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Potential effects of human and climate change on freshwater resources in Pakistan

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Abstract Pakistan is facing severe degradation of freshwater resources, threatening its environment and economy. Among the freshwater resources, rivers particularly are facing multiple problems such as; trans-boundary water exploitation, pollution, diversion and climate change. Water utilization agreements and practices have tremendously reduced the flow of the rivers and disrupt the aquatic ecological integrity. The water harvesting policy for hydropower generation and irrigation adopted by India and Pakistan has greatly influenced and disturbed the natural flow of rivers. The controlled and regulated water bodies, such as dams and barrages make the rivers poor in biodiversity through habitat fragmentation. The situation is further aggravated due to pollution stress, ill-planned industrialization, urbanization and agriculture. These factors have fragmented the populations of different endemic species such as Mahsheer (*Tor putitora*, Hamilton), Palla (*Hilsa ilisha*, Hamilton) and the Indus blind dolphin (*Platanista minor,* Owen) to the verge of extinction. Similarly, significant reduction in the annual catch of commercial fishes from rivers and lakes has been recorded. Pakistan is experiencing a change in rainfall pattern resulting in frequent floods and drought. Heavy rains, floods and drought destroy the agriculture and infrastructure putting unaffordable stress on the economy of Pakistan and affecting the ability of government to deal with the crisis. There is an urgent need to focus on the impacts of anthropogenic stress and climate change on aquatic organisms in the rivers of the Pakistan. This paper is an attempt to highlight the impacts of human and climate change on water resources and aquatic fauna.

Key words human activities; climate change; habitat fragmentation; water resources

INTRODUCTION

The human population globally is growing rapidly by about 80 million per annum and escalating pressure on freshwater demands by about 64 billion cubic metres every year (Hinrichsen, 2005). By the end of 2025, 63% of the global human population will experience freshwater shortage (Arnell, 1999). Global climate is ever changing, since the creation of Earth (Risse, 2009). The human population and activities are putting pressure on natural resources and disturbing biogeochemical cycles. Indiscriminate burning of fossil fuel, deforestation and agriculture have increased the CO_2 concentration in the atmosphere, which acts as a catalyst for climate change. The welfare of people living in developing countries depends on climate, but with the advent of the industrial revolution, its pace increased tremendously, which makes the stability of the climate system vulnerable (Pall, 2007). In some regions like South Asia, the effects of climate change are more pronounced, particularly in western parts of South Asia. Pakistan, situated at the tail end of monsoonal South Asia has experienced floods, drought and unusual rains during the last two decades as a result of climatic changes. Freshwater resources will face more stress and it also will be difficult for authorities with in the country to manage the problems along with population pressures and transboundary issues. Two processes are operating simultaneously and are aggravating the situation. First, the reduction or increase in supply of water resulting from climate change, and second human population pressure leading towards the environmental degradation (Gleick, 1998).

The Western Himalayas are the source of freshwater for more than 180 million people in Pakistan. These water resources are shared among several countries including Pakistan, India, China and Nepal (Pomeranz, 2009). These Asian countries are densely populated and require large volumes of water to satisfy their agricultural, industrial and domestic demands. Due to an alarmingly high population density and its growth rate, water resources have been adversely affected. Population pressure combined with problems such as urbanization, agriculture and

climate change has stringent effects on the water resources (Khalid, 2010). More demand for human utilization of freshwater resources has also created a situation of conflict among countries sharing the same water resources. Such conflicts develop from the upstream exploitation, construction of dams, barrages and canals on international rivers, where blockage, diversion or pollution reduce the availability of water to the downstream increasing the anxiety of people living downstream (Bernauer, 1997).

South Asia is the most focused-on regions of the world due to international peace because it has a poor historical record of sharing water resources. One of the major disputes in South Asia is the distribution of water resources between Pakistan and India. The long standing issue of Kashmir further aggravates the water crisis. Most of the rivers originate from the Western Himalayans and flow towards Pakistan. Being downstream, Pakistan receives limited and controlled water amounts (Fig. 1). This has complicated consequences for the economy as well as natural resources. Politicians mainly focus on the economy and water sharing, whereas aquatic biodiversity is a neglected component in the process of transboundary water exploitation. The irregular and inadequate flow of water is highly volatile due to climate and weather extremes. The water scarcity results in droughts, and is further aggravated by invasion of alien species and loss of habitat along with factors increasing industrial, agricultural and irrigational structure development that cause the loss of aquatic biodiversity (Alam & Yasar, 2011). It is a global phenomenon that decreasing outflow of flood water degrades the aquatic as well as the terrestrial environment (Yan *et al*., 2008) resulting in competition for water between neighbouring countries (Alam & Yasar, 2011).

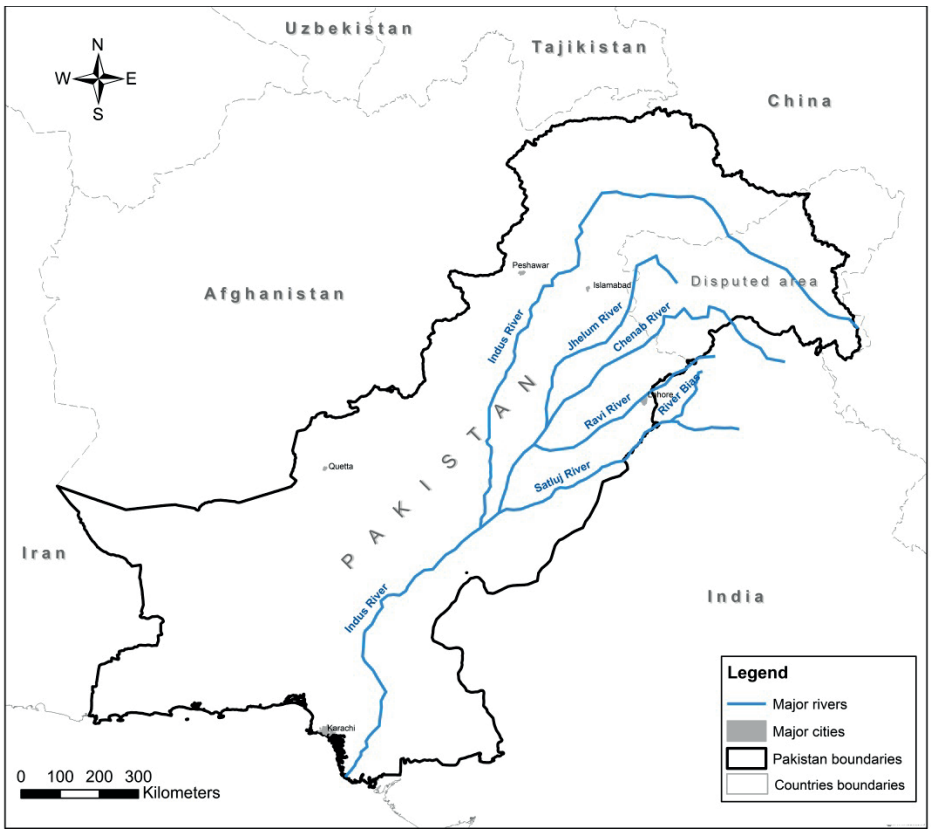

Fig. 1 Map showing rivers of the Indus basin that are located in Pakistan.

Massive population displacements and territorial issues have served to aggravate conflicts over the water disputes. In 1948, water conflict emerged due to interruption of the water supply for Bari Doab, in Punjab, Pakistan, by India. Later, in 1960, India and Pakistan reached an Indus water

treaty with the help of the World Bank and international community at Karachi. According to the water peace accord, Pakistan recognized the complete water rights of India on the Eastern Rivers the Sutlej, the Beas and the Ravi, and similarly India withdraw from its rights on Western Rivers viz: the Indus, Jhelum and Chenab rivers (UNEP, 1989; Nayyar, 2002). The expansion of agricultural land, population and new technologies for water harvesting increases the utilization of water resources in both countries. This situation is further intensified due to climate changes in monsoon regions. Pakistan is facing multiple transboundary water pollution issues because most of the rivers traverse from Indian territories, which are degraded due to reduced water flow and pollution (Alam & Yasar, 2011). The intensity of pollution is increasing, which affects the quality of water and threatens the integrity of aquatic ecosystems. Habitat losses for aquatic organisms have been observed in Pakistan due to transboundary management, especially in the Ravi and Satluj. During the last two decades in India, rapid economic growth and growing agricultural, industrial and urban development in the upper catchment areas have elevated the amount of toxic compounds in rivers (Nshimiyiman *et al*., 2010).

IMPACTS OF TRANSBOUNDARY WATER RESOURCES IN PAKISTAN

The Indus water treaty continued to be respected by both countries for decades, but later on India silently started many storage and hydro-projects in Jammu and Kashmir. In 2004, India re-started the negotiations on the Baglihar and Wular Barrage to address the grievances of Pakistan; but meanwhile, India continued the construction of dams to store and harvest the maximum water for irrigation (Table 1). India began to construct several dams and hydro projects (HP), viz; Baglihar Dam, Dulhasti HP, Salal HP, Kirthai Dam, Sawalkot Dam, Pakal-Dul Dam, Uri HP, NimooBazgo Project, Dumkhar Hydroelectric Dam, Kishanganga HP and Bursar Dam) on both the Western as well as Eastern Rivers (Akhtar, 2009). Due to these projects the economy of Pakistan was adversely affected as it is mainly based on agriculture and its by-products. Economic security is basically reliant on a continuous and appropriate supply of irrigation water from the Chenab, the Jhelum and the Indus rivers for growing crops. Due to construction of dams and storage bodies in Indian held Jammu and Kashmir, Pakistan is receiving less water than its share, whereas the International Water Treaty (IWT) allows India to generate electricity from potential sites located on Western rivers in Indian territories without affecting water quantity and flow to Pakistan (Sahni, 2006). The construction of an array of storage and hydropower facilities on the Chenab and the Jhelum rivers is turning into a source of conflict between the two countries. The Indian Government is planning to construct about 135 dams; many have been completed or are under construction. Pakistan is worried that India might be interested in getting complete control of the water resources (Akhtar, 2009). If the above projects are completed, they would affect the flow of the Chenab and the Jhelum and would badly affect Pakistan's agricultural based economy (Sahni, 2006). The construction of dams, reservoirs and barrages has severe environmental impacts. On a global scale, about 60% of the larger rivers are already fragmented by dams, diversions and canals,

Table 1 Major Indian dams and hydroelectric projects (HP), rivers, their locations and purpose; source Bhatti (2011) and Ammad (2011).

Name of dam/HP	Name of river	Location	Purpose
Baglihar	Chenab	Southern Doda	Water storage & HP
Dulhasti HP	Chenab	Kishtwar	HP
Salal HP	Chenab	Marala HW	Water storage & HP
Kirthai Dam	Chenab	Near Kishtwar	
Sawalkot Dam	Chenab		Water storage & HP
Pakal-Dul Dam	Chenab		
Uri HP, I & II	Jhelum	Uri, Baramula	HP
NimooBazgo	Indus	Alchi, Leh	Water storage & HP
Dumkhar H. Dam	Suru	Leh-KhalsiBatalik	HP
Krishna ganga H. Plant	Kishanganga	Bunkot	Diversion, water storage & HP
Bursar Dam	Marusudar	Doda	

which have caused rapid decline of freshwater biodiversity all over the world (Gaston, 2005). Hundreds of aquatic and terrestrial species depend on wetland and good water flows for their survival, food and reproduction. Due to construction of the series of dams on the River Chenab, cold water fish and macro-invertebrates are highly affected. These organisms are facing the severe problem of habitat fragmentation, which in most cases leads to extinction of aquatic species. There are many reports which indicate the gradual decrease in fish diversity in the River Chenab at Head Marala in Pakistan. One of the main reasons behind this decrease in fish diversity is trans-boundary water regulation.

The Krishna Ganga (Neelum) hydroelectric project (KHEP) is another subject of controversy between Pakistan and India. This project consists of the 100-km diversion of the Kishanganga River to a tributary of the Jhelum River by construction of a 22-km long tunnel (Amin, 2009). The Neelum River is a major tributary of the Jhelum River, joining the Jhelum near Muzzafarabad Azad Kashmir (Pakistan), which is an important source of water for the Neelum valley. In this project, the Neelum River will join the Jhelum River 204 km upstream of the existing confluence of Neelum River and Jhelum River (Akhtar, 2010; Ammad, 2011). Diverting the natural path of the river is one the serious violations of IWT. According to IWT, the upstream controlling government must release the water to the downstream to satisfy the storage, diversion requirements and sustain the aquatic life. As a result of the completion of KHEP, during summer and winter Pakistan will receive 11% and 27% less water, respectively. This will create a reduction of water by up to 1.4 million acre feet (MAF; 1727×10^6 m^3) water in Neelum valley (Amin, 2009; Ammad, 2011). However, Wular Lake will get additional water to its flow in the monsoon season and in other seasons. There will be huge fluctuations in water level in Wular Lake, affecting the ecological integrity of the River Jhelum as well as inducing a big ecological disaster in Neelum in Azad Kashmir. It will not only destroy the stream ecology of the River Neelum but will also be responsible for the extinction of some native fish and macro-invertebrate species resulting in a massive displacement of wildlife in Neelum valley.

The Eastern rivers are the main victims of cross-border pollution. The Ravi River is highly polluted with lowest discharge level of the major rivers. This river receives substantial amounts of pollutants, including industrial, municipal and agricultural waste from India and Pakistan through the Hudaira drain (Khan *et al*., 2004). The Jammu Tawi River is an important tributary of the Chenab River, which is continuously receiving hazardous waste and effluents from Jammu city. Heavy loads of toxic effluents are disturbing the balance of the riverine ecosystem with extinction of some species, and causing health hazards to humans (Sharma & Chowdhary, 2011). Municipal sewage and industrial effluents are continuously discharged into the Tawi River, causing deterioration of its water quality. There is no sewage treatment plant in the Jammu area to treat the sewage waste (Khanna, 2010). Farming communities in the catchment of the Tawi River are using tons of fertilizer and 70% of the urea drained into streams and rivers is due to agriculture runoff (Khanna, 2010). Also, the discharge of river has been declining due to abstraction of water to irrigate the cropland (Khanna, 2010). The highly polluted Tawi River enters Pakistan and degrades the water quality of the River Chenab (Elahi & Sikder, 2010). Benthic macro-invertebrates, fish and amphibians have been badly affected by pollutants in this river (Sharma & Chowdhary, 2011). Along with the aquatic organisms, many terrestrial organisms living in or near wetlands such as amphibians, reptiles, birds, mammals and insect pollinators become vulnerable due to human disturbance as well climate change (Khanna, 2010).

The Satluj River in the Indus Basin traverses the long distance from Indian territory and receives heavy metals, organic and inorganic pollutants from multiple sources including industry, cities, soil erosion, roads and agricultural runoff (Nshimiyiman *et al*., 2010; Singh & Saharan, 2010). The Buddha Nullah is an intermittent stream, which originates from Ludhiana, India, and after receiving large volume of pollutants and drains into the Sutlej River. Nowadays, the Nullah is the major sink of pollution in the Indian Punjab and flows during the monsoon while for the rest of the year it is a sewage drain. The sewage contains contaminants released from different point sources such as electroplating, mining, battery and metal processing units. The distribution of the

Indus Blind Dolphin is fragmented in the Indus and Satluj rivers due to transboundary water management. Recent reports from India indicated that more than six individuals have been seen in the Satluj and Bias rivers. In the past, the Indus Blind Dolphin had completely vanished from the River Satluj due to blockage of water at Head Gundah in Singh, India.

CLIMATE CHANGE AND BIODIVERSITY

The people living in China, India, Pakistan and Afghanistan depend upon water coming from glaciers but anthropogenic climate change is reducing the area covered by glaciers (Morrison *et al*., 2009). Pakistan is categorized among the high risk countries affected by climate change and included among the top ten countries most vulnerable to the effects of climate change (Khan, 2013). Extreme climatic events have occurred during the last two decades and Pakistan is experiencing changes in monsoon patterns which have caused flood, such as in 2010, and cyclones in 1997 and 2007 (Khan, 2013). On a global scale, the contribution of greenhouse gases from Pakistan (Malik *et al*., 2012) is small, but being at the border of the monsoon region the country faces the impacts of climate change. Weather patterns are changing, which directly or indirectly affects the surface water bodies. According to Hussain *et al*. (2005), during the past 50 years summer temperature had a slight decreasing trend over the Himalayan Mountains and northern Indus Plain, whereas the southern Indus Plain and Western Highlands in Baluchistan became slightly warmer. Meanwhile, winter temperature shows an increasing trend in the Northern Indian Sub-continent. This situation is favourable to unusual rains, floods and storms. In Pakistan, from the high Himalayas to the Indus delta, all wetlands are badly affected by the climate change (floods, drought, unusual rains) and human management. These wetlands are highly productive ecosystems and life lines in the economy of local people. Such landscapes become fragile due to degradation, invasion of exotic species and imbalance of nutrients (Heino *et al*., 2008). Glacier mass reduction is leading towards high flow alpine streams, which significantly disturb the stream integrity, streamwater temperature, sedimentation and stream biota (Xu *et al*., 2009). These glaciers are shrinking at an average speed of 10 to 15 m/year^{-1} due to global warming and climate change (Alam & Yasar, 2011). The rivers' flow has become unusual and increased due to melting of glaciers. Over the long term, shrinkage of glaciers would result in floods, wetland degradation and drying river systems. Limitations of water resources also create unfavourable conditions for aquatic wildlife. Aquatic mammals, birds, reptiles, fish and invertebrates are the major victims of climate change. The Indus Basin provides habitat to 25 amphibians and 147 fish species, and 22 species are endemic to this particular region (Qureshi & Ali, 2011).

Impacts of human-induced climate change on fisheries resources are prevalent and intense in tropical and sub-tropical countries. Pakistan is included among those countries where significant reduction of annual fish catch has occurred as a result of climate and pollution (Allison *et al*., 2009). In particular, frequent floods in lower riparian areas deteriorates the fisheries resources and economy of the fishing community (Rockström *et al*., 2009). The northern and northwestern areas of Pakistan are more vulnerable to climate change, having fragile ecosystems and delicate food web linkages. The Indus Blind Dolphin, migratory birds, freshwater turtles, Palla, Mahasheer and mangrove forests have been already affected. There will be a reduction of mangrove forests, which act as breeding site for shrimps (Farooqi *et al*., 2005). Already, reduced discharge of Indus River has significantly reduced mangrove forest and its associated wildlife (WWF, 2004). There will be a shift in habitat from monsoon forest to savannah grass land (Khan, 2011). This situation will create the extinction of many endemic plant and animal species. The process of desertification may further extend towards croplands.

RECENT EXTREME EVENTS IN PAKISTAN

About 40% of the people of Pakistan live in areas that are highly vulnerable to climate change and other natural disasters: heavy rains, floods, cyclone and drought (Khan, 2011). Melting of glaciers may be enhanced and lead to outburst floods, which are further intensified due to more rain and reduction in snow over the mountains. This changing climatic pattern induces frequent flood and

drought conditions in South Asia. Recently, Pakistan has experienced super floods and heavy rain spells in Sindh Province and drought conditions in western Baluchistan. Unusual climatic changes are greatly affecting the volume of water in rivers. In this situation, river flow fluctuates between extremes and this is further aggravated due to anthropogenic activities and water storage and regulation by dam operations. (Yan *et al*., 2008). During the last three years, it has been observed that in Pakistan, the distribution of the dengue virus has extended further northwards due to the warmer and humid weather conditions. Warm and humid conditions are favourable for the breeding and growth for the dengue vector *Aedes aegypti*. During 2011, the dengue problem spread as an epidemic in Lahore city and its adjoining areas. According to Farooqi *et al*. (2005), change in weather patterns will increase the incidence of epidemics in Pakistan.

As a result of climate change, Pakistan is facing three major challenges relating to water, food and energy, and these challenges interlink with each other (Sayed, 2011). The impacts of these threats can be overcome by an integrated approach and by reducing pressure on natural resources. The uncontrolled human population growth of Pakistan is continuously putting pressure on natural resources. Climate change along with human population growth makes the situation more severe. However, all challenges can be tackled with the participation of all stakeholders such as government agencies, NGOs, and even civil society. No country is excluded from the impacts of anthropogenic climate change. The only solution is a global stewardship approach towards the environment and climate focusing on the future of the Planet.

CONCLUSION

In Pakistan, water resources and aquatic biodiversity are vulnerable due to the intra-boundary and transboundary water management, pollution and climate change. Anthropogenic climate changes result from over exploitation of resources by man for industrial, agricultural and energy demands. Limited water resources cannot fulfil the demands of densely populated countries and may also trigger severe water crises among regional countries. Pakistan and India are both facing the same situation, but at the same time struggling to harvest maximum water resources for hydro power, water diversion and irrigation purposes. These projects are severely affecting the human population and aquatic biodiversity in the downstream of rivers. The current challenge is the protection of aquatic life from flow reduction, diversion, pollution and climate change. Every mega hydro-project must be designed to be ecofriendly and past projects must be re-evaluated and modified to make them sustainable. Sustainable natural resource management can only protect and conserve biodiversity from climate change on the basis of collaborative efforts. There is urgent need for an integrated global approach to reduce the impacts of climate change by adopting eco-friendly life styles and approaches.

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