported natural disaster events in many regions, affecting 140 million people per year on average. In Bangladesh, during the 1998 flood, about 70% of the country's area was inundated (compared to an average value of 20-25%).

Historically, flash floods in several parts damaged country's economy and left marks on the country's agriculture and economic growth. According to the early estimates more than 20 million people (almost 13% of the country's total population); including 9 million children were directly suffering. Almost 2000 lost their lives and financial damages were in the range of 40 billion dollars. Although excessive rainfall has been cited as the major causative factor for this disaster, the human interventions in the river system over the years made this disaster a catastrophe. Also its geomorphic character with a high sediment load, typical for many Himalayan rivers, adds to the extent of the catastrophe and the unpredictability of the river. Gaurav et al. (2011) compared the 2010 Indus floods to the Kosi disaster in 2008 in India because of many similarities. The average annual sediment load - originating from the relatively young Karakoram and Himalaya mountains is 291 million tons per year, ranks the Indus as one of the highest sediment load carrying rivers in the world.

Historically, Indus River had a very dynamic regime however it is now constrained by embankments on both sides, cutting it off from its natural floodplains. A variety of climatic and non-climatic processes influence flood processes, resulting in river floods, flash floods, urban floods, sewer floods, glacial lake outburst floods and coastal floods. These flood-producing processes include intense and/or long-lasting precipitation, snowmelt, dam break, reduced conveyance due to ice jams or landslides, or by storm. Floods depend on precipitation intensity, volume, timing, phase (rain or snow), antecedent conditions of rivers and their drainage basins (e.g., presence of snow and ice, soil character and status (frozen or not, saturated or unsaturated), wetness, rate and timing of snow/ice melt, urbanization, existence of dykes, dams and reservoirs). Human encroachment into flood plains and lack of flood response plans increase the damage potential. The draining of natural wetlands has increased flooding. Change in flow regimes due to low flows in eastern rivers after the Indus Water Treaty and enhanced flood protection measures have attracted economic activities and settlements in the floodplains, in a country with an increasing population and substantial poverty. Vulnerability on such locations has increased due to a false sense of safety.

Structural and non-structural measures for flood protection

Flood management and protection problems are closely related to land use and water management issues. These include inadequate water management at field and system level, insufficient pollution control, increased casualties and damages during floods and during flooding operation, maintenance and operational problems, negative environmental impacts and long term problems due to subsidence and impacts of climate change. In order to find solution of these problems, it is important to analyze who are the main actors in the field and what may be their roles and responsibilities. The standard measures for flood protection are usually divided by structural and non-structural measures.

Structural measures

Structural measures are related to physical provisions to reduce the risk of flooding. These include dams, dikes, storm surge barriers etc. Existence of enough storage to mitigate the impact of super floods is of paramount importance for flood protection. These storages should be built both on-channel and off-channel to attenuate flood peaks. In historic 2010 floods, the Tarbela reservoir the peak discharge from 835,000 cusecs at inflow to 604,000 cusecs at the outflow. Similarly, Mangla reservoir on the Jehlum River reduced peak flow of 344,000 cusecs at inflow to 225,000 cusecs at the outflow. These two reservoirs played a critical role in lowering the flood peaks at Jinnah and Punjnad Barrages downstream which otherwise could have played havoc with the Pakistan's strategic irrigation infrastructure.

The present reservoir capacity of Pakistan (live storage) corresponds to 9% of the IRS average annual flow and is far lower than world average of 40% and many water stressed countries of the region (India 33%; Nile basin 347% and Colorado basin 497%). Pakistan's current water storage capacity is 22.8 bcm (Mangla = 7.3 bcm; Chashma = 1.07 bcm and Tarbela = 14.4 bcm). It is estimated that storage capacity of Pakistan reservoirs will be reduced by 57% by the year 2025. The recent estimates suggest that to meet the future water requirements, 22 bcm more water will be needed by 2025 (World Bank, 2008a). This will need to at least double the existing storages.

In the past few years, government is emphasizing more and more on the construction of small dams to provide irrigation facilities to the small scale irrigation schemes. The small dams may address the poverty issues in selected villages but would not help in eradicating poverty in large areas. The envisaged small dams will have a storage capacity of about 1850 cubic meters, which is good to meet the requirements of small scale irrigation and meet domestic water requirements. But in no way can they be considered as true replacement for large dams. For instance, to store water equivalent to Kalabagh dam we would need to construct 750 small dams, and that too will be exclusive of power generation. Therefore, where it is necessary to build small dams, the importance of large dams should not be ignored as they are imperative for sustained national economic growth.

Pakistan is extraordinarily dependent on its water infrastructure, and it has invested in it heavily. Due to combination of age and neglect, much of the infrastructure is in decay. There is no modern asset management plan for repair and/or replacement of irrigation infrastructure. The amounts usually designated by government for repair and maintenance of infrastructure are only 5-10% of the actual required amount. The cumulative effect on the river barrages and head works has left these strategic structures very vulnerable to unforeseen damage with enormous consequences. The deteriorated conditions of many distributaries, minors and watercourses and their related structures such as gates and outlets has increased the seepage losses along the canals and their hydraulic performance is far below their design capacities.. This is causing lesser flows to the tail end command areas of the canals resulting in poor productivity and land degradation. Due to deferred maintenance and lack of rehabilitation, the delivery capacity of canals is 30 percent lower than the designed. Therefore immediate investments are needed to secure these strategic structures to ensure food security of 170 million people living in Pakistan.

Non-structural measures

These measures are related to flood forecasting, flood warning, flood mapping, emergency evacuation plans and land use zoning etc. In Pakistan, flood forecasting and flood warning systems are very week. The devastating floods of 2010 and 2011 are the good examples of our weak capabilities in this field which results in large scale damages of human life, livestock and properties. Therefore flood warning and forecasting systems all over the country need extension and improvement. Installation of modern tools such as weather radars and software and increasing capacity of individuals to interpret the data received from these radars needs immediate attention. Weather radars have proved to be efficient and effective in measuring real time precipitation in many countries especially in Japan, France. These radars can significantly improve the accuracy of meteorological forecasting which can help in better planning and preparedness for floods.

Non-structural measures such as restoration of wetlands for flood retentions and room for rivers should be given serious consideration. Hydrological responses to rainfall are strongly linked with the local characterization of soil such as water storage capacity, infiltration rates and preceding rainfall conditions. The type and density of vegetation are also equally important to understand the catchment response to rainfall. Human alteration to catchments and unplanned urban development also play a significant role in flood hazards. Therefore these need to be checked carefully. Loss of vegetation and changing pervious natural surfaces to less pervious or impervious artificial surfaces leads to an increased storm water runoffs and can result in san increased incidences of flash floods.

Pakistan also needs to enhance its capacity towards disaster management, preparedness and emergency relief efforts. In 2010 and 2011 floods more than 20 million were affected. Many of these damages could have been saved if we were better prepared to face these floods and our emergency relief services were adequate. Considering the reality that climate changes might bring more frequent floods in future, we need to develop separate contingency plans for the most vulnerable areas. For this purpose, mapping of flood zones and identification of most vulnerable areas would be the first step. This work should be given priority and then necessary protective measures should be taken in these areas.

Lack of coordination between inter-departments at the provincial and federal level has been one of the major bottlenecks in successful and effective implementation of various water management and flood protection strategies. In Pakistan, water resources are managed by different organizations therefore appropriate institutional arrangements should be made for proper coordination of different ministries and line agencies involved in the management of water resources. The roles and responsibilities of these organizations should be clearly defined to avoid overlapping and to ensure effective management of water resources at all levels.

The absence of institutional arrangements is perhaps the greatest barrier for the formulation and evaluation of strategic options and monitoring the implementation of national policies for public water sector. Therefore in addition to technical solutions, strong linkages between different organizations involved in the management of land and water resources need to be developed. This can happen if integrated water resources management approach is adopted at all levels by putting structural instruments and enabling environments in place.

Conclusions

Flooding has always been an issue in the Indus basin. Monsoon rainfalls are the main source of floods in the basin. High flows are experienced in summer due to the increased rate of melt water and monsoon rains. The nature of flooding varies according to geography. Fluvial floods in the Indus plain prove most devastating, as the terrain is flat, densely populated and economically developed. Hill torrents (flash floods) are the second most destructive type of flood.

Projected climate changes are expected to increased variability of monsoon and winter rains and glacier melting which can increase the inter-annual and intra-annual variability of river flows resulting in serious floods in future. In order to be prepared for this situation, Pakistan needs to work on both structural and non-structural measures for flood protection. Pakistan must increase its storage capacity to mitigate the effects of super floods. The role of two major reservoirs Tarbela and Mangla in reducing peaks of floods during 2010 has been enormous. Construction of small dams can help in small scale irrigation schemes but would not be able to play their effective role in hydropower generation and flood management. In addition to these structural measures, we need to give equal emphasize on non-structural measures.we need to enhance our flood forecasting and flood warning capacity which is currently very weak. Restoration of existing wetlands, proper planning of urban development, improving preparedness and relief services and increasing coordination between different provincial and federal departments involved in water management and flood protection are few steps that can significantly improve our capacity to protect and manage floods in the country.

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