

Water Use in Pakistan's Agricultural Sector: Water Conservation under the Changed Climatic Conditions

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Abstract: Pakistan's economy heavily relies on agriculture sector which accounts for a quarter of its GDP and employs two-fifths of total labourforce. Pakistan is located in a semiarid to arid region where rainfall is very low. The agriculture mainly depends on the Indus River System (IRS) for ninety percent of its irrigation needs, which also supply by about thirty percent of its total energy generation. According to Intergovernmental Panel on Climate Change-Fourth Assessment Report (IPCC-AR4), the world temperature is bound to rise by anywhere between one to six degrees Celsius by the end of this century. The IPCC forecast has special relevance for Pakistan, as IRS is heavily reliant on Himalayan Glaciers which release water in dry heat of summer before monsoon. The Himalayan glaciers feeding IRS can disappear in a few decades leaving very little water in IRS. The climate change is also forecasted to lead to more intense rainfall events at irregular intervals resulting in floods and droughts in Pakistan. This paper analyses the impacts of climate change on energy and water sector of Pakistan in future. Based on its findings it recommends certain policy changes as well as changes in the mindset of policy makers and planners regarding managing and mitigating vulnerability in water, energy and agriculture sectors. The paper also discusses the course of action policy makers can adopt for water conservation (engaging international community) to avoid a potential human tragedy. Also it has particular relevance for Gulf region as it is situated right next to Pakistan which has historic ties (in particular with Balochistan) and contemporary links by the way of migrant workers and food supplies. Any disruption caused by climate change in Pakistan can have spillover effect on the Gulf countries.

Key words: Climate Change • Indus River System • Glacier Melts • Adaptation

INTRODUCTION

Pakistan is a South Asian country situated between Latitude 24° and 37° N and Longitude 61° and 75° E. The area is about 796,095 km² and a population of 160 million. Population wise Pakistan is the ninth largest country in the World. The largest networks of surface irrigation systems in the World irrigating, about 18 million hectares (MH) of land, were found in.

Pakistan Is Divided into Three Major Geographic Areas:

The Northern Highlands, the Indus River Plain and the Balochistan Plateau. The Northern highlands include parts of Hindu Kush, Karakorum Range and the Himalayas. This area includes famous mountain peaks of K2 and Nanga Parbat and thousands of dry land glaciers, some of which are the World's largest outside the polar ice caps. The Indus plain stretches from the salt range to

Arabian Sea and is largely made of up to 300 m deep alluvium deposited by Indus River and its tributaries.

Politically the country is divided into four provinces, Punjab, Sindh, North West Frontier Province (NWFP) and Balochistan. Moreover many areas have special status, which include Federally Administrated Tribal Area (FATA), Federally Administrated Northern Area (FANA) and disputed (with India) State of Azad Jammu and Kashmir (Fig. 1).

Indus River System (IRS):

Agriculture in Pakistan is mostly dependent on Indus River System (IRS) which stretches from the Karakorum and Himalayan mountains in the North (Fig. 1), to dry alluvial plains of the Sindh Province in the South of Pakistan to the Arabian Sea. The flow in Indus largely depends on the melting of glaciers. Glaciers of Central Karakorum, Western Himalayas act as reservoirs capturing snow and ice

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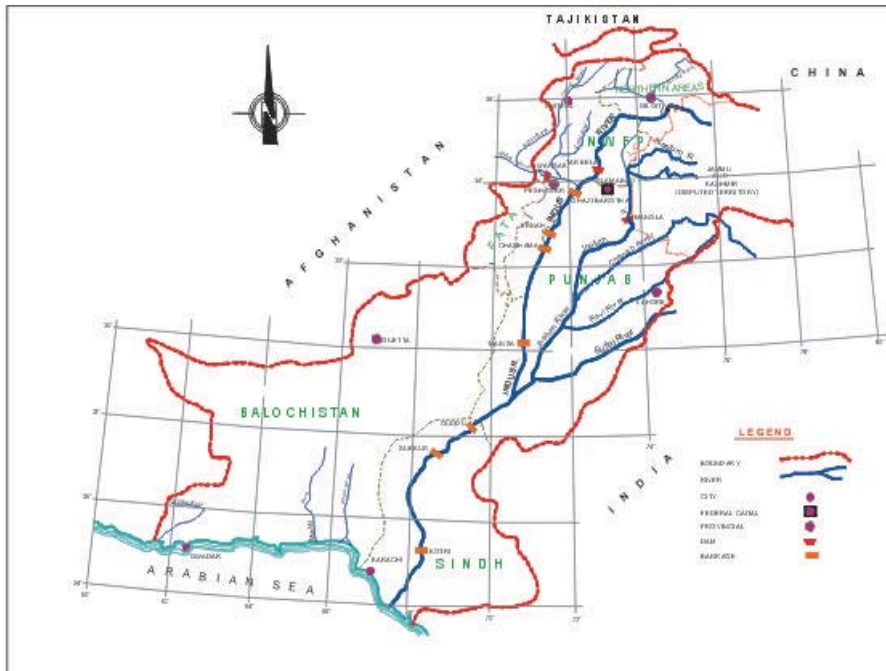


Fig. 1: Map of Pakistan showing Indus River System

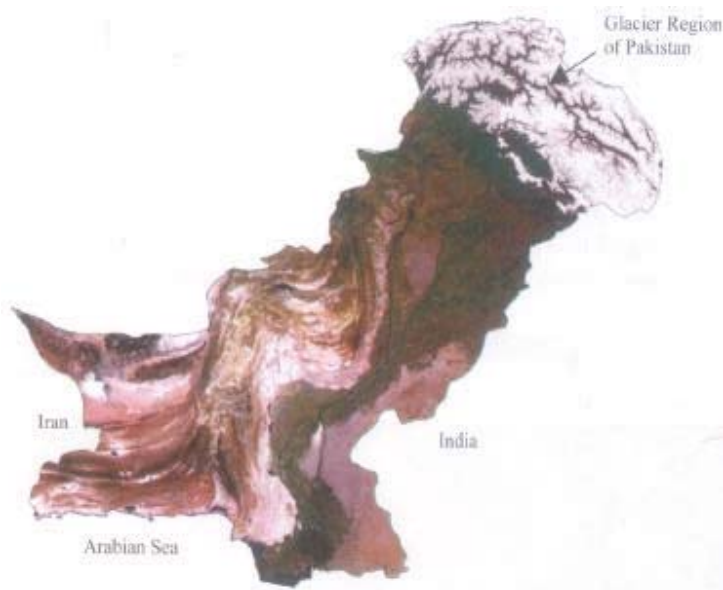


Fig. 2: Glacier Region of Pakistan in Northern Area of Pakistan

holding the water and releasing it into the rivers which feed Indus Plane. About 75% of summer flows of River Indus upstream of Tarbela Dam are contributed by highly glaciated central Karakorum Tributaries (Fig. 2).

The alluvial plains of Indus Basin cover an area of 207,200 km², which is about 25% of the land area of Pakistan. Five main rivers that join the Indus are Jhelum,

Chenab, Ravi, Bias and Sutlej. Beside these, two minor rivers, Soan and Harrow, also drain into the Indus. On the western side a number of small rivers also join this mighty river. The biggest of the Western rivers is Kabul whose main tributaries are Swat, Panjkora and Kunhar. Several small streams such as Kurram, Gomal, Kohat, Tai and Tank etc. also join the Indus on the right side (Fig. 1).

The impact of the Indus on Pakistan is extensive because of its size and capacity. It has the 7th largest delta and the 12th largest drainage area in the world. Its annual water runoff places it to be the 10th and annual sediment discharge places it in the 6th place in the world. Hence, by any yardstick, Indus River and its basin is a very large geographical and natural phenomenon [1].

Indus River and its tributaries on average carry about 180 BCM of water annually. River flow is highly variable ranging from 120 to 230 BCM. This includes about 169 BCM contributions from the three western rivers of Indus, Jhelum and Chenab and their tributaries. The remaining 11 BCM of water is contributed by the eastern rivers of Ravi, Sutlej and Bias. Most of the inflow, about 131 BCM is diverted for irrigation while the remainder flows to the sea [1].

Bulk of flows in IRS, about 88% of total mean annual are experienced in the 70 to 90 days from June to August of summer cropping period of Kharif (April to September). The remaining 12% flows are available for winter cropping period of Rabi (October to March) [2]. Flows in Rabi season are low because of the frozen glaciers and low rainfall during the winter season. It is reverse of the irrigation requirements, which is 60% for Rabi and 40% for Kharif. Therefore high flow variations in the river system dictate that large scale storage is provided to optimally use the water throughout the year [2]. Presently Terbela and Chashma at Indus River and Mangla at Jhelum with a total storage of about 15 BCM regulate the flows of Indus Basin Irrigation System (IBIS).

Indus Basin Irrigation System (IBIS): The IBIS is the largest integrated irrigation system in the World. Historically IBIS has been fed through run of river supplies derived from Indus and its five major tributaries. Pakistan, after its independence in 1947, had a water dispute with India when on April 1, 1948 India cutoff the flows of the Eastern rivers, on which most of the Pakistan's agriculture was dependent. The dispute was resolved through Indus Basin Treaty signed between Pakistan and India in September 1960 under aegis of the World Bank after lengthy negotiations.

The Indus Basin Treaty provided waters of three eastern rivers Sutlej, Beas and Ravi to India and three western Rivers Chenab, Jhelum and Indus to Pakistan. For supplying water to Pakistan's irrigation network (the largest manmade canal system in the world) the Indus Basin Project (IBP) was designed and constructed to replace the waters of Eastern Rivers. The agriculture in

IBIS is now dependent on waters of Indus, Chenab and Jhelum with about 80% water coming from Indus River itself.

The Network Which Regulates Ibis Has Three Major Reservoirs: Tarbela, Mangla and Chashma. It also includes 19 barrages, 12 link canals, 43 canal commands and over 107,000 watercourses. Barrage controlled irrigation systems were constructed during the period of 1908 to 1982. Existing IBIS is schematically shown in Fig. 3. IBIS consists of two sub-systems namely: Jhelum Chenab (J-C) also known as Mangla Command; and Indus known as Tarbela Command.

It is clear from the discussion above that the waters of Indus River are vitally important for the agriculture in Pakistan. Any reductions in those waters will make Pakistan's agriculture, food security and economy at great risk. In the follow sections this paper attempts at gauging the climate change impacts and devising the adaptation measures for Pakistan.

Climate Change and its Impacts: Population growth and the rapid pace of agricultural, urban and industrial development are placing increasing pressures on the global and regional environment and society. Technological advances during the last century led to low mortality rates and high birth rates across countries around the world. According to the United Nations [3], the world population is predicted to grow from 6.5 billion to 9.1 billion by 2050. In addition to this, increased migration and concentration of population clusters in selected locations have put extreme pressure on the surrounding regions. Scientists are now predicting that unless we bring a healthy balance in the growth rate, many countries will be facing acute food shortage and our environment may face irreversible damage that will jeopardize our future.

Any significant change in climate on a global scale may impact local agriculture and therefore affects the world's food supply. Although climate change is an inherently global issue, the impacts will not be felt equally across our planet. Regional changes are likely to differ from global averages in both magnitude and rates of change. Further, not all ecosystems and human settlements are equally sensitive to changes in climate. Nations (and regions within nations) vary in their relative vulnerability to changes in temperature, precipitation and extreme weather events and their ability to cope with such changes.

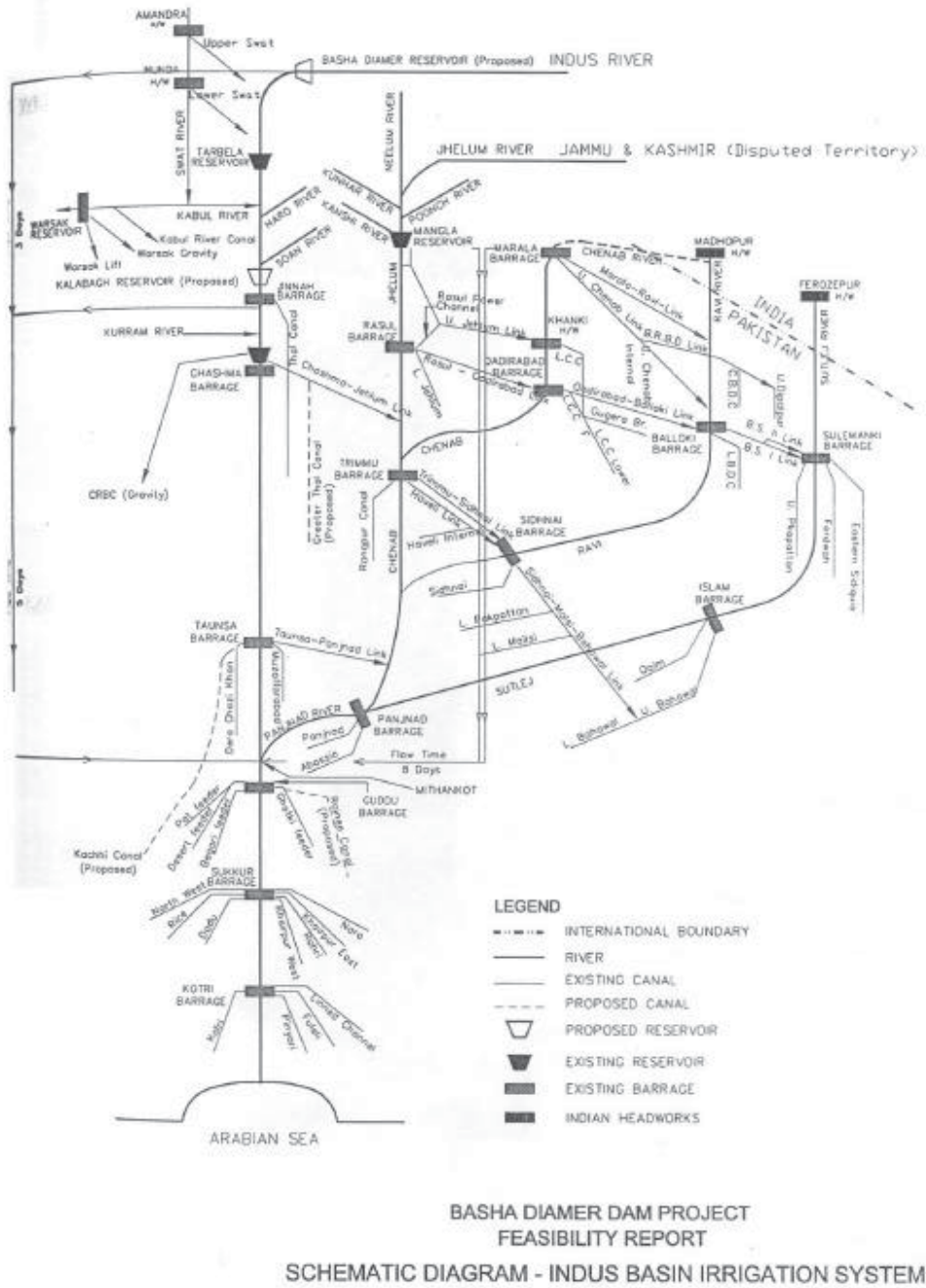


Fig. 3: Schematic Diagram-Indus Basin Irrigation System

The changing climate is generally deemed the greatest threat to mankind in modern times triggered by the greenhouse gases¹ (primarily produced by the developed nations). This will have profound consequences for water and energy resources, food production and human health etc.

in the developing countries like Pakistan. The harmful impacts of global warming are already manifesting themselves around the World in form of extreme weather events like storms, tornadoes, floods and droughts that are mounting in frequency and intensity.

¹Carbon dioxide, Nitrous oxide, Methane, Ozone and Chlorofluorocarbons.

According to its volume Summary for Policy Makers (SPM), IPCC-AR4, which shared Noble Peace Prize in 2007 with Al Gore film "An Incontinent Truth" the key conclusions about global climate changes are:

- Warming of climate is unequivocal.
- Global World temperature would rise between 1.1 and 6.4o C by the year 2100 and sea level will probably raise by 18 to 59 cm.
- There will be more frequent warm spells, heat waves and heavy rainfall.
- There will be an increase in droughts tropical cyclones and extreme high tides.

Impacts of Climate Change on Developing Countries:

According to Rahman [4] climate change is a result of unequal development and consumption and it is enhancing inequity across the world. The impacts are also unequally distributed, where poor in developing countries are becoming the worst victims. Maathai [5] citing the situation in Kenya as a typical developing country points to the drought, erratic rainfall and desertification that have likely intensified by climate change as realities for numerous communities that rely directly on land, soil and forests to meet basic needs.

Chairman of the IPCC, Pachauri [6] has pointed out that, "Negative effects of climate change include possible reductions in crop yields. In some African countries, for example, yields could decline by as much as 50% by 2020. Climate change would also lead to increased water stress, which by 2020 could affect 75-250 million people in Africa alone. Pachauri [6] further highlights there may be serious direct consequences for human health if climate change is not checked, particularly increased morbidity and mortality as a result of heat waves, floods and droughts. The IPCC [7] has identified specific impacts for the Asian region as following:

- Glacier melt in the Himalayas is projected to increase flooding, increase rock avalanches from destabilized slopes and affect water resources within the next two to three decades.
- Freshwater availability in Central, South, East and Southeast Asia, particularly in large river basins, is projected to decrease due to climate change, which, along with population growth and increasing demand from higher standards of living, could adversely affect more than a billion people by the 2050s.

- Coastal areas, especially heavily populated mega-delta regions in South, East and Southeast Asia, will be at greatest risk due to increased flooding from the sea and, in some mega-deltas, flooding from rivers.
- Crop yields could increase up to 20 percent in East and Southeast Asia, while they could decrease up to 30 percent in Central and South Asia by the mid-21st century.
- Sickness and death due to diarrheal disease, primarily associated with floods and droughts, are expected to rise in East, South and Southeast Asia due to projected changes in the hydrological cycle associated with global warming.

The IPCC predicts that "the effects of climate change are expected to be greatest in developing countries in terms of loss of life and relative effects on investment and economy". According to DFID [8] in Asia it is predicted that the rainfall will become more variable during the Indian summer monsoon. The timing and intensity of rainfall will become more erratic and between seasons. It further predicts that heavy rainfall and tropical cyclone intensity may increase due to disruption of the El Nino cycle and increasing sea surface temperature. A 1°C increase in sea surface temperatures in the Bay of Bengal could increase tropical cyclone intensity by 10%. The principal consequences of these changes in climate are greater risks to food and water security and greater health risks, which will affect the poor and vulnerable the most.

Impacts of Climate Change on Pakistan: Pakistan unfortunately falls in the group of countries highly exposed to negative consequences of climate change. Among the damages already evident in the country is growing frequency of droughts and flooding, increasingly erratic weather behavior, reduction in freshwater supply and changes in agriculture pattern. It has become clear that climate change threatens all progress targets and plans; from health, education to livelihoods, the whole process is endangered by the probability of disasters and uncertain environmental conditions.

Although Pakistan contributes least to global warming with one 35th of the world's average of carbon dioxide emissions and produces minimal chlorofluorocarbons and little sulphur dioxide emissions, thus making a negligible contribution to ozone depletion and acid rain, it will suffer disproportionately from climate change and other global environmental problems [9].

According to IUCN [10] press release, Prime Minister of Pakistan, Syed Yousuf Raza Gilani, in his speech, noted that, according to a recently published index, Pakistan was ranked 12th on the list of countries most vulnerable to the impacts of climate change. The Prime Minister said that the government realized the serious implications of climate change on the economy and on the environment and assured the audience that climate change was one of the government's top priorities.

In Pakistan, agricultural yields are also declining and climate change is the likely culprit. Changes in the timing of monsoons are already having an adverse effect on Pakistan and India. It is the very poor in low income countries that are the most susceptible to the effects of climate change [11]. Farooqi *et al.* [12] have explained that climate change represents an additional stress over an already resource stressed country (Pakistan). Projected climate changes in the region could result in major impacts on the country's ecosystems and biodiversity; hydrology and water resources; agriculture, forestry and fisheries; mountains and coastal lands; and human settlements and human health.

Farooqi *et al.* [12] argues that sea level rise due to climate change will decimate mangrove forests in Pakistan. These mangrove forests are the source of fuel wood and food to local inhabitants and breeding ground for 90 percent of Pakistan shrimp, its main fisheries export. Climate change will also have severe impact on agriculture, in particular on climate-sensitive crops such as rice, other grains and cereals, vegetables and spices. Khan [13] has summed up climate change related concerns of Pakistan as:

- Increased variability of Monsoon and a rapid recession of HKH (Hindu Kush Himalayan) Glaciers threatening IRS (Indus River System) flows and an associated reduction in capacity of natural reservoirs;
- Increased risks of floods and droughts along with severe water-stressed conditions in arid and semi-arid regions leading to food Insecurity due to reduced agriculture productivity;
- Upstream intrusion of saline water in the Indus delta; and risk to mangroves, coral reefs and breeding grounds of fish, increase in deforestation and loss of Biodiversity;
- Increased Health Risks (Heat Strokes, Pneumonia, Malaria and other vector-borne diseases);

Impacts of Climate Change on Water Resources of Pakistan: Water is the most crucial of natural resources for development in Pakistan. According to Adeel and Piracha [14], per capita water availability in Pakistan falls far short of the global average of more than 7,000 m³ per year. A government of Pakistan study of 1998 indicated that the total water storage in the river system remains insufficient and that the water resources operation under various climate scenarios shows that the problem will become more acute in the future. The report highlights the net overall capacity of the system to supply water in time will decrease in Pakistan unless some urgent actions are taken. GOP [15] further described that the climate change would demand a further increase in the annual growth rate in agriculture of around 0.1% and 0.2% for the periods 1997-2020 and 2021-2050 respectively.

Storage capacity of existing dams in Pakistan depleting at the rate of 0.18 BCM per year [16] leading to storage loss of 5 BCM to date which accounts for about 20% storage loss for irrigation. Furthermore with average annual increase in population of about 3 million, additional water resources of 0.62 BCM annually are required to sustain and extend irrigation network of remaining area to meet the food requirements of the country.

Citing from the World Bank and IPCC, Khan [13] describes that Western Himalayan glaciers will retreat for the next 50 years causing increase of Indus River flows. Then the glacier reservoirs will be empty, resulting in decrease of flows by up to 30 - 40% over the subsequent fifty years. Glacier melt in the Himalayas is projected to increase flooding within next two to three decades. This will be followed by decreased river flows as the Glaciers recede. Khan [13] and Butt [17] have outlined specific climate change impacts on water resources of Pakistan as:

- Glaciers in Pakistan cover 13,680 sq. km which is 13% of mountain regions of the Upper Indus Basin (UIB). Melt water from these Glaciers contributes more than 60% to the flows from UIB.
- According to a 1999 report of International Commission for Snow and Ice (ICSI) "Glaciers in Himalayas are receding faster than in any other part of the world and, if the present rate continue, the likelihood of them disappearing by the year 2035 is very high".

- Hewitt [18] reported widespread evidence of glacier expansion in the late 1990s in the Central Karakoram, in contrast to a worldwide decline of mountain glaciers.
- These conflicting findings make the impact of climate change on Karakoram glaciers and Indus River flows very uncertain.

If projections of water availability by IPCC are correct then Pakistan will receive higher levels of rainfall and snowmelt with the increasing temperatures, meaning that we will get additional water upto 2040 which will cause floods resulting from the increase in precipitation. After 3 decades the Indus will become a seasonal river as a consequence of glacial melt due to climate change and will severely affect the agriculture sector of the country.

Impact of Global Warming on Agriculture Sector in Pakistan: Pakistan is more susceptible to the affects of changing climate because of its agrarian base and high dependency on natural resources for livelihoods. Because Agriculture is the lifeline of our economy, the influence of water scarcity and changing temperatures is expected to be most lethal in this sector. Pakistan's Food Security has been put at risk and we are witnessing a reduction in annual crop yields brought on by various factors including increased water logging, desertification of land, growing frequency of pest attacks and disasters. According to projections, with just a 1° C rise in temperature, wheat yield in Pakistan is estimated to decline by 6-9% and an even lesser rise in temperature can severely impact cash crops like mango and cotton [19].

Pakistan's economy is dependent on agriculture in more ways than one and is poised to suffer risks greater than the ones already mentioned. The dependency of Pakistan's Industrial sector on agricultural raw material indicates that climate change is set to sabotage the supply chain of industry as well. Consequently, damages to livelihoods will not remain confined to the agricultural sector alone but will also spillover to the industrial markets.

Impact of Global Warming on Hydropower Sector in Pakistan: It is pertinent to mention here the risk to national energy security, as energy is both a cause and casualty of global warming. It is a casualty in Pakistan's

case because the shortage of water and variation in river flows affects our potential to generate hydropower. Presently hydropower contributes 35% to the country's power generation of 19600 MW.

The share of hydropower may increase in future as the government of Pakistan is planning to reduce the overall cost of generation. Note that the cost of generation has increased due to fossil fuel based generation, which constitutes 70% of the supply [20]. A number of power development projects have been identified on Indus which can be constructed in coming decades. If the availability of water reduces due to melting of glaciers then those projects cannot be operated at their planned capacities.

It is also likely that global energy costs will increasingly reflect the true environmental cost of production and consumption and become prohibitively expensive for populations of developing countries. Historical data demonstrates a positive correlation between per capita energy consumption and the development level of nations; hence a decrease in its consumption will setback even further development of the country.

Impact of Global Warming on Coastal Regions in Pakistan: Pakistan with 1100 km long coast is particularly vulnerable to the effects of sea level rise. Karachi² the largest city of Pakistan is going to be particular affected. Analysis of tide gauge data processed at the National Institute of Oceanography (NIO) shows that along the coast, sea level rise is approximately 1.1mm/year. This is similar to the global mean sea level rise reported by the IPCC [7]. Therefore, Pakistan may experience a sea level rise similar to the maximum global projected rise of 90 cm by 2100 [20].

The primary impacts of sea level rise include increased risk of erosion, coastal flooding, permanent inundation and displacement of wetlands and lowlands and degradation of water quality through salinization of ground and surface water [20]. Because of sea level rise, saltwater will penetrate further upstream and inland. This effect would be particularly evident during a drought. Sea level rise would also enable saltwater to ingress farther inland and upstream into the rivers, wetlands and aquifers, which would be harmful to aquatic flora and fauna and would threaten human uses of water [20].

²the largest city of Pakistan where almost 13 million of people lives and about 40% of all manufacturing units is situated o the coast.

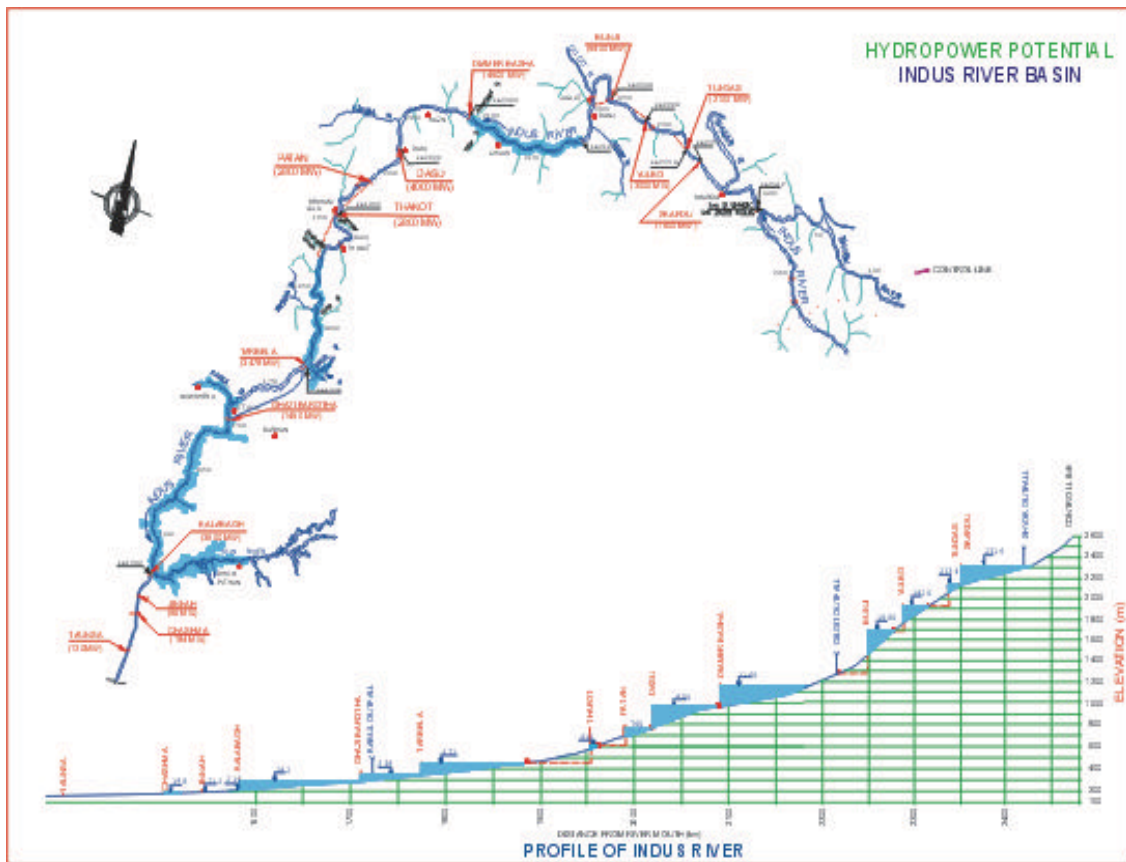


Fig. 4: Plan and Profile of Indus River

International Panel of Experts (IPOE) Review Studies on Water Escapages below Kotri Barrage recommended that an escape of 142 m³/s (5,000 ft³/s) at Kotri Barrage throughout the year be ensured to: check seawater intrusion; accommodate the need for fisheries and environmental sustainability; and to maintain and preserve the river channel morphology. Higher flow escapages to Arabian Sea will be required due to rise in sea level i.e. more water will be required to check the sea water intrusion in the coastal areas specially during low flow season. This factor will also add to the problem of water scarcity for Agriculture [21].

Conservation Measures to Save Agriculture in Pakistan:

Upper Indus Basin has extensive accumulation of glaciers, which are vulnerable to climate change. The expected increase in the climate change parameters (temperature and precipitation) due to global warming cannot be estimated as the meteorological stations network measuring these parameters is sparse and located in valley bottoms. There is a

need to setup an extensive network of meteorological stations in the region to closely monitor impacts of climate change.

As discussed earlier, Indus River is the lifeline of the country which provides food and energy security. The melting of glaciers due to global warming within next few decades is a risk to national food and energy security. It is likely that Pakistan will face floods in near future followed by severe shortage of water afterwards. The other complicating factor will be more intense rains and more droughts. An important way to deal with the unreliability is water availability is to provide more reservoirs. These reservoirs can serve the second purpose of power generation as well.

Upper Indus starting from proposed Kalabagh Dam site to the control line upstream of its confluence Shyok River can be used effectively to store water as reservoir and to generate hydropower (Plan and Profile of Indus River shown in Fig. 4). The total head/fall available in this reach is about 2000 m in 1800 km distance from Kalabagh upto the proposed Skardu Dam Site.

In the next four decades there will be floods in Indus Basin due to heavy flows when afterwards flows decreased due to disappearing of glaciers the river Indus behaves as a run of river. Therefore at the moment two storage reservoirs one at upstream of Tarbela i.e. Diamer Basha and other at downstream i.e. Kalabagh Dam is must to regulate the abnormal flows which are foreseen during next decade in Indus River for saving of IBIS.

Global warming due to greenhouse gases is a problem created by the developed nations of the world and more recently by India and China³. The developed world has acknowledged what they have created has triggered the vulnerability in water, energy and agriculture sectors of Indus River System of Pakistan. Therefore the international community must help in managing and mitigating vulnerability in water, energy and agriculture sectors in Indus Basin by giving full financial support to build two reservoirs immediately on Indus River to avoid a potential human tragedy. Furthermore the electricity production from nuclear energy on large scale will have to take place in Pakistan for giving energy security to the most threatened civilization of the World due to Climate Change.

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