Water Resources of the Indus River System: Challenges and Opportunities

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Abstract

Despite having the most extensive contiguous irrigation system, Pakistan is enlisted in the water-stressed countries. Its water resources are under enormous pressure due to numerous challenges, including poor water governance, low storage capacity, rapid population growth and urbanization, groundwater depletion, climate change and its associated extreme events, transboundary and inter-provincial water management/sharing issues, sea-level rise, Indus delta deterioration, and water pollution. This chapter describes the major water resources and the challenges of Pakistan in managing its water resources, with a way forward proposed to address these issues.

Keywords: Pakistan; Indus River, Climate Change, Water Resources

1. Introduction

1.1. Overview of Water Resources

Pakistan has been bestowed with one of the most extensive and contiguous irrigation systems, known as the Indus Basin Irrigation System (IBIS). Its water resources originate mainly from the main Indus River and its five tributaries as shown in Fig. 1. The Indus River Basin (IRB) is shared by four countries, i.e., Pakistan (47%), India (39%), China (8%), and Afghanistan (6%) (Watto et al., 2021). The Indus River has a length of over 3,000 km and a drainage area of about 1.12 million km^2 (Asad Sarwar, 2011, Watto et al., 2021). Currently, the IRB has three major dams, 19 barrages, 12 inter-river link canals, 45 major irrigation canal commands, and more than 120,000 watercourses providing water to farms (Yang et al., 2013).

The average annual water flow to the Indus River at the rim station is about 146 MAF (Savitsky et al., 2013) including 134 MAF from the western rivers and 12 MAF from the eastern rivers (Asad Sarwar, 2011, Dars et al., 2021, Podger et al.,

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2021). About 104 MAF of water (93% of the total flows) is diverted for irrigation. The IBIS serves about 21.5 million hectares of land, only 27% of the total geographical area of Pakistan (Qureshi, 2005).

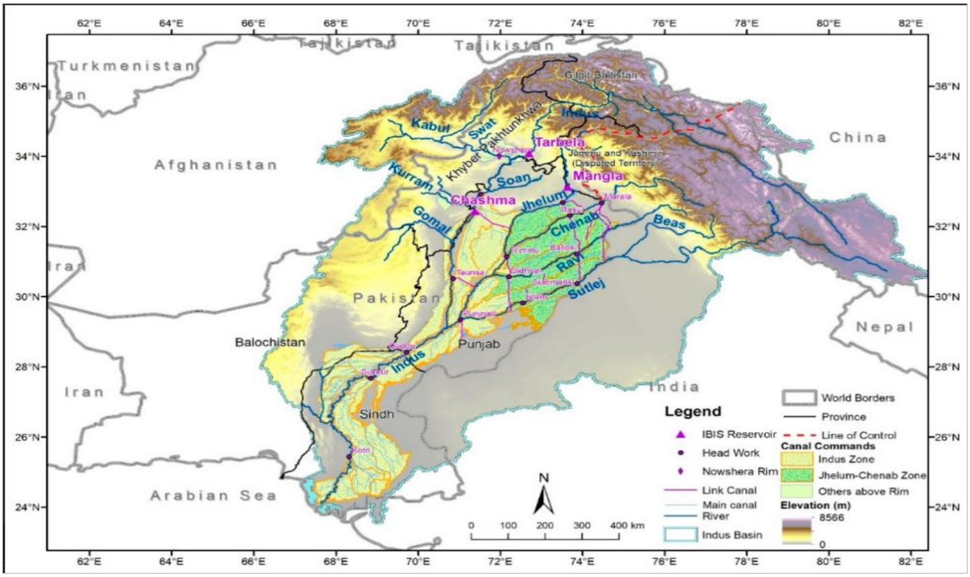

Figure 1. Map of the Indus Basin with its tributaries (Podger et al., 2021).

Assessing the water resources in the IRB is challenging due to insufficient water availability data, climatic data, the number of tube-wells, and transboundary hydrologic parameters. Therefore, it has become crucial to analyze the water resources information within the IRB based on updated and authentic data records. Three major sources contribute to the water flows to the Indus and its tributaries, i.e., monsoon precipitation, snow and glacial melt, and groundwater. Snow and glacial melt contribute about 50 to 80% of the flows to the total Indus River flows, with the remaining contribution from monsoon precipitation on the Indus plains (Savitsky et al., 2013). In addition, the average groundwater extraction is about 42 MAF (Asad Sarwar, 2011).

2. Water Management Issues/Challenges

Pakistan is facing challenges in the sustainable management of its limited freshwater resources. The country has either *"too much water"* or *"too little water."* Its water resources are under enormous pressure due to numerous challenges.

2.1. Water Governance Issues

Water governance deliberates the political, economic, and administrative structures that may control water resource management. However, in Pakistan after 70 years of independence, the year 2018 is considered a historical year wherein Pakistan officially launched its first National Water Policy. Nevertheless, a considerable gap still exists in policy-making and implementation. The Interprovincial Water Apportionment Accord (WAA) of 1991 is a good example of the policy and implementation gap. More than 30 years have passed, however, the issue of sufficient environmental flows to the Indus Delta has not yet been resolved (Watto et al., 2021).

Generally, water is considered a free commodity in Pakistan, with no water pricing concept. The political willpower and linkages between institutions, sectors, and provinces are lacking. Unfortunately, no big hydropower dam has been constructed after the Tarbela and Mangla Dam. Lack of proper operation and maintenance of the existing infrastructure causes deterioration of water quality. The intermittent water supply with poor water quality has compelled the communities either to purchase drinking water or use the contaminated water. It is strongly recommended to improve its water governance and manage the limited freshwater resources based on robust, sustainable, and transparent accountability mechanisms.

2.2. Low storage capacity

Pakistan's per-capita water storage capacity is only 150 m^3 (Fig. 2), which is lower than India, Morocco, the US, Australia, China, and Spain (Asad Sarwar, 2011).

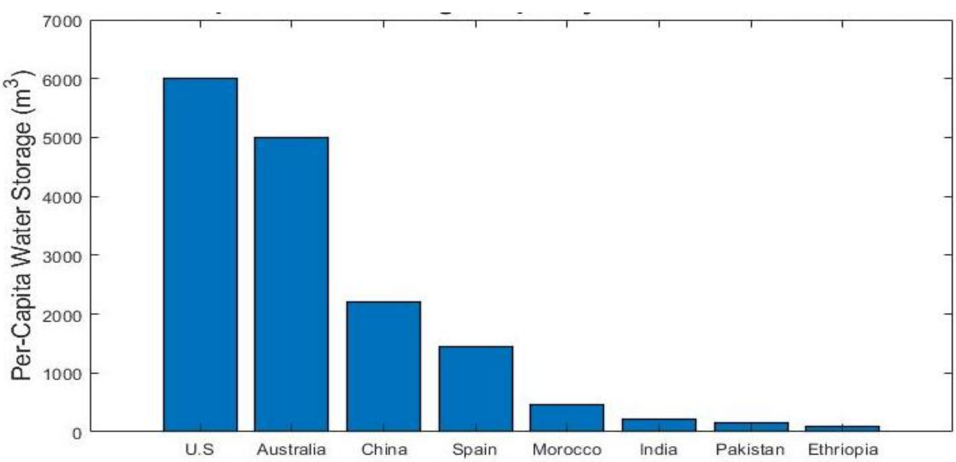

Figure 2. Per-Capita Water Storage Capacity in the Semi-Arid Countries (Savitsky et al., 2013).

Moreover, its per-capita water storage capacity is also expected to decline to less than 80 m^3 by the end of the 21st century due to the continuous siltation in the existing water reservoirs (Yang et al., 2013) and the growing population. Moreover, Pakistan can hardly store water for 30 days in the IRB, whereas the US (in Colorado River Basin) can store water for 1000 days, and even India can store water for 120 to 220 days in its different basins (Fig. 3) (Briscoe et al., 2005).

Moreover, the increasing water demands of other sectors, rapid population growth, and shrinking water availability will not only increase tensions between the provinces, but also with the neighboring countries in managing the limited freshwater resources.

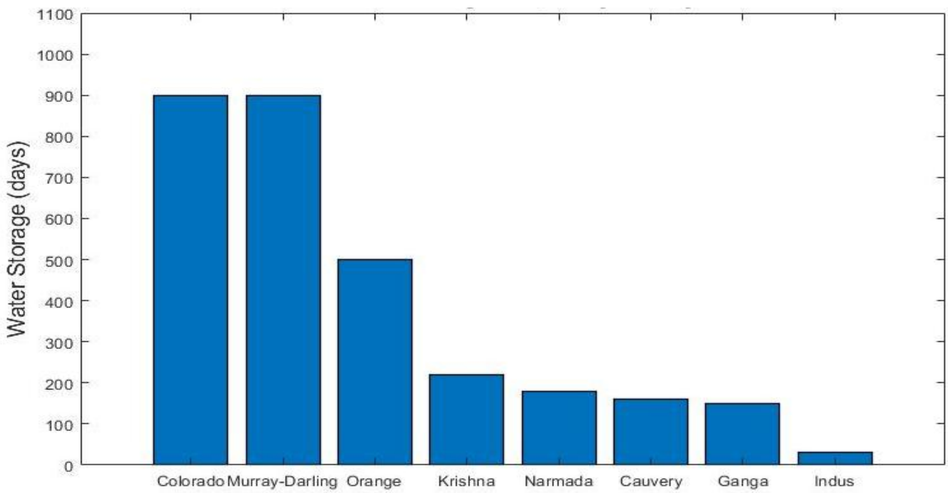

Figure 3. Water Storage Capacity of different countries in days (Asad Sarwar, 2011).

2.3. Rapid population growth and urbanization

Pakistan is the fifth most populous country; its population is about 2.83% of the global population (Worldometer, 2022). Its annual population growth rate is quite high, at about 2.4 percent (GoP, 2019). Despite being one of the most populous countries, Pakistan is also an arid country with an average annual rainfall of less than 240 mm (Briscoe et al., 2005). According to a United Nations report, more than half of its population will be living in urban cities by the mid of the 21st century (UN, 2019). Rapid urbanization could put huge pressure on the existing water infrastructure in urban areas, and access to safe and reliable drinking water could be very challenging.

2.4. Groundwater depletion

Groundwater is a valuable resource, especially in the lower plains of Pakistan. It is the fourth largest country in groundwater extraction (Qureshi and Ashraf, 2019) Studies show that a vast unconfined aquifer encompassing roughly 16 mha of the surface area lies beneath the Indus Basin, of which only six mha are fresh and the remaining is saline (Qureshi et al., 2008). The groundwater has significantly contributed to Pakistan's overall increase in crop intensity, which has gone from roughly 63 percent in 1947 to over 120 percent in 2000 (Iqbal et al., 2020) However, due to free accessibility and the absence of any regulatory framework, the exponential growth of tube-wells is observed (Fig. 4), which has caused a rapid depletion of groundwater in the country (GoP, 2021). The rapid groundwater depletion has compelled the farmers to dig deeper wells, and eventually, saline water is extracted and degrades the soil salinization in those areas (Watto et al., 2021).

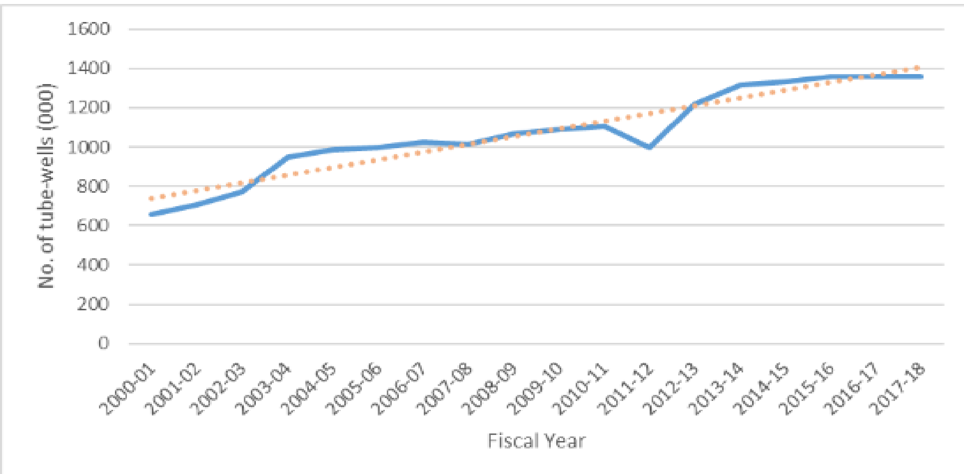

Figure 4. Growth of Tube-wells in Pakistan (Source: GoP, 2021).

2.5. Climate change and its impacts

Climate change has now become a reality, and its impacts are visible all over the world. Climate change intensifies the water cycle because more water evaporates due to increased air temperatures, and warmer air can hold more water vapor, leading to more intense rainstorms at one place and drought-like situations at the other (Dars et al., 2017). The Indus Basin has a diversified climate, with snow and glaciers in the UIB and vast plains in the lower Indus Basin. The climate in the UIB is mainly driven by the westerly disturbances, and the monsoons from the Bay of Bengal and South Eastern Asia (Anjum et al., 2021). Thus, the Indian and

Pacific Oceans and the Eurasian continent greatly influence the Indus Basin's climatic patterns.

The Indus River, being mainly dependent on the snow/glacial melt, could be inevitably affected due to the projected impacts of climate change. The UIB region has strategic importance due to its continuous flow contributions from snow and glaciers (Soncini et al., 2015). Some researchers have observed that snow/glacial melt contributions from the UIB to the Indus River is more than 70% (Hewitt et al., 1989, Krakauer et al., 2019, Dars et al., 2020). The yearly average temperature in Pakistan has increased by 0.6°C over the past century (Khan et al., 2016), but some exceptional variations in the temperature changes were observed more recently. For example, the temperature increased by about 0.24°C per decade between 1960 and 2007, much higher than the earlier increase of 0.06°C per decade (Khan et al., 2016). In addition, the temperature increase over the UIB was observed as 0.8°C compared to LIB (southern parts) had a temperature increase of 0.6°C in the last century. Moreover, (Chaudhry et al., 2009) observed an increase of 0.87°C and 0.48°C in the annual maximum and minimum temperatures respectively between the years 1960 to 2007. They also showed an increase in the frequency of heat waves in the UIB region.

Anjum et al., (2021) analyzed the changes in the climatic parameters in the HKH region from 1975 to 2014, using the gauge data. They observed an increasing trend in the average annual temperature with the highest warming in the Karakoram range, i.e., 0.08 °C/decade. In addition, they observed an increasing trend in total annual precipitation in the Hindu-Kush and Karakoram (Himalayas) regions. Moreover, it is projected that climate change could have severe impacts on shifts in the summer monsoon systems, increased snow and glacial melt, increased frequency and intensity of extreme events (floods, droughts and heatwaves), seawater intrusion, and Indus delta deterioration (Tahir et al., 2016). The likely impacts of climate change on the water availability and the people living in its downstream areas could be catastrophic and, therefore, need to urgently develop and implement adaptation and mitigation measures.

2.6. Extreme events (heat waves, floods, and droughts)

Despite its very low Greenhouse Gas (GHG) emissions, Pakistan is vulnerable to climate change impacts with increasing frequency and intensity of extreme events. The drought in 1998-2001 and floods in 2010, 2011, 2014, 2021, and 2022 are evident, affecting people's lives, economy, livelihood and, as a matter of fact, almost every sector. Moreover, due to a shortage of rainfall and increasing temperatures from January to April 2022, the PMD issued a drought alert on 16th

May 2022 in many regions of the country; however, only two months later, the country faced a flash flood situation with one-third of territory inundated and tens of thousands of people displaced. According to PMD records, rainfall in the summer of 2022 was more than 500% higher than the average rainfall in Sindh. Moreover, the frequency, severity, intensity and duration of extreme events are projected to increase in the future (Dars et al., 2017, Wijngaard et al., 2017, Jamro et al., 2019, Watto et al., 2021).

2.7. Transboundary and Inter-Provincial Water Management Issues

The mighty Indus River is shared by four countries, i.e., Afghanistan, China, India, and Pakistan, with a major portion (about 60%) lying in Pakistan. The Indus River system waters have been a source of contention between Pakistan and India (Yang et al., 2014). After lengthy negotiations and in the presence of international donors (World Bank), both countries signed an agreement called the Indus Water Treaty (IWT) in 1960. Under the IWT, the three eastern rivers (Ravi, Sutlej, and Beas) were given to India, which contribute about 20% of the flow into the Indus Basin, and the three western rivers (Indus, Jhelum, and Chenab) were given to Pakistan. Despite the IWT, severe disagreements over water sharing have been observed between the two neighbors in the past few years. Pakistan has raised serious concerns over India's allegedly building run of river projects.

Apart from India, Pakistan also shares its water with Afghanistan through the Kabul River. Its average annual contribution to the Indus River is about 17 MAF, including the Kunar River's flow. The Kunar River originates from Pakistan and contributes about 12 MAF (71%) to the Kabul River (Yousaf, 2017). So, Pakistan is both the upper and lower riparian of the Kabul River. Currently, no water treaty exists between Pakistan and Afghanistan. Afghanistan's current water utilization is about 8 MAF, and if Afghanistan can construct reservoirs and divert the Kabul River's water, it will have a severe impact on Pakistan, being a lower riparian. Therefore, both countries need to sign a Water Treaty on the Kabul River to share the benefits and arrive at a win-win situation before it turns into a serious dispute.

In the IRB within Pakistan, severe tensions continue among provinces over the distribution of surface water. Some committees were formed to resolve these tensions between the provinces, including the Akhtar Hussain Committee, the Judicial Committees, and the Haleem Committee, but none were successful (Yang et al., 2014). Ultimately, the Indus Water Apportionment Accord in 1991 (also known as the 1991 Water Accord) was signed between the provinces. Under this accord, the Indus River System Authority (IRSA) was established in 1992, responsible for regulating and distributing surface water among provinces. The baseline flow data for six years (1977-1982) was used to estimate the water allocations of each province (given in Table 1). Moreover, the agreement was made based on the annual water availability of 114.35 MAF flows (shown in Table 1). In the 1991 water accord, Sindh demanded a minimum flow of 10 MAF of water into the sea. The other three provinces also supported the minimum flow to the sea for environmental reasons, but were undecided about its quantity. Then, it was decided to conduct studies by renowned international experts. The International experts' panel (González et al., 2005) suggested maintaining a minimum flow of 0.3 MAF downstream of Kotri Barrage each month. It was also emphasized that a flood flow of about 25 MAF in any five years should be released during the Kharif season to accommodate the sediment supply for a stable coastline.

Table 1. Provincial water allocations (in MAF) under the 1991 Water Accord.

Provinces	Para 14b (1977-1982 average use) MAF	Para 2 (Agreed water sharing) MAF	Para 4 (Surplus water sharing in percentage)
Punjab	54.51	55.94	37
Sindh	43.53	48.76	37
KP	3.06	5.78	14
Baluchistan	1.63	3.87	12
Total	102.73	114.35	100

Despite the Accord being in force for more than 30 years, the water allocation issues between provinces are not fully resolved, including the construction of new reservoirs and minimum flow to Kotri downstream.

2.8. Sea level rise and Indus Delta deterioration

The Indus Delta is the fifth-largest delta and hosts the seventh-largest mangrove system in the world. It extends from Sir Creek in the east to Phitti Creek in the west, with Banoo Town in Sujawal Sindh, Sindh, Pakistan, serving as its summit (Siyal, 2018). The studies showed that the Indus Delta has shrunk from 1.3 mha (1833) to 0.1 mha (2018) and also degraded due to several factors, including declining river flows, decreased sediment deposition, seawater intrusion, and sea level rise due to climate change (Majeed et al., 2010, Rasul and Ahmad, 2012). Siyal (2018) has emphasized following the International experts' panel's (González et al., 2005) guidelines to maintain a minimum release of 0.3 MAF downstream of Kotri Barrage each month and a heavy flood flow of about 25 MAF in any five years during the Kharif season to accommodate the sediment supply for a stable coastline.

2.9. *Water pollution/increased health risks*

There are two broad classifications of water pollution - point sources and non-point sources. Point sources mean any single identifiable source of discharge effluents into water bodies, including factories, industries, sewage treatment plans, power plants, etc. However, non-point source pollution may come from many diffuse sources, including land runoff, drainage water, etc. The main causes of water contamination in Pakistan are domestic and industrial effluents, solid wastes, and agricultural runoff. Pakistan is listed in the top five wastewater-producing countries and treats only 1.2% of its wastewater (Watto et al., 2021). Moreover, a huge amount of human waste (about 50%) produced in urban areas is discharged into water bodies, and approximately 92% of sewage is disposed off without being cleaned (Watto et al., 2021). These untreated waste effluents eventually cause widespread diseases. In addition, treatment plants are not installed in most industries despite the government's clear instructions, which is causing severe water contamination. (Sial et al., 2006) observed that out of more than 6,000 industrial units in Karachi, 1,228 industries discharged heavy metals, oils, and other contaminants.

In Pakistan, access to sanitation has improved, but more than 25 million people still practice open defecation according to UNICEF (2022), and 53,000 children under five die annually from water-borne diseases. Poor living conditions, lack of education and awareness, and implementation of laws are the main causes of water contamination.

2.10. Low system efficiency and crop water productivity

Pakistan’s irrigation efficiency is very low, i.e., only 40% due to its outdated irrigation system (Asad Sarwar, 2011). Pakistan’s wheat production/ha is 65% lower than China and 17% lower than India.~~,~~ Various factors cause low crop productivity, for example, low operation and maintenance of the irrigation infrastructure, insufficient water availability, waterlogging and salinity, water theft, low collection of abiana (water charges), outdated irrigation practices and, in some cases, seed type (Dars et al., 2021). Pakistan should enhance its crop-water productivity and improve its system efficiently by adopting modern tools and techniques for managing limited water resources.

3. Conclusions/way forward

i) Resolve governance issues through the implementation of policies and laws in the true spirit, ensure proper operation and maintenance of the infrastructure, ensure coordination among provinces/organizations, update regulations for groundwater extraction and its proper implementation, institutional reforms and regulations, and reinforce knowledge/data sharing.

ii) Enhance transparency in the sharing of water resources at the distributaries/canals, so that trust can build among water users between upper and lower riparian.

iii) Develop and remodel the water storage to enhance the water storage capacity.

iv) Implement IWRM at all levels instead of ad-hoc or project-based approach.

v) Recharge the groundwater wherever possible by different measures, including the construction of check dams, delay action dams, etc.

vi) Raising awareness, focus on developing ecosystems across the Indus River (for example - Yangtze River). It will help the communities in improving their livelihood. It also helps in reducing the flood impacts.

vii) Focus on adaptive water management practices, including water conservation technologies, recycling and reuse of water, water pricing, conjunctive water management, raised bed technology, grow heat-resistant crops, promoting renewable energy, and giving incentives to progressive farmers.

viii) Strengthen early warning systems and ensure adequate storm water drainage systems at the canals and urban areas.

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