LESSONS FROM FLOODS OF 2010 IN PAKISTAN TO HELP DEVELOP SUSTAINABLE HOLISTIC MANAGEMENT FOR THE INDUS RIVER BASIN

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ABSTRACT: Pakistan is a country prone to natural hazards where dense populations in poor living conditions are highly vulnerable to natural hazards. Events like the floods of 2010 are likely to become more frequent in the era of climate change, putting the human populations in the basin even more exposed to the next inevitable disaster. Most damages in 2010 floods were exacerbated by the presence of existing infrastructure such as major head works, flood protection levees, and unplanned ingress of population centers in the active flood zones. This study identifies challenges and recommends approaches for holistic flood management. Using the extent of 2010 floods derived from remote sensing data, we identified areas of different land use impacted by floods. It was identified that large quantities of diversions from the river for irrigation in past 50 years have dried up many low lying areas within the river corridor to the extent that population centers have emerged in these agriculturally fertile, but risk prone areas. A strategy is recommended to manage the risk which shifts the focus from current practices of flood control/fighting to integrated flood management, i.e. living with the floods. The plan integrates flood management and water management in the basin and calls for minimizing diversions for irrigation in order to restore wetlands/riparian vegetation zones so that the basin's capacity of absorbing floods and slowing down velocities could be reinstated. The plan recommends for an overhaul of the current inefficient flood-irrigation system in the basin by systematically analyzing the potential of improving irrigation efficiency. The existing ageing infrastructure for water diversion and flood control could be remodeled to suit the contemporary and future flood/water management practices. The plan could be implemented in phases over the next 50 to 100 years.

Key Words: Indus Floods, IFM, IWRM, River Restoration, Irrigation Efficiency

1. INTRODUCTION

The flow observed in the Indus River during late July and August 2010 was not unprecedented. Historical data shows that Indus has regularly shown immense increase in flow once in every 50 years. Floods of 1929, 1976 and 2010 were recorded with peak flows of 31,150 m^3/s, 28,300 m^3/s and 34,000 m^3/s respectively (Akhtar 2011, Oxley 2011). 2010 flood was enormous making it the most severe flood in the history of Pakistan (Akhtar 2011, Webster 2011). Events like the floods of 2010 have demonstrated unusual hydrologic hazards in the Indus Basin, and those hazards could become more frequent in the era of climate change as we saw, yet again, the devastating floods in 2011 in southern part of the Indus Basin due to exceptionally heavy rains. And it is not just the Indus basin in Pakistan – recent unusual events caused widespread floods with catastrophic damages in other Southeast Asian countries, including Thailand, Cambodia, Laos, Malaysia, Myanmar, and the Philippines (Ziegler 2012, DFO 2012). Trenberth (2012) has also quoted 2010 floods as one of extreme climate events.

Extra-ordinary flows in Indus in 2010 can be attributed to two factors: one, the exceptionally high rainfall over the western catchment areas of Indus (rivers Swat, Panjkora and Kabul) where 250 mm of rainfall occurred within twenty four hours causing flash floods in mountainous districts reaching River Indus through River Kabul; and two, heavy monsoon rains caused high floods in the eastern tributaries of Indus which further intensified flow in River Indus. These inflows combined to produce an enormous 34,000 cubic meter per second (m^3/s) of flood into the Indus (Akhtar 2011, Oxley 2011). The floods spread chaos and destruction along its path, submerging entire villages, sweeping roads and bridges, devastating agricultural land and livestock, and damaging other infrastructure. Approximately 2,000 people lost their lives, an estimated one million homes were destroyed, and 20 million people were seriously affected – making it the largest disaster ever recorded in terms of affected population, area covered, and number of households damaged (Solberg 2010). On the scale of 'duration–area affected–intensity' the magnitude of the flood was 7.5 (Chorynski et al., 2012; Brakenridge, 2012). A wider area and more people were affected by the 2010 floods in Pakistan than by the 2004 Indian Ocean tsunami, the 2005 Kashmir earthquake, and the 2010 Haiti earthquake combined (NDMA 2011). The estimated cost of the damages was more than U$10 billion (World Bank 2011, Emerson 2011). Most of the flooded populations living too close to the river comprise the lowest socioeconomic quintiles (Warraich 2011).

The rainfall events triggering the floods were unusually intense but not unprecedented. Syvitski and Brakenridge analyzed the damage done during 2010 floods using multi temporal remote sensing and topography data and concluded that most of the damage was caused by dam and barrage-related backwater effects, reduced water and sediment conveyance capacity, and multiple failures of irrigation system levees. Some of these breaches resulted in catastrophic avulsions, flooding thousands of square kilometers of populated areas (Syvitski and Brakenridge 2013). Flood plains of the Indus Basin are well capable of containing larger floods, but in the quest for the land, populations centers and public/private development got too close to the river. Infrastructure such as dams, barrages and flood levees, had successfully averted small to medium scale disasters in past 60 years or so, making the current generation complacent about the risks of settling into the active flood plains. The complacency led to extensive development without caution or fear in the risk prone areas, not only putting large populations and economy at risk, but also severely degraded the natural capacity of absorbing floods in those areas. However, when the system is breached in case of catastrophic events, as of 2010, the damages are orders of magnitude more (Zeigler 2012).

To understand why flood damages were catastrophic in 2010, an understanding of planned and unplanned anthropogenic modifications in the river basin in recent times is necessary. Modern canal based irrigation was introduced by the British around the 1850's (Hasan 2010).The scale and extent of these modifications grew to enormous proportions over time. Today, using a network of two major dams and 16 barrages, more than two thirds of the Indus River's flow is annually diverted into canal irrigation system of the basin. Out of total 190 billion cubic meter (BCM) of water, 129 BCM is diverted for irrigation, 12 BCM is consumed in system losses and only 49 BCM flows into the sea (Ahmed et al. 2008, FIRC 2011). Number of dykes, bunds, dams and barrages now control and limit the flow of water in the river. With a network of irrigation levees and flood dykes, the riverine areas are confined to a narrow corridor. The southern parts of the river are now confined within an engineered floodplain 15 – 20 kilometer wide, which lies within a historical flood plain wider than 200 kilometer (Syvitski and Brakenridge 2013). Extensive deforestation in the catchment areas for timber and fuel wood has reduced the water-retention capacity of the forest eco-systems resulting in increased runoff quantity and velocity, with increased sediment loads entering the headwaters. Deforestation has also increased the risk of landslides, damaging riverine infrastructure and resulting in additional siltation of the downstream water channels (Oxley 2011). Diversion infrastructures (barrages and headworks) increase upstream siltation in the river beds. There has been a significant decrease in the carrying capacity of the river system due to sedimentation causing raising of river bed and thus making the existing dykes insufficient to contain extremely high floods (Syvitski and Brakenridge 2013). The historical average coastal discharge had been ~3000 m^3/s but with diversions it is reduced between 800 to 300 m^3/s, while the sediment delivery to delta has reduced by 10 folds (Asif et al. 2007, Milliman and Syvitski 1992).

There is a common consensus that anthropogenic modifications in the Indus Basin spanning over the past 160 years have gone without ensuring that the physical infrastructure is in balance with limits of natural ecosystems. The construction of dual-purpose dams, barrages, flood embankments and drainage channels all constrain the natural waterways of the river. A combination of increased inflows and reduced water-carrying capacities of the river channel exposes large numbers of people to increased risk from severe flooding during times of heavy rains. In the short-term these infrastructure protect from localized flooding and people grow complacent, but in the longer term the river system significantly loses the flexibility to absorb floods, putting the complacent populations at a greater risk in case of extreme events.

It is a growing consensus that solutions such as reinforcing the existing engineering structures, building higher dykes and cascades of dams etc. are not a sustainable strategy for avoiding future flood catastrophes (Newell and Wasson 2002, Ziegler et al. 2012, Ziegler 2012, Syvitski and Brakenridge 2013).

Agriculture is central to economic growth and development in Pakistan. Being the dominant sector it contributes 21.4 percent to GDP, employs 45 percent of the country's labor force and contributes in the growth of other sectors of the economy (Farooq 2014). Agriculture sector draws more than two third of the basin's waters therefore any plan to manage floods in the basin cannot be isolated from the requirements and management of water usage in the agriculture sector. Water distribution and management for agriculture is dependent on the major diversions, dams, barrages, dykes, levees and bunds. On one hand, the agriculture sector is demanding even more water (despite the fact that the system is already exploited to its capacity), but on the other hand, a lot more water needs to be reverted back to the river in order to restore wetlands, forests and grasslands in riverine areas to enhance their flood absorbing capacity, and to prevent erosion and ingress of seawater at the Indus Delta.

This study looks into the key question: Is there any possibility to increase environmental flows in the Indus River to improve the ecological health of the system, restore wetlands and riparian vegetation, and improve flood peak absorption capacity of the basin without jeopardizing the agriculture production and food security in the face of increasing population and receding water resources due to climate change?

We first look at flooding mechanisms of 2010 floods which impacted the areas outside the riverine boundaries and also look at the damages within the riverine boundaries. We then look at possibilities of sparing water from the agriculture sector by improving irrigation efficiency. Finally we discuss policy actions which promote contemporary methods in flood management as well as in improving irrigation efficiency.

2. PATTERN OF 2010 FLOODS

Using the boundary for maximum extent of 2010 floods generated through satellite data (UNITAR 2010) and the riverine boundaries with polygons of land use (FFC 2005), we estimated the extent of flooding in comparison with the riverine areas. 2010 floods impacted large areas outside the riverine zones, demonstrating the insufficient capacity of the system to handle exceptional events. There were three distinct patterns which caused flooding out of riverine areas as illustrated in Figure 1.

The first one is development of hill torrents due to intense rains in the western catchments. These torrents combined to create flooding conditions, as shown in inset A of Figure 1, when they approached low lands towards the main floodplains of Indus.

The second pattern emerged from backwater flow at the barrages. Inset B shows backwater ponding caused by Trimmu Barrage just downstream at the junction of Jhelum and Chenab. Heavy rains cause high floods in Jhelum, but situation in Chenab was calm. However, as shown in the figure, backwater effect caused major flooding in Chenab just upstream of the barrage. Similar situations were observed at some other barrages (Syvitski and Brakenridge 2013).

The third flooding pattern was river avulsion. Inset C shows the extent of the Northern Avulsion. This avulsion was caused due to breaching of Tori Bund. Flood Inquiry Commission Report highlighted the fact that peak flows of 32,500 m^3/s were sustained by this infrastructure in 1976, yet similar flows caused avulsion in 2010, due to mismanagement (FICR 2011). However, since the confinement of river within engineered (narrower than natural) flood plains, excessive sedimentation has also reduced the carrying capacity of the current waterway. Moreover, Indus in this area is currently flowing over an alluvial ridge, 10-15 m higher than surroundings and about a 100 kilometer wide (Syvitski and Brakenridge 2013). All these facts have implications for the future of flood management in the Indus Basin.

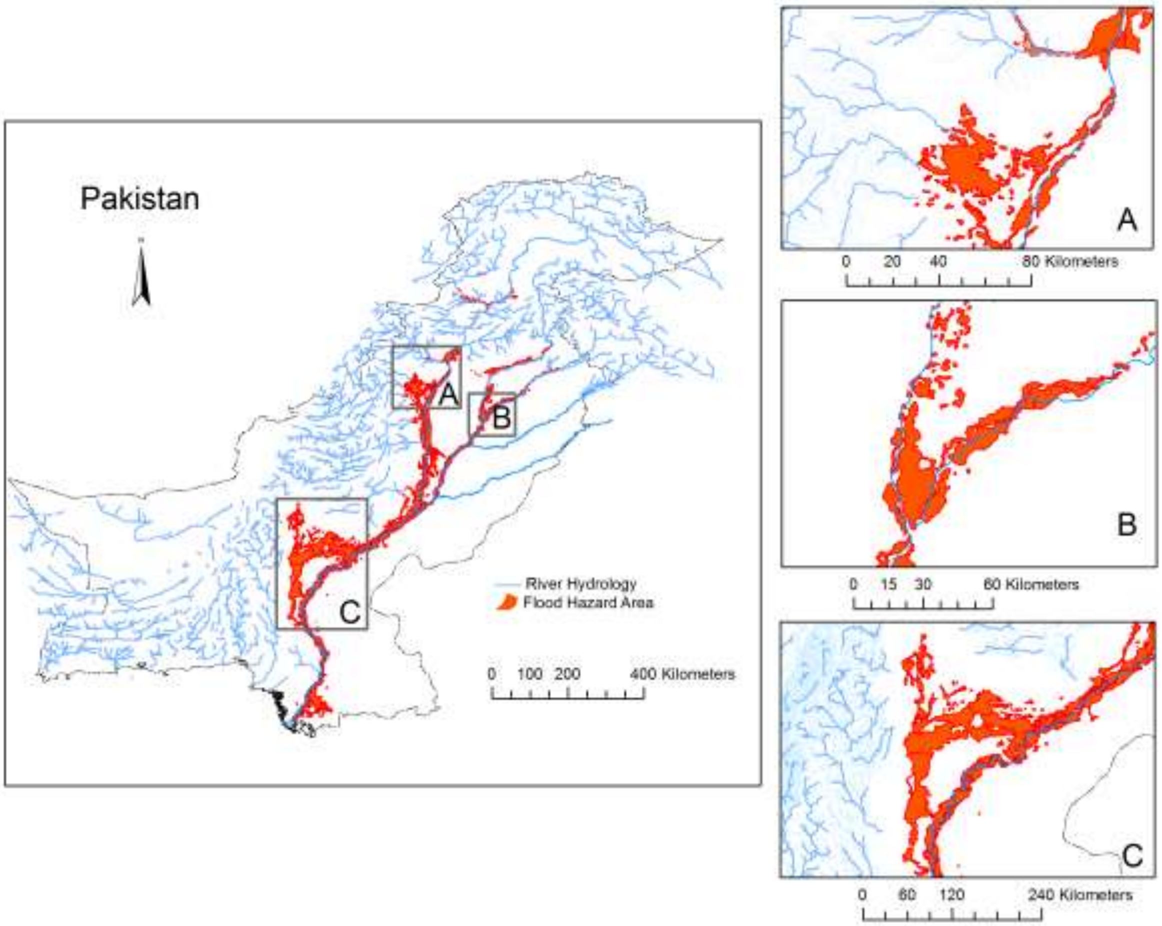

Figure 1: Hill torrent, backwater and river avulsion impacts

3. TEMPORAL CHANGES IN RIVERINE AREAS

Riverine boundaries along the Indus and its eastern tributaries, i.e., Jhelum, Chenab, Ravi and Sutlej were identified in the late fifties and classes of land use within these areas were documented. With the availability of satellite remote sensing data since the early seventies, data on land use including agricultural and forestry resources became available with temporal coverage. Using remote sensing data from various sources, Federal Flood Commission of Pakistan conducted a comprehensive study to evaluate changes in land use in the riverine areas of the Indus Basin between 1976 and 2000 (FFC 2005). The study points out that more and more riverine areas are being brought under tube well irrigation while there is corresponding decrease in riverine forests, wetlands and grasslands. These changes have effectively reduced the natural capacity of riverine areas to absorb floods and slow down flood velocities. Along with uncontrolled growth in agriculture lands in the riverine areas, population centers, industry, communication and transportation infrastructure also continues to grow in the active flood zones. Figure 2 shows the superimposed limits of 2010 floods over the riverine area boundaries. The figure demonstrates that backwater and avulsion impacts (insets B and C) far exceed the riverine boundaries.

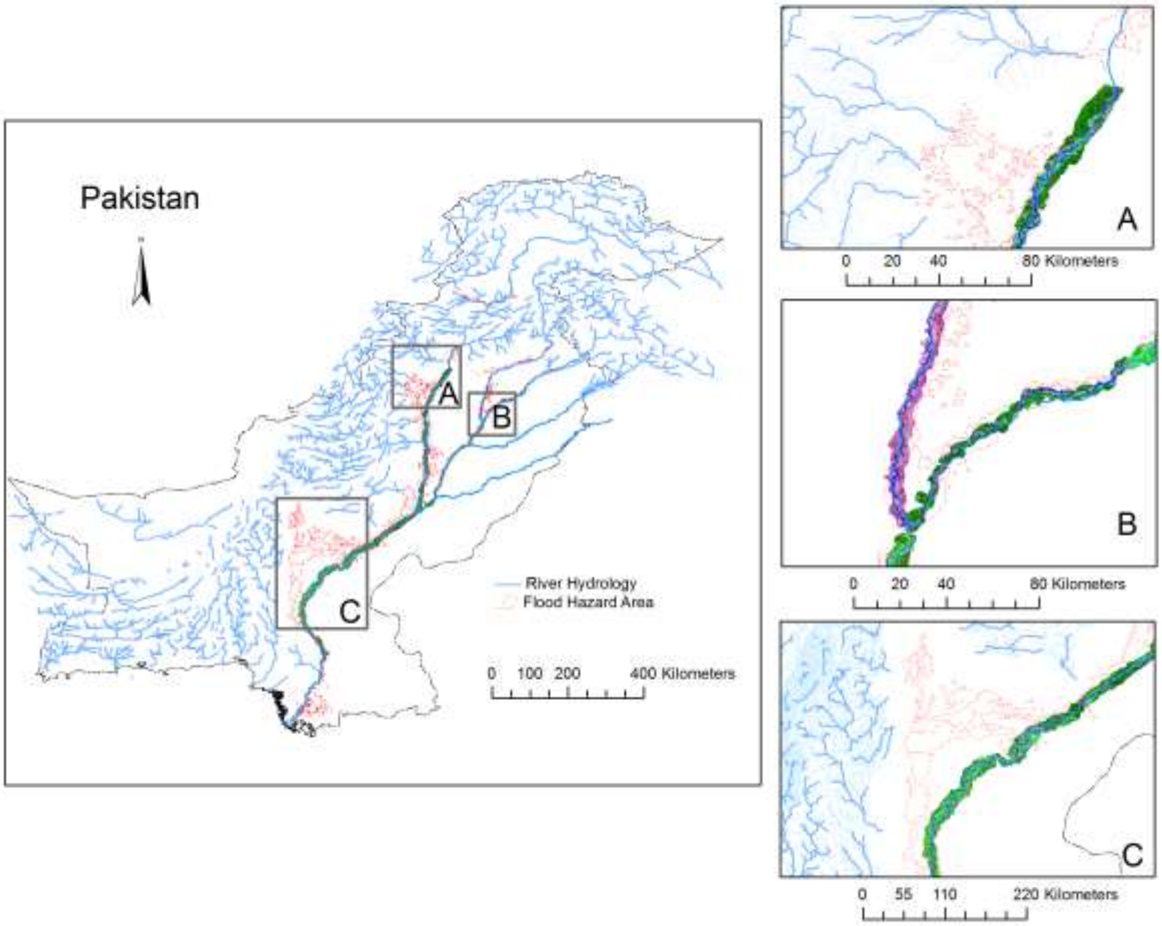

Figure 2: Riverine boundaries and the extent of 2010 floods

Figure 3 illustrates changes in land use between 1976 and 2000. Figure 3 also highlights proportions of riverine areas within the basin impacted by floods. It is interesting to note that maximum flood damages occurred in the tube well irrigated areas which have increased from 754,000 hectare (ha) in 1976 increasing to 1,070,236 ha in 2000. On the other hand, riverine forests, wetlands and grasslands areas have reduced from 409,079 ha, 182,224 ha and 201,325 ha respectively in 1976, to 288,450 ha, 96068 ha and 155,000 ha in 2000 respectively. No comprehensive study exists which had ever evaluated the flood absorption capacity of riverine forests, grasslands and wetlands – and we are continuously losing them without knowing their richness nor their role in the ecosystem.

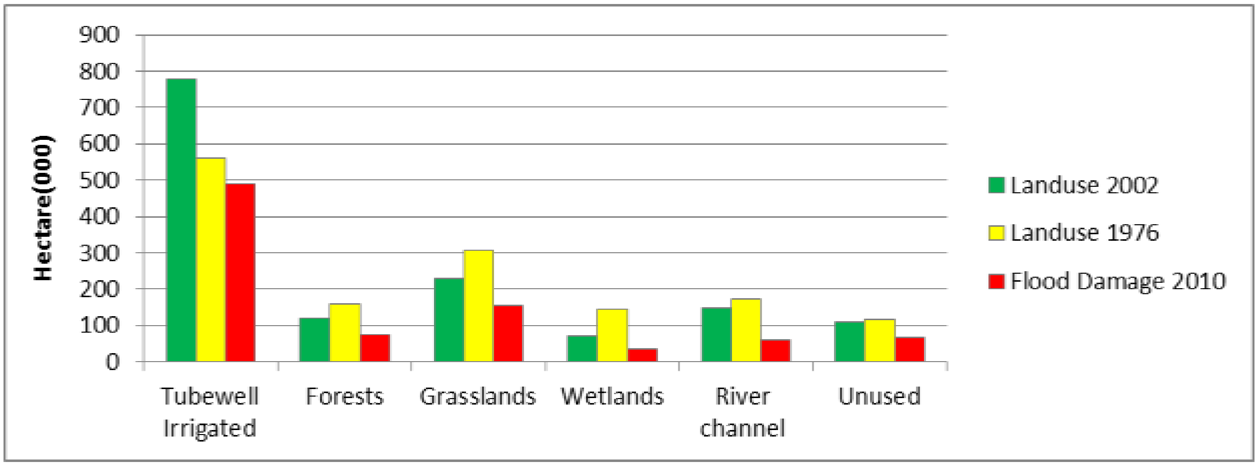

Figure 3: Changes in use in riverine areas and areas affected by floods

4. GAINING WATER FOR ENVIRONMENT BY IMPROVING IRRIGATION EFFICIENCY

Pakistan's agriculture sector consumes 95% of water diverted from the rivers for human consumption. The water diversions from the rivers are already stretched to the limits and the rivers are almost sucked dry – drying up of many wetlands in the riparian zones, loss of ecological services, and shortages of water at the delta causing many social and ecological problems. It is not possible to manage flood risk in the basin without fully integrating agriculture water use into the flood management plans for the basin. Climate models predict decrease in surface flows in the range of 5 to 20% over the next 100 years while the population growth is projected to be more than doubled within this time span. The big challenge facing the country is how to produce more food for increasing population with diminishing water resources. Wastage of water in the agriculture sector of Pakistan due to inefficient irrigation practices and old/aging infrastructure across the basin is well documented.

There does not seem to be a viable plan for the Indus Basin which ensures food security for its inhabitants without further reducing environmental flows to the already water stressed ecology of the river, and there seems no viable environmental protection/restoration plan which does not suggest reductions in water withdrawals for the already water scarce irrigation sector.

In this section we present a conceptual plan which ensures food security in the basin while simultaneously sparing large quantities of water for environmental restoration. The concept shifts focus from construction of mega diversion and large scale storage dams to small storages at farm scale coupled with innovative efficient irrigation methodologies plus the regional-scale plans of utilizing storage spaces available in the depleted aquifers.

Besides promoting existing efficient irrigation techniques such a s drip and sprinkler systems, we have also developed and tested a sub-irrigation technology nick-named ZiZAK (Abbas at al. in preparation). ZiZAK consists of a layer of growing medium of certain thickness composed of carefully selected soils with optimum quantities of nutrients and organic content based on the requirements of a set of targeted crops. Underneath the growing medium is a network of pipes to deliver moisture in the root zone though regularly spaced inverted filters. Water levels in the filters are raised or lowered to maintain moisture requirements in the root zone. The system can ensures the availability of soil moisture within the root zone for the plants at every critical stage of their growth, thus improving biomass productivity and per hectare crop yields. The system almost eliminates water losses due to deep drainage and overland flow, and greatly minimizes direct evaporation from the soil. This brings water requirements to a bare minimum - roughly equal to evapotranspiration rate of the plants. The sub-irrigation system also ensures that the root zone of the plants does not get fully saturated and the direction of moisture fluxes within the root zone always remain upwards through the capillary forces, preventing leaching and deep drainage of minerals and fertilizers from the growing medium, thus reducing the net requirement of fertilizers at the farm as well as preventing pollution of aquifers from fertilizers and pesticides etc. Rainfall harvesting is also fully integrated within the farm design. The whole water delivery system operates at atmospheric pressure ensuring lesser maintenance costs. The first pilot farm based on ZiZAK irrigation system has achieved water efficiency for Maize at a staggering 15 kg of corn for every cubic meter of water. Our on-going experiments demonstrate that with this system water can be saved by more than six folds compared to the currently in vogue flood irrigation practices in the basin.

In an ideal scenario, if irrigation efficiency is achieved to the potential bieng demonstrated in ZiZAK pilot projects, over 100 BCM of water can be spared annually from the 128 BCM being diverted to irrigation. The anticipated success of efficient irrigation opens a huge opportunity, for the first time, to spare significantly large quantities of water for environmental restoration projects. Following a carefully worked out long term plan, the efficient irrigation methodologies can be encouraged through incentives to begin with, then gradually adopted by progressive farmers, then mandated on all farms and ultimately enforced throughout the basin. As more water starts becoming available in the river, the management of riparian zones, restoration of lost wetland habitats, replantation of riparian forests, and reintroduction of lost species can commence in the basin. Flood plain management plans can also be re-aligned using contemporary methodologies which minimize damages without restricting natural flow paths. Infrastructure to harvest storm and floods waters for replenishing the aquifers can also be gradually put in place. Even if half of the 100 BCM potential is exploited over a period of half a century or so, the Indus River can be restored to much of its lost glory, generating huge ecological services. Long term adaptive management in the next 100 years can turn Indus Basin into a model of restoration for the other large river systems of the world.

5. TOWARDS SUSTAINABILITY

In 2003, Pakistan's National Communication on Climate Change identified Water management and planning for the Indus and Monitoring coastal zones in order to protect biodiversity as two of the country's many urgent needs for adaptation action (World Bank 2011). The 'green' engineering solutions [such as ZiZAK], fully integrated with a holistic basin-wide flood management, including supportive policies, regulatory framework, incentive systems, and public participation are necessary to create sustainable flood management (DEFRA 2004; FAO 2005; Lebel et al. 2011; Ziegler et al., 2012).

Expanding conventional flood water drainage systems, putting cascades of dams along the rivers and constructing higher dikes to restrict river's flooding are the short-term engineering solutions limited by their design capacity and unsustainable due to factors such as sedimentation and environmental degradation. Another down side of such solutions is that while they can help avoid disasters within their design capacity, they make populations even more vulnerable to catastrophic events (Newell and Wasson, 2002).

The notions such as 'flood protection' and 'flood fighting' have no space in the contemporary (yet age old) concept of 'living with floods'. Let the nature take its course and we must adapt to live with it. There is a need to identify and quantify ecosystem services that the Indus River System can generate. The planning and management of the river system should aim at conserving and enhancing the capacities of the basin's ecosystems services in both rural and urban areas

Social, economic and ecological systems are interdependent. This interdependence has to be better understood and built environment in the riverine areas and active flood zones should be regulated. Uncontrolled and unregulated growth of population centers and infrastructure in risk prone areas must be checked through regulations, enforcement and education. Disaster risk reduction need to be fully integrated in any future planning.

The recent floods have demonstrated that high levels of economic growth based on major engineered modifications of the river systems, are ultimately unsustainable. Adaptation and learning to live with the floods is the key to sustainability. It has taken approximately 150 years of human interventions to degrade and disrupt the natural flow regime of the Indus River System, and it might take another 150 years of interventions to restore it back to its original glory. The scientific possibilities are already on the horizon.

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